# OIL FUEL AND THE EMPIRE

BY

J. D. HENRY

FOUNDER OF "THE PETROLEUM WORLD" AND AUTHOR OF 'BAKU; AN EVENTFUL HISTORY," "THIRTY-FIVE YEARS OF OIL TRANSPORT; THE EVOLUTION OF THE TANK STEAMER," ETC

HALF-TONE ILLUSTRATIONS, DIAGRAMS AND ORIGINAL DRAWINGS

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JULY, 1908.

TO THE

OIL MEN OF THE DOMINION OF CANADA

WHO MADE THE FIRST OFFER

TO SUPPLY COLONIAL OIL FUEL

TO THE BRITISH NAVY

"LIQUID fuel is already substituted for coal in many steamships. When sufficient quantities can be obtained it has many obvious advantages over coal. At present it does not appear that adequate supplies are available. Competent authorities, here and abroad, are giving attention to this question, and to the development of supplies. If the want can be met at prices justifying the use of liquid fuel there will undoubtedly be a movement in that direction."

SIR WILLIAM H. WHITE, Chief Constructor at the Admiralty, in 1899.

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MR. Thomas Gibson Bowles, in a lively letter to *The Times*, in 1900, hit the Admiralty hard for reducing "a fleet-in-being to a fleet in building," and denounced "the persistent refusal seriously to entertain or examine the matter of oil fuel."

. . . . . .

In July, 1904, Mr. Bowles asked whether the oil fuel experiments in warships had been satisfactory. Oil, he added, would carry a ship twice the distance coal would, but he doubted whether we could get a sufficient supply.

Mr. Pretyman said it was an important question, to which a great deal of attention had been paid, but he did not think it would be in the interest of the service if he were to go into the matter.

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"EXPERIMENTS with oil fuel have been steadily prosecuted with constantly encouraging results. The problem which the Navy has to solve in the use of oil fuel is a much more difficult one than that which the mercantile marine has had to solve, because oil fuel can be of no use to the Navy, as compared with Welsh steam coal, unless the combustion can be brought to such perfection as to render the fuel practically smokeless."

LORD SELBORNE, First Lord of the Admiralty, in the Navy Estimates, in 1903.

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"THIS question has for some years been receiving the attention of His Majesty's Government. The Governments of the self-governing Dominions are actively exploring their oil-bearing areas, and at the present time the oil-bearing strata of the Island of Trinidad are being surveyed by a geologist, while in several other areas, especially in West Africa, important investigations are being carried on."

LORD ELGIN'S reply to a correspondent who pointed out that the British Empire ought to be the greatest producer of petroleum in the world, and suggested that as the matter was one concerning the prosperity of our Colonies the Government should take steps to develop the petroleum-producing industry in those possessions where the oil was known to lie in large quantities.

*New York Herald Staff Photo.*] [*May 20th*, 1908.

J. D. HENRY.

# AUTHOR'S NOTE

THE proofs of this book were read on a western run across the Atlantic, and this note of explanation is being written at Detroit on my way back to New York after a visit to the new oil fields of Southern Canada. Last autumn I published a book on the marine branch of the oil distributing business, and at the beginning of this year I started on the present volume in the hope that I would be able to finish it before I set out to visit some of the oil fields of the Empire. I miscalculated the time necessary for the production of a work of this kind, but was able to save the situation by placing the responsibility of publication on the shoulders of my colleagues and giving a free hand to Messrs. Bradbury, Agnew & Co., the printers of all my works on oil.

Considering the importance of the subject, this ought not to be the least useful of my books, and I hope the publishing results will show that there is room for a work of this kind in the associated literatures of petroleum and engineering.

Only these two further explanations: that the criticisms of oil fuel by Rear-Admiral Evans appeared in *The North*

*American Review*, and that I am under obligation to Mr. Goulichambaroff, of St. Petersburg, for Russian literary assistance, to Mr. F. Rushton Ablett, my colleague, for the practical interest he has taken in the burner section, and to Mr. Blanchard, a clever marine artist, for several original drawings.

DETROIT,
*June 1st*, 1908.

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# OIL FUEL AND THE EMPIRE

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### I

THIS is one of the few countries in which the use of crude oil as a combustible for mercantile marine and industrial purposes is more than an ordinary business risk. The chief reasons are patent and must be frankly acknowledged; they are economic, and, no matter how unwillingly some of us may make the confession, we cannot keep back the truth that the unsolved problems of a prohibitive price, largely the result of high and fluctuating transport charges, preclude the possibility of its early becoming a standard fuel of our national industrial organisation. Not only is this true to-day, but it will probably stand true for ten years, and, some of us think, possibly for a generation, if we are content to depend exclusively on foreign supplies and do not develop the oil fields of the Empire.

In this country foreign oil fuel is too dear to flow freely in industrial channels blocked by practically inexhaustible supplies of home-produced coal. It is a commercial truism that it does not pay to send coal to Newcastle; to any one who has a knowledge of the geography of the world's oil fields, and knows anything about oil transport rates of 1907-8, it must be obvious that, this being a coal-producing and not an oil-producing country, it is hopeless to expect an early crystallisation of a commercial system in liquid fuel.

It is no part of my duty to explain the commercial features of the case in favour of coal against liquid fuel. Inasmuch, however, as it is my intention to show that oil has considerable and undoubted economic advantages over coal in some of the principal oil-producing countries, and also in what I may call neutral territories, where the dominion of coal for marine purposes is no longer absolutely unchallenged, I think it wise to deal with this purely British coal-versus-oil phase of the subject before I discuss the progress and prosperity of liquid fuel in other parts of the world.

The world's production of coal in 1906 was 1,106,478,707 short tons. Of this huge quantity the United States produced 414,157,278 tons, 37 per cent. of the total. Great Britain, second on the list, produced 281,195,743 tons, and Germany, the third largest producer, followed with 222,350,526 tons. Exclusive of Great Britain, the United

States produced more than all the countries of the world. The railway consumption of coal in the United States was 95,804,002 tons against 16,632,963 barrels of fuel oil (equivalent to about 4,160,000 tons of coal).

Official figures for 1907 show that the American coal output exceeded that of 1906 by upwards of 60,000,000 tons. The total quantity imported into America amounted to 2,116,122 tons as compared with 1,712,150 tons in 1906, an increase of 403,972 tons. The chief country of export was British North America, which sent 1,398,194 tons to America in 1907, a decrease of 29,537 tons on the quantity exported in the previous year. The United Kingdom sent 32,934 tons, which is less than one half of the quantity sent in 1906. The exports in 1907 amounted to 13,146,748 tons, an increase of 3,224,929 tons over those of 1906.

To-day the coal fields are admittedly more extensive and advantageously situated than the oil fields, but these disadvantages will be less pronounced when practical exploitation work is undertaken in the numerous oil-bearing parts of the British Empire. Moreover, the demands for illuminating and lubricating oils and those of the benzine varieties are substantially more than half the world's production of crude, while, calculating on the basis of $3\frac{1}{2}$ barrels of oil as the equivalent of a ton of coal, we bring the oil contribution to the world's production of fuel down to three or four per cent.

Experts find it convenient to leave this phase of the subject at this point. This is a mistake. In some of the present fields, California, Texas-Louisiana, Mid-Continent and Baku, and certainly in the oil fields of the future—those of the British Empire—the proprietors will have a greater inducement to convert a larger percentage of the output into fuel. The Texas-Louisiana fields have practically and energetically put into operation the sound business idea of working up a substantial increase of the oil fuel percentage of the output. The heavy oils of these States are a great and increasingly popular factor in their industrial development and give us an example of what oil is capable of doing for the British Colonies.

Compared with the cost of coal the average price of oil during the past seven years justifies the statement that it is a cheap fuel in many parts of the world. By far the greater portion of Texas and Louisiana crude which has reached the fuel market—and this means probably four-fifths of the entire production since 1901—has sold at from 15 to 40 cents on cars. The average price is put at 50 cents a barrel, plus the freight, which has not averaged more than 25 cents a barrel. Thus the cost to the consumer has been 75 cents (3*s.*) a barrel. This is the equivalent of coal at 12*s.* 6*d.* a ton, delivered. The average price of coal delivered to Louisiana points is not less than 15*s.* 6*d.* or 16*s.* 8*d.* a ton, and in Texas the average cost per ton is not much under £1.

During the seven years oil has been in use in Texas and Louisiana there have been only two periods when the price has been greater than that of coal. One of these was early in 1903, when Spindle Top began to decline, and the other was in the autumn of 1906. These were brief periods compared with the years 1901, 1902, the last seven months of 1903, all of 1904 and 1905, and nine months of 1906, when prices ranged from 10 cents to 75 cents a barrel on cars.

For seven years California and Texas consumers have recognised the superior merits of oil and have only hesitated to permanently use it on account of the apparent uncertainty of an adequate and lasting supply;

"but (and I quote from a letter I have received from Mr. Holland Reavis) the reasons for this uncertainty are being eliminated by the construction of the pipe lines from the Oklahoma fields to the Gulf Coast, where the refineries are turning out a perfect liquid fuel from Oklahoma light crude." *

The supply of oil in Oklahoma is limitless, and I write this sentence, a common one in petroleum literature, with a full sense of all that it means when introduced into a serious work of this description. Last year the quantity of Oklahoma crude and residuum shipped to Texas fuel consumers was over 5,000 barrels a day, the crude coming from Glenn Pool and the residuum from the Standard's refineries at Sugar Creek and Neodesha and from the Muskogee refinery at Muskogee. The Texas Company, operating a skimming plant at Dallas, is providing 4,000 barrels of fuel oil per day from Glenn Pool region. The surplus of oil in Oklahoma goes to supply a very important part of the Texas and British fuel oil markets.

In Russia the comparative figures are still more significant; they show that coal has absolutely no position in the maritime and manufacturing industries of the Caspian and the Volga.

The world's production of oil is given on the next page

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* From what I know of these fields I should say that in a few years time there will be half-a-dozen pipe lines carrying the oil to tidewater on the Gulf Coast. The termini will not necessarily be Port Arthur, for I have good ground for saying that Standard Oil Company experts, on a thorough investigation of the engineering features of the route, have recommended New Orleans as a terminus for at least one pipe line. This port, 520 miles from Glenn Pool, would bring Oklahoma oil fifty miles nearer a water shipment point than Port Arthur.

THE WORLD'S PRODUCTION OF CRUDE PETROLEUM (IN TONS).

| Year. | United States. | Russia. | Dutch East Indies. | Roumania. | Galicia. | India. | Japan. | Germany. | Other Countries. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1880 | 3,443,482 | 400,237 | — | 5,900 | 32,000 | — | 3,992 | 1,309 | 283 | 3,897,203 |
| 1881 | 3,623,622 | 640,542 | — | 16,900 | 40,000 | — | 2,622 | 4,108 | 172 | 4,327,966 |
| 1882 | 3,996,918 | 800,637 | — | 19,000 | 46,100 | — | 2,434 | 8,158 | 183 | 4,873,430 |
| 1883 | 3,071,901 | 960,732 | — | 19,400 | 51,000 | — | 3,205 | 3,755 | 225 | 4,110,218 |
| 1884 | 3,172,615 | 1,441,343 | — | 29,300 | 57,000 | — | 4,372 | 6,490 | 397 | 4,711,517 |
| 1885 | 2,863,500 | 1,857,558 | — | 26,900 | 65,000 | — | 4,577 | 5,815 | 270 | 4,823,620 |
| 1886 | 3,676,494 | 2,402,076 | — | 23,450 | 42,640 | — | 5,936 | 10,385 | 262 | 6,161,243 |
| 1887 | 3,705,136 | 2,642,382 | — | 25,300 | 47,817 | — | 4,484 | 10,444 | 274 | 6,435,837 |
| 1888 | 3,617,175 | 3,102,757 | — | 30,400 | 64,882 | — | 5,861 | 11,920 | 209 | 6,833,204 |
| 1889 | 4,606,420 | 3,083,303 | — | 41,400 | 71,659 | 12,346 | 8,268 | 9,591 | 207 | 7,833,194 |
| 1890 | 6,002,887 | 3,630,663 | — | 53,300 | 91,650 | 15,466 | 8,051 | 15,226 | 452 | 9,817,695 |
| 1891 | 7,112,337 | 4,404,513 | — | 67,900 | 87,717 | 24,907 | 8,285 | 15,315 | 1,255 | 11,722,229 |
| 1892 | 6,616,765 | 4,593,556 | — | 82,500 | 89,871 | 31,739 | 10,788 | 14,257 | 2,766 | 11,442,242 |
| 1893 | 6,344,469 | 5,338,426 | 41,920 | 74,500 | 96,331 | 39,165 | 13,933 | 13,974 | 2,912 | 11,965,630 |
| 1894 | 6,464,131 | 4,851,124 | 111,200 | 70,550 | 132,000 | 42,865 | 22,493 | 17,232 | 2,903 | 11,714,498 |
| 1895 | 6,928,888 | 6,509,713 | 133,440 | 80,000 | 214,800 | 48,671 | 22,125 | 17,051 | 3,609 | 13,958,297 |
| 1896 | 7,985,807 | 6,571,026 | 191,200 | 81,570 | 339,765 | 56,327 | 30,858 | 20,395 | 2,536 | 15,279,484 |
| 1897 | 7,922,292 | 7,126,341 | 360,960 | 110,000 | 309,626 | 71,487 | 34,220 | 23,303 | 1,944 | 15,960,173 |
| 1898 | 7,252,714 | 8,070,425 | 414,400 | 180,000 | 323,142 | 71,016 | 41,553 | 25,789 | 2,021 | 16,381,060 |
| 1899 | 7,476,281 | 8,640,098 | 246,400 | 250,000 | 324,681 | 123,267 | 70,212 | 27,027 | 2,247 | 17,160,213 |
| 1900 | 8,334,289 | 9,927.101 | 425,600 | 250,000 | 326,334 | 141,252 | 113,529 | 50,375 | 1,683 | 19,570,163 |
| 1901 | 9,089,984 | 11,157,078 | 624,800 | 270,000 | 452,200 | 187,423 | 145,484 | 44,095 | 3,256 | 21,974,320 |
| 1902 | 11,628,665 | 10,550,745 | 800,000 | 310,000 | 576,060 | 211,874 | 156,880 | 49,725 | 4,074 | 24,288,023 |
| 1903 | 13,160,435 | 9,902,454 | 869,840 | 384,302 | 727,971 | 328,843 | 126,284 | 58,402 | 83,872 | 25,642,403 |
| 1904 | 15,335,318 | 10,283,618 | 1,049,087 | 500,561 | 827,117 | 443,496 | 184,968 | 83,490 | 88,636 | 28,796,291 |
| 1905 | 17,648,003 | 7,335,381 | 1,200,000 | 614,870 | 801,796 | 541,960 | 175,745 | 78,869 | 90,000 | 28,486,424 |
| 1906 | 16,113,000 | 8,060,763 | 1,350,000 | 887,091 | 760,443 | 560,000 | 175,000 | 80,000 | 90,000 | 28,076,297 |
| 1907 | 21,000,000 | 8,600,000 | 1,600,000 | 1,129,000 | 1,172,000 | — | — | 81,000 | — | 33,582,000 |
| Total | 218,193,528 | 152,884,592 | 9,418,847 | 5,644,094 | 8,171,602 | 2,952,104 | 1,386,159 | 787,500 | 386,648 | 399,825,074 |

in order that the reader may see at a glance the absurdity of the contention that liquid fuel, a comparatively small percentage of the world's yield of oil, is destined to seriously imperil the supremacy of coal as a power creator. Clearly, the two fuels have their own well defined spheres—oil, for example, has its Bakus and coal its Newcastles—and wherever oil gets a foothold in a coal-mining region or in the warships of a coal-producing country it will only do so because those who use it are not seriously influenced by questions of expense.

## II

Most reluctantly do I confess that in this country the use of liquid fuel suitable for marine purposes is limited to our warships and tank steamers trading to oil ports, although I cherish the hope that we are fast approaching a time when the development of the oil resources of our Dominions and Colonies will create and maintain an economically sound liquid fuel market in this country.

British shipowners and manufacturers have less faith in liquid fuel than they had six years ago. They prefer to work with coal for the good reason that no one is in a position to offer them the same splendid advantages which are enjoyed by liquid fuel users in many parts of America, Russia, and Roumania.

All oil men, and, no doubt, some shipowners, will remember that the future of liquid fuel never looked so bright as it did in 1902, when the old Shell Transport and Trading Company (believing that the wonderful field known as Spindle Top, in Texas, had all the elements of Pennsylvania's permanence and Baku's oceanic fecundity) advertised the working of a liquid fuel business on ordinary commercial lines. Spindle Top looked like being the greatest fuel oil proposition of the age, and that was certainly the opinion of some of us when we saw the first wells gushing and the neighbouring town of Beaumont making daily progress towards the architectural dignity of a fair-sized Texas city.

A circular was distributed by the Shell Company in 1902 offering liquid fuel at the following prices:—Suez, 50*s.* per ton; Alexandria, Kurachee, Madras, Shanghai, and Yokohama, 40*s.*; Colombo and Bangkok, 37*s.* 6*d.*; Penang, Hong Kong, Batavia, and Sura Bay, 35*s.*; Singapore, 32*s.* 6*d.*; Kotei, 20*s.*; and Southampton, Liverpool, London, and other English ports, 35*s.** The company undertook to pump liquid fuel into steamers at the rate of 100 tons per hour.

The price at which the company thought it could sell and guarantee supply in London six years ago is just about the rate paid to tank steamers for bringing Texas liquid fuel to this country at the present time. We find in the figures an illustration of the instability of liquid fuel prices. The 35*s.* per ton was equal to 26½ copecks per pood. At that time liquid fuel was selling in Baku at 7½ copecks, while the freight from Black Sea ports to this country was about 10½ copecks, leaving 8½ copecks for transport across the Caucasus. To-day tank steamers are getting 26½ copecks per pood, equal to 35*s.* per ton (the

* In an article written by the author for *The Times* (published on January 16th, 1908, and reproduced, by permission, near the end of this work) the current prices of liquid fuel are given, and if these are compared with the Shell rates of six years ago the reader will see what a difference there is between the theories of those Spindle Top boom days and the actualities of this time of abnormally high freights and limited supplies.

actual selling price quoted in 1902), while the price of crude at Baku is practically the same as the sea transport figure given above. In other words, the Shell Company's price for Texas liquid fuel in 1902 is only about a third of the price at which Russian liquid fuel could be sold in this country to-day if it were possible for importers to purchase Russian oil in Baku and ship it to the Black Sea—a dangerous business, commercially, owing to the high tariffs and the great expense of working tank cars on the Baku-Batoum line. The great firms at Baku oppose the construction of a pipe line for crude because if adequate transport facilities were provided it is highly probable that part of the Baku refining industry would be taken across the Caucasus to the Black Sea port.

The tremendous risks of fluctuation spring from a multiplicity of different conditions in widely-scattered and competing oil fields, a constant movement of prices at the wells, the instability of pipe line and railway tariffs, and the absolute inability of any company or federation of shipping interests to reasonably limit the rise and fall of the rates for the sea transport of oil. There is nothing permanent in the petroleum business; in it everything is problematical, at times wildly speculative, and we have not only to calculate on the phenomena of production but also take into account some of those powerful financial interests which frequently aim at an artificial manipulation of our huge distributing and marketing systems.

Evidently the Shell Company, however, by increasing production in Borneo and rushing over supplementary supplies from Texas, on safe contracts and in their own steamers, thought it saw the dawn of the oil fuel era, that large quantities of oil would be required for the mercantile marine, and that the Navy would be compelled to adopt it as a standard fuel. It was a premature move in business—a misreading of exciting events worked up to boom pitch by the wildest of oil field reports. Unfortunately, the contracts of that day, good as they were, never justified the extension of an Anglo-Texas liquid fuel business on the basis of these advertised prices.

There were reports that the Standard Oil Company also contemplated going into the oil fuel business on a large scale and had decided to devote a considerable amount of capital (some reports put the figure at £6,000,000) to the supply of liquid fuel to steamship companies, but, always cautious to a degree in matters of new oil field developments, there was no advertisement, no price list, and no guarantee of supply.

For seven years Texas has shipped liquid fuel abroad, but it has never on an ordinary market been sold in this country at 35*s*., and there is no immediate prospect of anything at the price reaching us from the still more promising oil fields of the Mid-Continent region.

Up to the present I have confined these references to cost chiefly to the oil shipped from the Gulf Coast, because these are the only oil fields which have in recent times led British shipowners to hope that a thirty-five-shilling oil is possible. After this discouraging experience in connection with Texas oil we must not be surprised if shipowners and manufacturers insist more than ever on reducing the question to the unsentimental and mercenary one of pounds, shillings, and pence. If they can ever see their way to make an extra one or two per cent. by using liquid fuel, if they can be certain that it will be stored at ports along the lines of ocean traffic, if they can load 300 tons of bunker oil per hour without dirtying the steamers, and if by using this light fuel they can carry more cargo, we may be pretty certain that it will not be long before they adopt it. Without these advantages guaranteed ship-owners will go on using coal, excepting in special trades, of course.

Mr. Owen Philipps, M.P., chairman of one of the Thames oil storage companies, did not go far wrong in his estimate of the future when, speaking in 1902, he said :—"I am a shipowner, and I know that it may be many years before ordinary cargo steamers are able profitably to use oil for fuel, except for vessels engaged in very special trades. But liquid fuel for torpedo boats, for destroyers, and for a large number of Government vessels, has, I believe, already become a necessity, and in the case of many passenger steamers, where speed is of the utmost importance, it is also rapidly becoming a necessity. Although we may not have seen such an advance already, it is well known that many lines are making experiments, and as soon as there are depôts in all parts of the world they are open to favourably consider the matter."

Sir Fortescue Flannery, although he has a knowledge of oil transport subjects that is equalled by few and certainly surpassed by none, was too optimistic to be successful as a prophet. About the same time he said :—"I believe that in a few years very few vessels will be running East, where coal is dear, owing to the cost of long transport, which will not be fitted to burn liquid fuel. . . . If the price of coal increases, as it threatens to do, we shall have liquid fuel imported into this country at a cost which will make its use profitable."

When Sir Fortescue hazarded this prophecy he was, subsequent developments have proved, at sea in a double sense. His forecast has not been justified by events. Only in a scientific way has there been a satisfactory practical consummation of the tests of 1891–2, and, then, only in the British Navy, for the owners of merchant vessels have never adopted liquid fuel for economic reasons and because oil men have been unable to guarantee supply.

Writing on this subject in 1902,* my own predictions were less optimistic and more correct than the one ventured upon by Sir Fortescue. In that year I wrote:—

"The manufacturer is more conservative than the ship-owner. It is most natural that men who have built up considerable business concerns should remember that they have done so with the assistance of old-fashioned and reliable coal-burning systems sufficiently well suited to the needs of the closing years of last century. I am not surprised that they should hesitate and even appear sceptical when they are asked to throw off their allegiance to coal and become supporters of liquid fuel with its partly tried systems of distribution and consumption. It is not prejudice which temporarily blocks the way to the admission of oil to a foremost position as a steam-raising power; the barrier is thrown up by the old-fashioned business caution of the average British manufacturer. I do not wish to suggest that liquid fuel has only to overcome this peculiarity of the British manufacturer. There are other adverse influences at work. For instance, those railway companies which are large coal carriers in the mining districts must play a waiting game, and appear not to favour liquid fuel if they wish to avoid the hostility of the coal-owners. When an unanswerable case is made out to prove the efficiency and economy of fuel oil, the cautious manufacturer asks these questions: 'Can you honestly

* *Petroleum*, March 8th.

guarantee continuity of supply? Can we have oil in adequate quantities at all times? Remember, oil is a foreign liquid; coal is a British mineral. Up to the present time we have generally been able to rely on a steady supply of coal. Will the supply of the foreign fuel prove sufficient, even inexhaustible, when once its consumption has become popular? Then, if we are satisfied with your guarantee as to supply, will you tell us who is going to guarantee that there will not be a combination of oil fuel merchants to put the prices up when once the demand has come abreast of the supply?' These are shrewd queries; they are questions which must be answered, if not to-day, then shortly, by the highest authorities on the subject. Up to the present time no absolutely conclusive and convincing answers have been given to the common-sense interrogations of the cautious ones. When trying to account for any opposition there may be to this movement, we should not forget that we are engaged in a peculiar business—a most exclusive and mysterious foreign industry never mentioned in British school books, and seldom handled with intelligence by the daily Press of the country. We cannot ignore the fact that the abstruse question of oil fuel, so full of technical points and peculiar trade characteristics, needs further illuminating, and requires treatment from the supply and demand point of view, before we can hope to see the manufacturers of the country converted to its adoption in anything like large numbers. I need not point out that in this business of liquid fuel we have little, if anything, to do with the man in the street. The subject is only of real interest to the wealthy commercial classes—those who run engines and employ hands. In this respect it is different from the trade in illuminating oil. Very few persons on this terrestrial globe know anything whatever about the oil spots on it. The man in the street knows as much about the spots on the sun as he does about the oil fields of the world. He may have some slight knowledge of its domestic use; he may know there are at least two descriptions of oil, Russian and American, and, if his information is not too crude, he may be able to tell you something about a third kind imported into this country from Roumania. We owe the man in the street no great grudge because he thinks that oil is the nasty produce of an uninteresting trade. Neither do we look scornfully at him because he thinks kerosene comes out of the earth, pure, refined, and ready for his lamp. His ignorance is most natural, seeing that the great business of releasing and drawing oil from the bowels of the earth is so very mysterious and foreign. What we are most concerned about is the conversion of thousands and thousands of manufacturers to the use of liquid fuel."

Every phase of the question of securing a wide adoption of liquid fuel for marine and manufacturing purposes—every detail in any discussion that may be started—must be considered in relation to these two vitally important factors: price and supply. This difficulty, created by exceptional circumstances, and so glaringly obvious, stares us in the face: no company can, with safety, guarantee supply. As a matter of fact, no company in this country is to-day guaranteeing continuity of supply; or, perhaps I should say, no company is pushing business along the lines of a written guarantee for, say, three years, the minimum time for which a manufacturer would care to remodel the firing arrangements of his furnaces. If a company were to guarantee supplies, with legal responsibilities, it would be embarking on a very hazardous experiment; it would be engaging in a speculation that no public company would be justified in entering upon.

Other times, other undertakings; certainly definite guarantees do not fit into the commerce of liquid fuel to-day.

This deficiency of supply is a fault which can be remedied by the employment of finance, expert knowledge, and engineering skill. Oil exists almost anywhere; prospective petroleum areas are dotted all over the world; the striking developments of the last three years prove this. As I have already explained, such immense quantities are required in the localities of production and for the inland markets of the oil-producing countries that it is practically impossible to establish a system for the liberal importation of fuel oil into the United Kingdom. We want a sensible and systemised search for oil; the discoveries will pay handsomely for the money expended and the trouble taken; in other words, money is wanted for the industry, and this should not be difficult to secure if the countries in which oil is known to exist will only offer proper encouragement to reasonably capitalised companies and *bonâ fide* speculators.

While oil is too dear to permit of the free development of the liquid fuel business in Great Britain, I think that prices will decline and give the best friends of the industry a better opportunity of pushing oil against coal. Our greatest hope, however, lies in the direction of entirely new oil fields and the linking up of old and only partly developed ones with ports of shipment and centres of civilisation.

## III

Having outlined some of the factors which militate against a generous adhesion of this country to the new fuel, I come to this irresistible argument in its favour—that the British Admiralty, controlling a matchless Navy charged with the protection of the richest and most widely scattered Empire the world has ever known, must see that the warships of every class are equipped with the power-creator which is able to give them the greatest speed under war conditions. After all, the best work of our naval architects and engineering experts must fall short of perfection directly it fails in an emergency test of speed. Recognising that in swift ships oil saves space and labour, if it does not save money, the Admiralty has decided to use oil fuel in every type of warship, and it is this fact which gives the Imperial aspects of the subject such tremendous importance. The oil fields of this Empire cannot be compared with the huge territories of petroleum-producing powers; indeed, it says little for British enterprise in Colonial petroleum field development work that our record of success is practically limited to a Scotch undertaking in the ancient fields of Burmah. When the possibilities of oil fuel for naval purposes became manifest some ten years ago, England practically neglected to develop her oil resources, and there is much truth in the statement that, instead of building up a Baku in Canada, a Texas in Australia, and a Pennsylvania in New Zealand, we deliberately placed English capital and skill at the service of the foreigner.

Admiralty experts, by organising a system of depôts, are showing that they do not altogether deny the reliability of existing foreign producing sources and are really

The torpedo boat destroyer Cossack, one of the Tribal Fleet of oil-fired expresses of the British Navy, steaming 33 knots, her contract speed, on the measured mile at Skelmorlie. After she passed into the Navy she exceeded her contract speed by more than two knots, and in this respect she is like the Tartar and others of her class turned out by private builders. Her builders, Messrs. Cammell, Laird and Company, Ltd., of Birkenhead, who have had many striking successes in the construction of oil-fired destroyers, are now building the 36-knot torpedo boat chaser Swift, which is expected to break all records for speed in the world's navies.

[*To face p.* 17.

hopeful that the idea of an Imperial supply will be practically developed by British capital and enterprise. This is a decided step forward, but I should say that it marks the limit of justifiable surmise if we omit the financial support given by the Government in the case of Nigerian oil exploitation developments and an improved system of geological surveys in some of the most promising of the virgin oil regions of the Empire.

One of the unsatisfactory results of the Admiralty's earliest experiments with liquid fuel was found in the commercially questionable guarantee of Russian and Bornean supplies. It was only too obvious that Russia had it in her power to cut off the supply for either commercial or political reasons. At that time there was a strong movement in Canada in favour of a diversion of British official attention to the undoubted ability of the Dominion to supply oil fuel. The Portsmouth experiments had been far from satisfactory, and reports were being circulated that the smoke trouble could not be overcome by the Admiralty's engineers and experts. It was then that the following clear case was made out on behalf of Canada—"The difficulty would be entirely overcome if England would look to her own loyal colony, the Dominion of Canada, for her liquid fuel. We are producing in the oil fields of Western Ontario about 28,000,000 gallons of crude petroleum annually. Our oil is of a heavier specific gravity than the U. S. oil, and contains a larger percentage of carbon than either the Russian or American oil, and is, therefore, specially adapted for use as fuel. We have been successfully burning oil as fuel here for the last twenty-five years under ordinary steam boilers, as well as under the stills, where a much higher temperature is required, and no difficulty whatever is experienced in applying this admirable system of heating by liquid fuel wherever it is desired to use it. The combustion is absolute and complete, there is no trace of smoke visible from a chimney where Canadian petroleum fuel is used, and the heat can be regulated and controlled with great ease and precision. The oil that is used here for fuel is not the crude petroleum just as it is pumped from the rock, but a residuum which is obtained after the distillation of the water and lighter hydrocarbons from the crude, which are of little use as heat-giving elements. This Canadian petroleum is without doubt the best liquid fuel obtainable in the world to-day, and it must be apparent to all that it would be extremely desirable for England to draw the supply of liquid fuel for her warships from British territory. A large quantity of the best liquid fuel for warships could be delivered either at Halifax or at Vancouver, B.C., as it might be required, and if the British Government will make some tests with Canadian oil fuel they will speedily find that the results will be highly satisfactory. All the difficulties which they have experienced will be overcome, and they will find the same ease in adopting liquid fuel in the Navy that we have found in using it under boilers and stills. One great advantage of Canadian oil fuel is its absolute safety; it successfully stands a very high flash test."

This early appeal by Canada was neglected by the Mother-country. Before long the same appeal will come to us from the Dominion, and I am pleased to think that the times are increasingly propitious and opportune for its revival. Canada has more oil than any part of the Empire, and, what is more, she has it near tide-water.

Elsewhere I have written at great length on this subject, and am content, at this point, to quote the following from M. C. de Thierry—

"Our lethargy is remarkable when we remember that nature, in addition to endowing us with the fuel of the future, as bountifully as she has with the fuel of the present, has been equally kind in its strategical distribution. As it is with our coal supplies so it is with our petroleum supplies ; they are found in abundance at every vital point on our frontier—in Egypt, Burmah, Borneo, Australasia, Canada, the West Indies, South Africa and Nigeria. Nor is this all ; they are found near the coast, and in the vicinity of good harbours. Our want of enterprise in developing this Imperial asset, though culpable from the commercial point of view, is intelligible from the strategical. Coal is a main factor in our industrial success, and we have been able to work on the assumption that our resources are practically inexhaustible. Should oil be substituted, as it will be to a greater or less degree, England must draw her supplies from the Dominions and Crown Colonies. Without these she must be absolutely dependent on the foreigner for the power producer of the Navy, a state of things which would soon undermine our maritime supremacy. More than ever, therefore, an Imperial policy is necessary to safeguard our future in defence, for it may be the means of determining our success in war at a critical moment. It is no use waiting till the need arises. The only question is one of supply, which England can answer better than any of her rivals."

This subject of the duty of the Government to do something for Colonial oil is not a new one. Charles Marvin urged the Government of his day to develop the Eastern oil fields of the Empire ; but outside of Burmah, with its old and productive oil fields, this has not been done. It is now being pointed out that if we had developed the petroleum deposits in the British sphere of influence at the head of the Persian Gulf the Bagdad Railway would have been built by us long ago and the necessity for paper Conventions would never have arisen.

Some political controversialists talk of Russia's advance from the Caucasus as purely military, but they forget that her position on the Caspian has a firm commercial basis in oil. In Batoum, once a broken-down Turkish village, she has created an important port of immense service to Baku, and there is something to be said in favour of the argument that had we done the same by Koweit and the Karun Valley we should have raised a natural as well as a moral barrier to aggression from the north and saved ourselves the nervous apprehensions as to foreign designs on the flank of India. We have missed our opportunities there, so far as petroleum is concerned, just as we have in the Empire proper, or, as C. de Thierry puts it, "we might have had a Baku, Texas, and Pennsylvania of our own if we had conceived commercial strategy on national and Imperial lines."

"It will pay us to keep a sharp eye on Baku," Marvin once said. There is no good political reason why we should do this to-day, but there is a commercial one, and it is found in the lesson which Baku is capable of teaching this country: that a huge and productive oil region is an asset of naval concern and Imperial importance.

Russia has found that the Baku oil wells run streams of gold in St. Petersburg. There are many undiscovered Bakus in the British Empire, and yet the one and only Imperial oil field which has supplied fuel oil (and then only to the extent of a small cargo) for the Navy is in

Burmah. About Upper Burmah, Marvin wrote that the valley of the Irrawady and elsewhere contained enormous deposits of petroleum, potentially as copious as those of America, and, perhaps, as those of Baku. "There is (he wrote in 1888) no reason why the wonders of Baku should not be repeated in Burmah."

Last year Baku produced 7,661,290 tons, and India 500,000 tons. But, all the same, I think Marvin's confidence in Burmah will one day be justified by developments.

With our Imperial oil sources awaiting development, we need not envy Russia her Baku, and if we look at this question philosophically we will find some consolation in the fact that progress at the Russian oil fields is calculated to favourably re-act on the development of the petroleum deposits of Burmah, the Punjab and Beluchistan, and add to the prosperity and comfort of the people of our Indian Empire, for there is little doubt that some day liquid fuel will be exclusively used throughout the Peninsula.

In the by no means distant future when some of our first-class possessions will support and control their own navies, each one should be able to supply its own warships with liquid fuel, and, if necessary, contribute to the general needs of the Empire. The fuel supply of a greater British Navy is a problem which must be solved before very long. Not only must there be plentiful supplies of oil and ample storage at tide-water, but there must be a naval system of quick transport which will work effectively in times of crisis and respond readily to the high-pressure demands of actual warfare. The great questions of Colonial naval organisation, and particularly the one of the two-standard supremacy in sea power, cannot be settled without the assistance of liquid fuel. There are two reasons why this is so. Manœuvre tests in home waters have proved that a battleship is 10 per cent. faster with liquid fuel than she is with coal, and, in the second place, it is only too obvious that British coal cannot compete successfully with Colonial oil when it is a case of supplying warships in remote parts of the Empire.

To coal go all the risks of difficult transport, capture, and loss of time, resulting probably in a breakdown of the entire system; to the newer and more scientifically successful fuel go the advantages of safe transport and greater speed.

## IV

For many months outside experts in liquid fuel burning have shown the greatest anxiety to get at the secrets of the engineers and artificers of the Navy and expert engineers and fitters employed by shipbuilding firms engaged on Admiralty work. All attempts to glean information have failed.* For self-evident reasons the important secrets connected with the mechanics of oil burning and the results which are being obtained ought not to be made public in any way; they are a Naval asset of immense value, albeit there are those who contend that independent systems ought to be placed in competition

* When the cruisers Bedford and Arrogant were being prepared for their oil fuel trials in 1903 so jealously did the Mount Wise authorities guard the secrets of the preparations that working parties of engine-room artificers were specially brought round from the Portsmouth yard to carry out the trials, and every effort was made to ensure secrecy by keeping the results in the hands of strangers in Devonport.

with the Admiralty-owned installations. These secrets are covered by the Admiralty's emphatically-worded instructions that no one connected with the Navy shall publish information without official permission. No officer or man is permitted to read a paper or deliver a lecture upon Naval subjects unless a copy has been submitted to the Admiralty and permission for its publication obtained. There have been occasional indiscretions, but only of a trifling kind, and, so far as liquid fuel burning is concerned, they have been limited to the employment of retired naval experts by private firms concerned in the building of oil-burning warships.

Admiralty secrets concerning oil-fired vessels included in this year's building programme are also being well guarded. This is most satisfactory, seeing that the steam-raising equipment of the new vessels will be absolutely British and the result of much valuable experience gained by our naval engineering experts during trial trips and manœuvres. The published information is practically limited to the fact that a number of oil-burning torpedo destroyers will be launched during the year, and that one vessel of an entirely new type, the Swift, built by Messrs. Cammell, Laird and Company, will average 36 knots (a fraction over 45 miles) an hour on a six hours' continuous trial. Turbine-driven and oil-fired, she will probably be the first war vessel to steam fifty miles in an hour. She will have bunker space for 180 tons of oil fuel.

The Admiralty is to be congratulated on the pertinacity with which it has endeavoured to find out the real value of oil as a fuel and in what way it can be burned without smoke, which, during the early trials, made it a great objection rather than an advantage for war purposes. Two things have been aimed at: the elimination of smoke and the obtaining of proper supplies of oil within the British Isles. As I show in chapters of greater technical interest, the Admiralty has annihilated the smoke bogey, and we can now hope that it will soon have an Imperial-fed source of supply within our own islands. If oil fuel ever becomes the predominant fuel for the Navy (and this comes within the realm of applied science in the case of our warship expresses *), it will be a bad day for this country if she has to depend on foreign supplies.

## V

The Admiralty may be trusted to shortly take up the idea of providing specially designed fast tank steamers to look after the fuel needs of the Navy. They will have to be much faster than the Petroleum and Kharki, sufficiently fast, in fact, to not impede the progress of a squadron working under war conditions and with a reserve power which will enable them to steam at least 16 or 17 knots, which is fully four knots better than the speed of the fastest tank steamers afloat to-day.

At the 1903 summer meeting of the Institution of Naval Architects, held in Ireland, this phase of the question was brought before the notice of the members by Mr. E. H. Tennyson D'Eyncourt in a paper on "Fast Coaling Ships for the Navy." It appeared essential, he said, that the Navy should possess a sufficient number of vessels with all modern appliances, such as Temperley transporters, for quickly dealing with coal, both in harbour, when

* Coal in the smaller swift ships of the Navy has seen its day and has been banished—now it is oil, only oil, easy to stow and easy to manipulate, and representing not only a direct saving in weight, but an immense saving of labour.—Naval Correspondent of *The Daily Telegraph*.

THE torpedo boat destroyer Ghurka, built by Messrs. Hawthorn, Leslie and Company, Ltd., Hebburn-on-Tyne, is 255 ft. × 25 ft. 6 in. × 16 ft. 6 in. Fitted with turbine engines arranged on three shafts, she develops between 14,000 and 15,000 h.p. in the aggregate. There is a high-pressure turbine on the centre shaft exhausting into two low-pressure turbines on the wing shafts, the astern turbines being incorporated with the latter. Ahead of the low-pressure turbines on the wing shafts is a high-pressure and low-pressure cruising turbine, each turbine driving a shaft with one propeller. Steam is supplied from five improved Yarrow water-tube boilers working at a pressure of 220 lb. per square inch. Like others of her type, she burns oil fuel. She has coal for heating and cooking purposes, and it is expected that in a very short time these vessels will be equipped to burn oil in the galley and for heating purposes. Of her preliminary trials, when she steamed over 33 knots, there was an exceptional freedom from vibration, and her small bow feather was considered remarkable evidence of her excellence of design.

[To face p 24

taking it on board, and at sea, when discharging it into warships alongside. These vessels should also be capable of maintaining a sea speed of 17 knots, and do 18 knots in the case of an emergency. Eight vessels might first be tried, two to each of our four most important squadrons, and they should be located in pairs or larger groups at the principal coaling stations, so that, while one of each pair was taking in coal in port, the other might be giving coal to the vessels of the squadron at a distance. The various requirements could be met by vessels of approximately the following dimensions—Length, 550 ft.; beam, 66 ft.; draught of water, 27 ft., with 10,000 tons of coal on board, so as to be able to go through the Suez Canal when loaded. The cost of each of these colliers, fully equipped with transporters and all the necessaries for quick coaling, would, he estimated, be about £270,000.

Admiral Cleveland, who followed, said he was sorry to join issue with the reader of the paper, but he did not think coal would be the fuel of their ships for very long, and he would be sorry to see the Admiralty embarking on such an expenditure as that proposed. He felt clear, from the Admiralty point of view, they would be forced to take oil as their future fuel. Coaling at sea would be a very difficult problem, but he did not see any difficulty in supplying a warship with oil from an oil ship at sea. That was the direction in which they should direct their efforts.

If £270,000 (practically the cost of the two largest oil-carriers afloat) were spent on a tank steamer she would have numerous advantages over a collier turned out at the same price. She would probably carry a little less cargo, but it would consist of a better and more valuable fuel (in fact, double the quantity of steam-raising material), and she would steam faster and keep up a more regular speed, while it would obviously be much easier to take in a stock of fuel from her at sea, when only hose connections would be required between the two ships, than it would be to transfer coal with the complicated arrangements and gear of a steam collier of the type advocated by Mr. D'Eyncourt.

Oil fuel has beaten coal in speed tests in the Navy; some day it will beat it in bunkering tests, with the result, let us hope, that the heavy and filthy work of taking in coal bunkers will be abolished altogether.

## VI

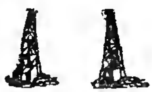
Come we now to the final section of a too lengthy Introduction. There is one respect in which I think a too enthusiastic advocacy of the claims of liquid fuel may eventually do the Admiralty and the petroleum industry a disservice. Some authorities, convinced that the oil era has dawned, are enthusiastically fostering the idea that the Admiralty has actually decided to create a world's chain of stations for the supply of liquid fuel. No such decision has been arrived at. It is a fact, however, that the authorities are devoting serious attention to questions of Imperial supply and storage, but the only thing that will justify the early provision of world-embracing storage facilities will be a widespread expert confession that the coal supplies of the country can no longer be depended upon and that there must be an absolute dependence on oil. The figures I have already given show that there is not likely to be any such admission in a country which is famous the world over for its splendid coal supplies. But, given time, the Admiralty may be depended upon to work up to the high ideals of those who in a reasonable way support the commanding claims of oil fuel against the practically effete steam-raising qualities of coal.

I have noticed that some of those who are financially interested in the development of Imperial oil fields are giving undue prominence to their value as money-making propositions, and the Imperial idea is in danger of being worked for mercenary ends. Colonial oil development is just emerging from the embryo stage, and when the Britisher speaks of the value of these widely-scattered fields he should think of them as the chief source of the nation's future oil supplies and not so much as a means of making money for shareholders. To some the Imperial idea must always be of paramount importance, and these are very properly pointing out that the question of what the investor may make out of the oil fields of the Empire is of comparatively little consequence at this time of crisis and expanding naval budgets.

Another word of caution, and I bring this Introduction to an end. The statement is frequently made "that all our rivals are as fully alive to the vital importance of this matter as we are." This is a fallacy. We are far ahead of the two greatest oil-yielding countries, America and Russia, and no one need hesitate to assert that the British Navy easily leads the world in the use of oil fuel.

"I WONDER how many people think, as they shovel on coal, what a terrible price has often to be paid for it. I shall not be able for a long time to sit before a fire without thinking of those mangled bodies, of the hopeless agony of the women's faces, some old and wrinkled, others fresh and young; and of the tiny tear-stained features of a child standing all day against a doorway, waiting to hear if she will ever be able to fling her little arms round daddy's neck again."

From the *Daily Mail* (at the time of the Hamstead colliery disaster).



OIL is unreasonably denounced by unreasoning critics as a dangerous fuel. This one thing should not be forgotten: the winning of it is a safe business, very much safer than is the mining of coal. Never a year goes by but the heart of the nation is profoundly touched by the tragic calamities of our coal mines, and yet no one suggests a restriction of the use of coal. The ordinary production and transport of oil makes no exceptional demand on human life; the oil world has no great death roll.

AUTHOR.

# CHAPTER I

THE GROWTH OF A GREAT INDUSTRY. HOW A WORTHLESS BY-PRODUCT BECAME A STANDARD FUEL IN THE BRITISH NAVY.

IN oil-versus-coal controversies and the ordinary newspaper reports of experiments in warships and tank steamers practically nothing has been written about the early history of the use of oil as a fuel.

Early Persian records and the works of Arabs of the eighth century refer to the use of Baku oil for heating purposes; Marco Polo, the famous Venetian traveller, mentions that it was exported to Bagdad; in Peter the Great's time the sale of Baku oil was a regular branch of Persian commerce, and the late Shah, father of the present occupant of the Persian throne, when he started on his first journey to Europe, crossed the Caspian in an oil-fired passenger steamer.

Charles Marvin, in one of his many pamphlets on the politics and industries of the Caucasus, writing before the new conditions at the Baku oil fields reached their zenith, said, if a London newspaper in his day published a leading article on the substitution of petroleum refuse for wood or coal, it regarded it as a purely speculative idea—feasible enough may be, but still, for the moment, merely an interesting topic for *dilettante* writing.

Two Philadelphians, Benjamin J. Crew and W. T. Brannt, in the pre-Redwoodian days of petroleum literature, wrote adequately and lucidly on the technology of the industry, and I notice that they both started their short chapters devoted to the history of oil fuel with the following paragraph :—

CREW (1887).

The use of petroleum in one or other of its varied forms as fuel is traceable to the remotest antiquity. Its combustible nature, with its heat-producing and light-bearing properties, very early attracted the notice of even the most barbarous and uncivilised nations. Its scientific adaptation to numerous practical uses, in accordance with its chemical composition, belongs to modern times. During the last twenty years a great deal of attention has been paid to the subject, resulting in many valuable inventions which have been reduced to practice.

BRANNT (1894).

The use of petroleum in one or other of its varied forms as fuel is traceable to the remotest antiquity. Its combustible nature, with its heat-producing and light-bearing properties, very early attracted the notice of even the most *barbaric* and uncivilised nations. Its scientific adaptation to numerous practical uses, in accordance with its chemical composition, belongs to modern times. During the last *thirty* years a great deal of attention has been paid to the subject, resulting in many valuable inventions which have been reduced to practice.

Marvin preceded these authorities with his descriptions of the oil industry at Baku; Redwood followed Marvin with his works, which, while they primarily deal with the modern technology and chemistry of oil, do not overlook the subject of its origin and history; and then, in 1903, we had Booth's book on Liquid Fuel and its Consumption, in which, however, the author is content to say—"The history of liquid fuel need hardly be referred to, for it is of slight value unless to confirm the generally accepted position of to-day that the only satisfactory system of supplying liquid fuel is to reduce it to fine spray—to atomise it, in fact, in terms of to-day."

Oil fuel has become a subject of international importance, and one of such immense interest in this country owing to its having been adopted as a fuel in the Navy, that I think the time is opportune for an English-written record of historical facts about the early experiments in different parts of the world.

The scientific use of liquid fuel was first studied and practised in the early sixties. The idea was to improve on the crude methods of burning pitch and coal and wood tars. About 1860 the subject received attention at the oil fields of Pennsylvania and Baku, and several experts discussed it in this country and in France. Oil discoveries in Western Pennsylvania awakened an interest in the subject in different parts of America, where even the rough-and-ready experiments of that day demonstrated the immense advantages of oil over any form of solid fuel.

Baku should have beaten America in the use of oil as fuel; it failed to do this, and, to quote the words of Mr. Goulichambaroff, "the Americans were the real pioneers of the use of liquid fuel." In the Apscheron Peninsula it was never employed when natural gas could be more easily obtained; moreover, the natives did not possess any apparatus for burning the liquid fuel and their ingenuity did not go beyond a primitive mixing of the oil with dirt and ashes. When the Transcaspian Trading Company started a kerosene refinery at Baku (1858) they kept away from the Bay at Black Town (the world-famous refinery region of to-day), and went eight miles inland to Surakhani, the scene of the Eternal Fires, where they got an unlimited supply of free fuel in the form of natural gas. Justus Liebick, who designed the refinery, adopted Wrangle's idea of burning the gas. He covered the fissures with boxes, made gas-tight by means of stones and cement, and tapping these primitive tanks by means of pipes he led the gas to the refinery furnaces. This is the first known instance of the practical use of natural gas, one of the derivatives of petroleum, under steam boilers.

In 1861 a mechanic named Weiser, employed at a Holy Island refinery, off the Apscheron Peninsula in the Caspian Sea, adopted various contrivances before he settled on an apparatus consisting of a series of grates or griddles, "which his employers (Witte and Co.) did not consider a commercially effective method of burning oil."

At the time of the first fountains in the Bibi-Eibat and Balakhani fields enormous quantities of crude oil were wasted. It was not, however, crude oil which was most advantageous for fuel, although, then as now, it could have been readily utilised, but the residue at the refineries known then as, and still called, astatki, or, frequently, mazoot (a Tartar word), having a flash point as high as 300° Fahr. (close test) and representing from 60 to 70 per cent. of the crude oil.

Owing to the rapid growth of the refining industry huge quantities of astatki were produced, and there were periods when it could not be given away and had to be burned or run off into the Caspian.* This was all the more remarkable because wood and coal, the common fuels of the oil fields, were expensive.

Nobel Bros., Marvin calculated, when they completed their first refinery, turned out oil refuse at the rate of 1,300 tons a day, or 450,000 tons a year, and "as in a good furnace a ton of oil went as far as three tons of hard fuel, this refinery alone produced annually the equivalent of 1,350,000 tons of coal."

In various parts of Western Europe, the use of oil refuse as fuel was enthusiastically advocated, but it was not until 1862, when Drake's new system of drilling wells was working at Titusville, that John Biddle and Shaw and Linton took out United States patents for the oil firing of furnaces on steamers.

The records of that time show that Biddle's idea was unsatisfactory, but in the case of the Shaw and Linton invention the United States Government appointed a commission to investigate its merits with the result that the report was distinctly favourable to the employment of liquid fuel, and, says one historian, "the interest excited

* Similar scenes have been witnessed in most of the great oil fields of the world. At Spindle Top there were floods of oil and fires which got beyond human control, and as recently as February, this year, the oil on Pole Cat Creek, near the Glenn field, started to blaze "so that the cloud of smoke covered the oil city of Tulsa, fifteen miles away, with a black pall and shut out the light of the sun as if there had been an eclipse." During the first two months of this year immense quantities of oil were wasted owing to the inadequate means for taking care of it, and "thousands of barrels found their way to Pole Cat Creek and made it look like a river of oil"—a repetition of sensational flooding of Bibi-Eibat and its bay nearly thirty years ago.

in America penetrated even to Russia, where the naval authorities in the Caspian region were experimenting with petroleum bricks—oil worked into masses of pitch-like consistency and thrown into the furnaces in the same manner as ordinary coal." This was undoubtedly true, because, according to a report of the Russian Ministry of Marine (1864), the following resolutions were adopted—

"That our agents in America be instructed to investigate the methods of using oil as a fuel and forward drawings of boilers, showing the types adopted, the disposition of the flues, and the method of arranging the fire bars, report on the types of vessels equipped with oil-burning furnaces, and supply all possible information regarding the construction of reservoirs used for the storage of oil.

"That our agents communicate this information to the Academy of Science in order that that body may be able to better investigate the burning qualities of Russian oil and determine where and in what quantities it can be obtained so as to be able to make their calculations on a sound basis and make this country independent of supplies from abroad.

"That we order for the Academy of Science samples of American oil used as fuel to enable that body to report on the best means for the use of crude petroleum for marine purposes."

Commenting on these resolutions, Mr. Goulichambaroff, in one of his works on the subject of liquid fuel, says—"Considering that the learned committee of the Ministry of Marine had at that time such hazy notions respecting oil fuel it is scarcely to be wondered at that the unsophisticated Baku refiners of that day were content to devote their ability to the carrying out of some very primitive experiments."

At that time Black Town, in Baku, was being built,* and there was a boom in refineries. When many of these started work the refiners could not handle the huge quantities of waste residuum; tanks were filled to overflowing, and vast areas of waste lands were trenched and used for the destruction of the oil by fire.

In this country the Government did not overlook events out at Baku and in America. England, being in close touch with America, was quicker than Russia to grasp the importance of liquid fuel, and during 1863 devices of highly complicated design compared with the pioneer burners in Russia were invented. Experiments were carried out in Woolwich Arsenal, and during 1864 Richardson made an offer to the British Admiralty to test an apparatus invented by him. This apparatus differed materially from, although it was based on, the principle of burning liquid fuel by means of porous materials proposed by Mills a few years before. Mills worked mainly with lamps, into which he placed sponges, saturated with volatile hydrocarbons, and then passed through the lamps a current of air, which, impregnated with the hydrocarbons, burned like gas. In Richardson's apparatus petroleum gas was generated in the furnace itself. Near the top of this apparatus, which resembled an M-shaped grate, there were pieces of porous material such as charcoal, pumice stone, coke, &c. The supply of oil was admitted by a pipe at the bottom of the apparatus,

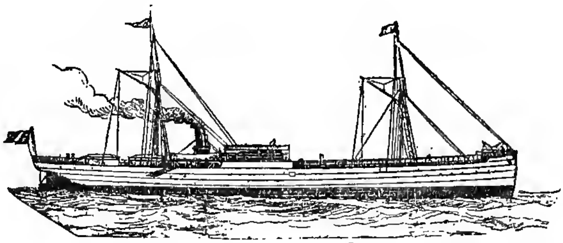
* Before the sprinkler was invented at Baku oil was burned in ordinary ovens and gave off clouds of black smoke. This led the workmen to christen the refinery region Black Town, the name it goes by to-day. The part of the town built after the invention of the sprinkler was named White Town.

and means were provided for cutting off the supply at any moment.

The fireproof porous materials were practically the wicks along which the petroleum ascended, and the space between the side walls of the grate was filled with water to prevent over-heating. Combustion began after the vapours and gases had passed through the porous materials. The grate used by Richardson at Woolwich had a surface of two square feet; the boiler was of 17 h.p., and two hours after starting the fires the steam had reached a pressure of 10lb.

"Richardson's apparatus (Mr. Goulichambaroff wrote) reminds one of a water bottle, in that it is absolutely impossible for the oil to be entirely evaporated, but there is bound to be a heavy residuum varying in quantity according to the quality of the oil used. That my contention rests on a substantial basis is borne out by the results obtained by others who have tried to work petroleum furnaces on this principle. Of course, assisted by the steam which formed between the walls of the grate, it was quite possible to obtain a more or less complete combustion, but hardly at a uniform rate, inasmuch as every kind of petroleum gives off first its lighter and then its heavier constituents, the first being more easily volatilised. Therefore, it follows that as thick residuum no doubt accumulated in the grate, evaporation would gradually slacken and cease entirely as soon as all the constituents which boil at lower temperature than water had been driven off from the fuel."

Although the Admiralty abandoned these experiments, they were, from an engineering point of view, very far from being complete failures, and they were rejected chiefly because these early inventions for burning oil fuel in England could not make headway against the steadily rising price of Baku astatki.



[*From an old drawing.*

ONE of the earliest of the oil-burning tank steamers on the Caspian Sea. Although many improvements have been made in the construction of vessels of this type, they have not increased in size on account of it being impossible to get large foreign-built steamers through the Volga locks.

When Baku producers recognised the advantages of liquid fuel burning, and a number of bulk oil-carrying steamers arrived on the Caspian, there was a demand for the waste oil, and the price went up to a figure which made competition with coal impossible, in this country at any rate.

When the value of astatki as fuel became recognised the commercial and refining conditions were speedily changed; the residue became the important product and the distilled oil the by-product, with the result that the refiners made as little of the latter as possible consistent with the production of a suitable astatki to meet the new need of the times. For that reason it may be claimed that Russian petroleum became a great fuel industry upwards of thirty years ago.

The honour of inventing the apparatus which first led to the general adoption of oil fuel was divided between Aydon, an Englishman, and Spakovsky, a Russian, who, strangely enough, was not an engineer. They hit upon the idea of an apparatus to pulverise the oil and blow it into the furnace in the form of spray, which is the principle of a large percentage of the burners in use in all parts of the world at the present time.

The late Professor Mendelaieff contended that Aydon copied Spakovsky's invention and that his fellow countryman secured registration three-and-a-half months before the Englishman. To that extent the eminent professor was right, but during the period mentioned Spakovsky's drawings were deposited in the Patent Office (June 27th, 1865), where Aydon had no access to them, and it is also known that Spakovsky simply put in a sketch while Aydon lodged a complete and elaborate set of practical designs. Spakovsky used a blast of hot air in his pulveriser, while Aydon employed superheated steam. Subsequently the resourceful Spakovsky improved upon this method by adopting ordinary steam, but there is no denying that the Englishman was the first to hit upon the idea of using steam. Aydon had this further victory: his apparatus was the first tested under working conditions and the first to place the employment of pulverised petroleum on a practical basis. In it the oil ran through a small orifice, about one-eighth of an inch in diameter, in a continuous stream at the rate of about three gallons per hour. As the oil fell vertically it was met by a jet of superheated steam, which forced it into the furnace in the form of a cloud of exceedingly fine spray and converted it into vapour which took fire and was consumed.

Mr. Ragosine was one of the first to understand the real value of Spakovsky's invention, and concerning it he said "it was the first appliance designed for the smokeless consumption of oil." This is how he describes the invention—

"When fire extinguishers were introduced by the fire brigade in St. Petersburg, a difficulty was, how to raise steam in the shortest space of time. Spakovsky, a photographer, became deeply interested in the question. He must have noticed that all organic substances of the animal and vegetable world, and some mineral organic substances like sulphur, phosphorus, nitre, &c., burn, that the burning of combustible substances begins at the surface and extends inwards with more or less difficulty, and that if the surface of a combustible substance be increased, say, tenfold, the burning will be ten times as rapid. Thus the surface of a cubic centimetre is equal to six square centimetres. If the cube be broken into cubic millimetres, their total will amount to 1,000, while their aggregate surface will amount to 6,000 millimetres, or 60 square centimetres—*i.e.*, we get ten times more surface than is given by a small cubic centimetre. The burning will be ten times as rapid, and the heat, therefore, produced in a given time ten times as great. Spakovsky, experimenting with turpentine, made his sprinkler from an ordinary pulveriser, which broke the turpentine into very fine sprays, and when lighted, and allowed to play under the tubes, raised steam in an exceedingly short time. It is very likely that Spakovsky had no idea even of the existence of petroleum, but his invention was applied later on by others to oil and gave it such a wide application as a fuel."

Mr. Goulichambaroff, than whom there is no more impartial historian, after examining the claims of the rival inventors, says—"Aydon's was the first attempt at the steam pulveriser for petroleum, which gives such brilliant results to-day ; only the apparatus has undergone considerable modifications, and is still in a state of transition."

But, after all, it was not a question of pulverisation, but one of the agent used to inject the oil into the furnace, and when Spakovsky replaced the hot air and superheated steam with ordinary steam he triumphed to the extent that he ultimately hit upon the best solution of the problem.

In this country there was no great need for liquid fuel, and Aydon's clever apparatus became nothing better than a Patent Office curiosity. Marvin tells us that in the sixties new ideas were being constantly registered in this country, but there was no industrial opening for them and they simply stagnated and died out. On the other hand, these same failures in Western Europe were adopted and improved upon by clever plagiarists in the Caspian region.*

The question of the employment of petroleum as fuel in this country in competition with the abundant coal supplies engaged the minds of inventors, but the general opinion was that where economy of fuel alone was considered petroleum took a second place, although when economy of space for storage of fuel and convenience of handling were of importance no fuel could be placed in competition with it.

Here is a description of oil fuel in 1866—an extract from the *Press* newspaper, which was quoted with approval

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* Details of numerous oil-burning inventions in the early days of the industry are given in convenient chronological order in the somewhat lengthy burner section.

by Mr. H. H. Vivian in the House of Commons twenty years later, and now reproduced for the benefit of readers of this work—"A boiler made at Woolwich to test the practicability of burning the oil for steam purposes has been tried, and the result is pronounced exceedingly satisfactory. . . . The fires were kept up so easily that the stoker was quite at a discount. Other people besides enthusiasts in oil talk of petroleum as certain to come into use for marine and other engines. It would seem that it is more plentiful in the world than coal, it occupies a small space, and it burns without having any waste in the way of cinders or ashes. There appears no reason why it should not be really much cheaper as a steam generator than coal."

That might almost be an extract from yesterday's Press. Evidently, the merits of petroleum were almost as fully recognised in 1866 as they are to-day.

About 1867 experiments were made by Mr. Isherwood, an American naval engineer, on the gunboat Pallas. Convinced of the superiority of oil over coal in heating value, convenience of storage, weight, bulk, absence of stoking, and economy of manual labour, he found that the lighter oils, which exploded very easily, burned completely and left no deposit, but there was, he confessed, this great drawback against the use of petroleum as a marine fuel: the danger of carrying an inflammable oil which gave off volatile gases at a low temperature.

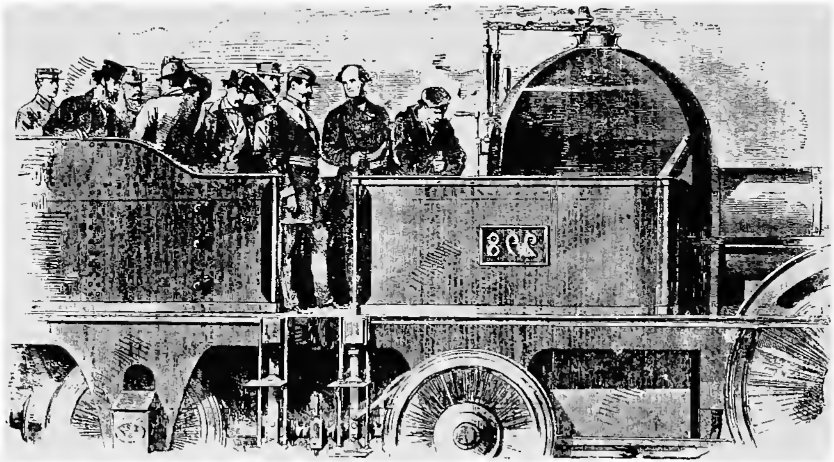
The first liquid fuel burner of the pulveriser type in the Caspian region was invented by Kamensky, Government Engineer at Baku, in 1869. The oil fields were not developed on modern lines, and Baku at that time owed its position of industrial importance to the Government Dockyard, the headquarters of the Caspian fleet having been removed from Astrakhan to the embryonic oil metropolis a couple of years earlier.

Kamensky obtained plans of an apparatus which Deville brought out in 1868 and fitted to the 60 h.p. engines of the Le Pouebla, one of the yachts of the Emperor Napoleon III. He made one or two alterations and passed the invention off as his own. In France, Deville obtained a great reputation as the result of the able and elaborate manner in which he dealt with the subject of liquid fuel, but his apparatus was a failure; Kamensky was equally unsuccessful with his copy of it, and the Baku naval authorities refused to sanction any further experiments by him.

Meanwhile, the Caucasus and Mercury Company, a State-assisted company with vessels on the Caspian, had been making unsatisfactory trials with liquid fuel at Astrakhan Dockyard, and the directors sent their chief engineer on a tour through Europe "to pick up ideas." Mr. Lentz * visited England (in 1869), where he saw Aydon and Dorsett, and afterwards went to France, where he made the acquaintance of Deville. The French apparatus pleased him most, and he returned to Russia with drawings prepared by Deville for the Derjavin, one of the company's steamers. This proving a failure, Lentz grafted the best features of Aydon's apparatus upon it, and this composite apparatus, working for a couple of months, made the Derjavin the first

* In later years this resourceful and clever engineer made a name for himself in the Baku fields. He employed hundreds of drillers and engineers, kept his oil burners well to the front, and did a great deal of important contract drilling and engineering work. A few years ago, just before the massacres, he left Baku, and is, I understand, enjoying a well-deserved rest in Germany.

WHEN the Emperor Napoleon visited the camp at Chalons he made part of the journey on an engine, "the furnace of which was constructed to burn neither coal nor coke, but petroleum." The apparatus for using the oil as fuel was the invention of M. Sainte-Claire Deville. The engine drew the train over the 28 kiloms. between the station of Chalons and that of Mourmelon, where the Emperor, in the uniform of a general, descended from the saloon carriage and went towards the engine, accompanied by M. Sauvage and M. Sainte-Claire Deville, who had awaited His Majesty's arrival at Chalons. The Emperor mounted the tender and took his place on the platform by the side of the engineer, manifesting a desire to watch the operation of the oil-fired engine during the journey from Chalons to the camp. The complete precision of the working fully substantiated the claims of the inventor to having produced a new method of substituting petroleum for coal in locomotive engines. One writer said: "The oil is supplied by a kind of spout which can be so regulated that the flame can be increased or diminished with as great facility as water can be supplied to a boiler. There is almost an entire absence, not only of smoke, but of any disagreeable smell, and it is said that the probabilities of explosion are reduced to a minimum, if they are not altogether at an end."




*From a Sketch in an Illustrated Journal in 1868*

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steamer worked with liquid fuel in Russia. The experiment was, however, considered a failure, and the apparatus was not used after 1870.

Meanwhile the ubiquitous Spakovsky, Aydon's rival, had not been idle; he had been improving his apparatus, and within a day or two of the stoppage of the Derjavin, the Volga steamer, Alexai, belonging to the Lebed Company, an unsubsidised steamboat corporation competing with the Caucasus and Mercury, started to run with it. The Alexai experiment was sufficiently successful to justify a more extended application of the new idea, and in May, 1870, the Iran, the first oil-burning steamer, appeared on the Caspian. This vessel had low pressure engines of 45 h.p., with a couple of furnaces, and Spakovsky fitted each of these with his pulverisers. He took out the coal bunkers and built into her six oil tanks, each one holding seven or eight tons, and two others in the bows, containing ten tons each. The expenditure of oil fuel was found to be not more than seventy pounds an hour. This apparatus was the one with which Spakovsky solved the steam-raising problems of the marine use of liquid fuel, since, apart from his early discovery of the advantages of steam as a pulveriser, his apparatus was the first to undergo a permanent and really practical test at sea.

In 1871 the company had the steamer Russia fitted with Spakovsky's apparatus, in 1873 the Helma, and in 1879 the Daghestan and Pir-Bazaar, the latter having engines of 80 h.p. To prevent the flame from damaging the end of the furnace, the inventor introduced bricks made of the ordinary clay at Baku, and as these lasted a long time Mr. Goulichambaroff, as the result of a personal investigation, expressed the opinion "that the alleged ruinous effects of the heat upon the boilers by the use of Spakovsky's apparatus were exaggerated."

When Lentz failed with his combined Deville-Aydon apparatus he did not give up. When the oil was injected in the Spakovsky furnace it was necessary to get up steam by burning a little wood. This arrangement suggested to Lentz the idea of replacing Deville's patent furnace with an ordinary wood-burning device on the lines adopted by Spakovsky, and when the Deville pulveriser gave unsatisfactory results he replaced it with the Aydon pulveriser, which worked very much better. After this he set to work to improve upon the English patent, and in 1872 produced the apparatus which has been employed in many of the steamers of the Volga and Caspian for upwards of a quarter of a century. His was an improved copy of Aydon's apparatus, consisting of two horizontal pipes, thrust a little way into the furnace, the upper one being fed with oil and the lower one with steam, and each pipe was regulated by a cock. When the two fluids entered the pulveriser they were prevented from mingling by a diaphragm, containing notches in the lip through which the petroleum trickled and was blown off by steam.

Lentz made an improvement in regulating the flow of oil and steam by placing the check, not before the entry of the fluid into the pulveriser, but at the point of issue, an arrangement which led to easier and steadier working. The pulveriser was also subjected to numerous alterations, and many experiments resulted in Lentz adopting a flat flame instead of the conical flare or the ring of jets common in most other appliances of that time.

Lentz's apparatus, having become the most generally adopted, was fitted to the Turcoman (the Caucasus and Mercury Company) in 1873, and soon afterwards to the

Bariariasky, 120 h.p.; the Michael, 100 h.p.; the Volga, 70 h.p.; the Armenian, Caspian, and other vessels belonging to the same company. In 1874, the Russian Government, deciding to use it in the Caspian fleet, gradually equipped the following vessels, and I give the list because they formed the first oil-fired fleet of warships in the world—

| Year adopted. | Name of War Vessel. | |
|---|---|---|
| 1874 | Khivenets | 60 h.p. |
| 1874 | Araxes | 40 h.p. |
| 1875 | Nasr-Eddin Shah | 160 h.p. |
| 1876 | Sekeera | 70 h.p. |
| 1878 | Ural | 100 h.p. |
| 1878 | Persianin | 60 h.p. |
| 1878 | Lotsman | 22 h.p. |
| 1879 | Griboyadoff, Pestchal and Legki | various. |

After Lentz had triumphed over all difficulties a number of rival appliances were invented. Benkston, an engineer in the employ of the Caucasus and Mercury Company, brought out a pulveriser on the Spakovsky principle, and it was used in a Baku engineering establishment in 1878. Sandgren, who succeeded Lentz as engineer of the same company, patented a pulveriser which was fitted to several vessels.

Brandt, head of the engineering firm at Baku, devoted himself chiefly to the oil firing of locomotives, and his pulveriser was one of those adopted on the Transcaspian lines. This ingenious arrangement was distinguished from previous inventions by its all-round discharge and tubular flame. The petroleum entered through the central pipe, and, overflowing on to the diaphragm, trickled down to the lip, where it met the steam and was driven off in spray. The regulation of the supply of oil was effected by the cocks from the footplate, while the burner was set in the centre of the fire-box and delivered a sheet of flame, which was carried upwards by the draught and impinged upon all the plates. When it was tried on the Transcaucasian Railway, Karapetoff, the engineer, reported unfavourably, but the Baku Technical Society, remembering that he had his own appliance in use, declared in Brandt's favour. In the steamers of the Caucasus and Mercury Company and the stationary engines of many of the Baku refineries Brandt's pulveriser proved a great success, and the Transcaucasian Railway Company, in spite of Karapetoff's report, ordered a number of locomotives to be fitted with it.

Karapetoff's arrangement, in use on the locomotives running between the Caspian and the Black Sea, was declared to be an imitation of Lentz's. The pulveriser was fixed in the fire-box door in such a way that it threw a flat flame on to a refractory brick bottom, which soon attained a high temperature and completed the combustion of any small bubbles of petroleum which reached it unconsumed.

Ludwig Nobel brought out a pulveriser intended to be an improvement upon the Brandt model. By cutting one or more spiral grooves in the conical head he gave the flame a rolling motion, which swept it along the inner surface of the cylindrical boiler flue. Various other modifications made a most economical appliance, but this was not an important matter at Baku, where oil refuse was dirt cheap and it was a matter of indifference whether an apparatus was wasteful or not.

Lentz reckoned that his apparatus did not consume more than 6lb. of oil per h.p. an hour, but it was found that the furnaces of the different steamers varied considerably in point of consumption, and the actual practice with Lentz's apparatus was said to range from 11 to 17lb. Ludwig Nobel estimated the expenditure of his apparatus at from 5 to 7lb. per h.p. per hour.

Mr. Herbert Coxon, of Newcastle-on-Tyne, when he visited the Caucasus in 1884, wrote—

"The refuse called astatki is sold for fuel. The steamers on the Caspian and the locomotives on the Transcaucasian Railway use nothing else. The mode of using it is simple and inexpensive. A small pipe, say half an inch in diameter, is taken from the tank of astatki and joins another in the form of a V issuing from the boilers. From the junction the pipe penetrates the furnace, and terminates in a rose. The steam from the boiler meeting the astatki drives it along with force through the rose in the form of spray, which bursts into flames in the furnace on a match being applied. The fire can be increased or diminished in intensity by simply turning the cocks of the steam and the oil pipes, and this is done as readily as one can regulate gas. In starting the astatki apparatus all that is needed is 3lb. of steam pressure, which is obtained by firing the boiler with a little tow or wood steeped in oil. So perfect is this system of firing that the chief engineer of one of the steamers on the Caspian told me that when he goes from Baku to the mouth of the Volga, a voyage of two or three days, he turns on the taps on leaving and never needs to touch them again until he reaches his destination. When I add that one ton of astatki goes as far as two tons of best steam coal, and that the present value of astatki is little more than three shillings a ton, the value of this system over all others will be readily seen."

In Marvin's day, it was thought that a ton of liquid fuel should go as far as two tons of coal, and, as a matter of fact, in the more economical furnaces a proportion of one to three was often attained. This feature was of extreme importance away from Baku, but at Baku the firms, like the Government, were quite content if a ton of astatki went as far as a ton of coal. A ton of astatki was thirty or forty times cheaper than a ton of coal.

Some of the early experiments with Russian petroleum refuse burned in a series of shallow troughs under ordinary boilers showed that it evaporated 14½lb. of water per lb. of refuse; coal burned under the same boiler gave an evaporation of 7 to 8lb. of water per lb. of coal. Prof. Unwin tested the evaporative value of petroleum under a steam boiler and found it to be 12·16 lb. water (from and at 212° F.) per lb. of oil burned. The rate of evaporation was 0·75lb. of water per square foot of heating surface. He estimated the calorific value of the petroleum he used at about 25 per cent. higher than an equal weight of Welsh coal.

Experts found that the evaporative power of liquid fuel was greater than that of solid descriptions, but not only had the evaporative power to be considered, but also the quantity of heat which could be utilised. With solid fuels only about 60 per cent. of the evaporative power was utilised, the other 40 per cent. being lost, owing to the fact that in heating with solid materials the loss was four times greater than with liquid fuel.

Attempts to obtain complete combustion with solid materials were successful only at the expense of the heat evolved, an excess of air required for complete combustion having a cooling effect. On the other hand, with liquid fuel burned in a pulverising apparatus of correct construction and working properly an excess of air was not required, and only gases of combustion escaped from the chimney.

Experiments conducted in 1883 on the Grazi and Tzaritzin Railway showed that the cost per verst of a train driven by an oil-burning locomotive was 11·64 copecks as compared with 26·35 copecks expended on anthracite coal. Writing on the results at the time when he was locomotive superintendent of the railway, Mr. Thomas Urquhart* said:—"Out of 131 locomotives on the Grazi and Tzaritzin Railway, 72 are now altered and burn petroleum refuse as fuel, and in a few months the whole of the locomotives on the line (465 miles) will be burning petroleum. From fully a year's experience with petroleum as a fuel on a large scale with passenger and goods engines of various types, I venture to state that petroleum refuse is the best and most convenient form of fuel ever used for locomotives or marine purposes. Space will not admit of my enumerating the many advantages this fuel possesses, but a few will suffice to show the saving in time and money which is possible by its use on sea or land—certainly only in countries where it abounds in large quantities, and at prices favourably compared with other forms of fuel. A practical evaporation of from 12 to 13½lb. of petroleum is quite possible in locomotives under ordinary conditions. A cold locomotive can be fired up to eight atmospheres in from 50 to 55 minutes, and in engines in daily service where the water remains warm steam can be made to eight atmospheres in from 20 to 25 minutes. Water and fuel can be taken at

* Important evidence given by this high authority on Russian railway subjects before a British Commission on Coal Supplies is referred to in a later chapter.

the same time by simply having the water and petroleum tanks or columns conveniently arranged, the latter being required only at engine depôts, say, from 100 to 150 miles apart. From three to four tons of petroleum carefully measured can be run into the tank on the tender in about four minutes, requiring the presence of only one fuel attendant. The combustion is smokelessly complete, leaving no soot or other residue in the tubes or furnace. A cast-iron plate, with a two-inch sight-hole, is fixed over the firing door, thus virtually having no door whatever. The main obstacles hitherto encountered when applying petroleum as a fuel for locomotives are completely obviated by new and improved appliances especially designed for the purpose, a saving of nearly 50 per cent. in weight as compared with coal being attained in regular practice. Besides locomotive consumption, petroleum has become quite general as a fuel for pumping and other engines at the several stations and works on the line."

After the successful adoption of oil fuel on the Caspian war vessels, the Russian Government conducted experiments at Sevastopol with a view to using Baku oil instead of English coal for the men-of-war of the Black Sea fleet,*

* The veriest tyro in naval fuel matters will grasp the significance of the fact that the Muscovite must gain a great deal by the Black Sea fleet, stationed within easy reach of the Baku oil fields, burning oil fuel, while our own Mediterranean fleet, six days from the chief source of its coal supply, depends on the hard fuel of this country. Russia, with her permanent and prolific sources of oil fuel supply, has undoubted advantages over this country when it comes to a question of using liquid fuel, and the same argument can be used against us in the case of all first-class Powers which have oil fields of their own.

experts contending that the Caspian was a more convenient source of fuel supply than either Newcastle-on-Tyne or Cardiff; moreover, they said, once petroleum fuel spread to the Black Sea its extension to the Mediterranean was merely a matter of time, as the expensive English coal would be hardly able to compete with it there.* It was through the Suez Canal, along the eastern trade routes, that the greatest triumphs of liquid fuel were expected. Supporters of Baku oil fuel theories declared that every mile added to the cost of English coal and rendered competition with astatki shipped from Batoum more difficult, and it was prophesied that Baku would be able to keep coaling stations all the way from Malta to Singapore abundantly supplied with inexpensive oil refuse.

"Then (said Marvin, who favoured this view) from Singapore to China the task of maintaining the cheap oil supply could be undertaken by British Burmah, which possesses enormous deposits of petroleum. Baku and Rangoon could readily furnish enough petroleum fuel for all the trade routes of the East, and may, in fact, be expected some day to do so, once its advantages are generally recognised." Marvin, with his immense experience of what was being done on the Caspian, but wrong in the forecast I have just quoted, said the fuel was perfectly smokeless, a very great merit on board cruisers and men-of-war, and burned in locomotives on the Metropolitan Railway it would put an end at once to the greatest difficulty experienced in working the line—the annoyance to the passengers caused by the smoke.† If petroleum-burning engines ran on the Underground, as they were

* Neither this forecast nor the one about the Channel Tunnel has been justified by events.

† Marvin, wrong again, failed to remember electricity.

run on the Transcaucasian Railway, there would be no need for hideous smoke holes, while if it were employed in the projected Channel Tunnel the necessity for using an elaborate and problematical system of ventilation would be done away with.

Concerning the great advantage of the absence of stoking, and the ease with which a fire could be lighted or suppressed at a moment's notice, Marvin pointed out that few people realised the miserable life led by stokers afloat, particularly during the passage through the Suez Canal and Red Sea; the sufferings of thousands of these unfortunates would be suspended at a stroke by using liquid fuel, which, being burned in the form of a huge gas jet, required no stoking or personal attention, and maintained what it was impossible to secure with coal—a steady and even temperature. The fire could be manipulated to any degree of intensity by simply touching the cock of the pipes, and the one trouble—the burning a few handfuls of cotton waste or wood in the first instance to get up a little steam to start pulverising the oil (the work of ten minutes)—was abolished by the Walker furnace, in which some hydrocarbon gas was kept stored for this purpose. Instead of there being a stoker or two to each furnace, a single man could look after a dozen or twenty furnaces, just as, as a matter of fact, he did in the Caspian oil refineries.

So simple was the fuel to use, and so reliable was the action of the pulveriser, that the English and the Russian engineers running the steamers from Baku to the mouth of the Volga told Marvin what they told Coxon—that, having turned on and adjusted the flame at starting, they concerned themselves no more about their fires until they reached their destination. The fuel was clean to use, and there was none of the dust arising from coal or wood.

Equally important was the economy gained in storage room. A ton of liquid fuel did the work of two or three tons of coal; thus a steamer could either take two or three times less fuel, and utilise the bunker space for cargo purposes, or she could go two or three times as far without stopping to coal. But there was an additional economy beyond even this. A ton of oil refuse took up very little more than half the space of a ton of coal.

These were some of the remarkable advantages which sprang from the use of Russian oil fuel twenty years ago; those which are in evidence to-day are still more remarkable and make the oil fuel industry of that unfortunate country one of the brightest spots in its gigantic industrial system.

IN England experiments were commenced by Selwyn in 1864, and the systems of Aydon, Terbuth, and others were tried in propelling vessels of various tonnages, their non-success being solely due to the high price of oil.

THE mechanics of oil fuel burning have ceased to be a mystery even to rank-and-file oil men. Believed in by those who have a knowledge of its successful application, and having the authoritative recommendation of the highest naval authorities in Great Britain, there is no denying the fact that its permanent establishment near the head of the list of steam-raising agencies is absolutely assured.

J. D. H.

THE practical difference is that while with solid fuel it is impossible to prevent a considerable part of the heating material from passing away unburned, with a properly arranged system for oil burning everything is burned in the front part of the furnace, so that an analysis of the waste gases shows only a trace of combustible matter. This is an advantage apt to be overlooked, but, nevertheless, very important.

PAUL W. PRUTZMAN.

# CHAPTER II

## EARLY AMERICAN HISTORY, SOME FRENCH AND ITALIAN EXPERIMENTS, AND NOTES ON VITRIOL AND SODA TARS IN THE SCOTCH SHALE OIL INDUSTRY

IN the previous chapter I deal chiefly with the early historical facts of Russian experiments made to prove the utility and economy of liquid fuel burning, and I have woven in a little information about British inventions. Other countries have had their ventures in this sphere of mechanical invention, and first amongst these comes America, the old and aggressive rival of Russia in every branch of the petroleum industry.

In 1862 oil fuel was burned at Corry, Pennsylvania, with an apparatus which was a copy of a Russian type of spraying injector. Those who tested it admitted that it was a complete mechanical success under refinery boilers, but some high American authorities pronounced against its use on ocean-going vessels on the ground "that the heat of the engine-room might generate dangerous explosive vapours and would undoubtedly make the close quarters of the vessel uncomfortable owing to the stench."

The Bureau of Steam Engineering, in a report to the Secretary of the Navy, in 1867, said—"It appears that the use of petroleum as a fuel for steamers is hopeless; convenience is against it, comfort is against it, health is against it, and *economy* is against it." At that time petroleum was much dearer than it is now, and there was the same strong opinion that petroleum which was required for kerosene should not be converted into fuel. Still, there was a strong scientific opinion that one pound of petroleum contained twice as many heat units as a pound of coal, and the Isherwood experiments showed that one pound of petroleum evaporated two-thirds more water than a pound of American anthracite. Isherwood made his tests with a Giffard injector, by which the petroleum was injected into the furnace in the form of minutely divided spray by the agency of steam.

The point was early urged that one great advantage possessed by oil as a fuel lay in its smaller bulk; and, while this was true, I find that there was a great deal of loose writing on the subject at the time of the earliest tests in connection with the American Navy. The respective weights of anthracite and oil carried on a steamer depend largely upon the manner in which the hard fuel is stowed. American anthracite has a specific gravity of 1·50, and, properly stowed, sixty pounds can be placed in a cubic foot of space. The specific gravity of petroleum at engine-room temperature is but little over one-half that of anthracite, but fifty pounds of it can be placed in a cubic foot of space, provided it is carried in specially-built bunkers.

During a warm controversy which took place at the time of the Isherwood trials the following statement was made—"The compartments must be numerous and small, on account of the rolling and pitching of the vessel at sea, for the weight of a large quantity of petroleum could not be allowed to shift position. Assuming that the petroleum is carried in tanks, and that it evaporates two-thirds more steam per pound than anthracite, we have for the relative steam-producing capabilities of the anthracite and petroleum in equal spaces (1 × 60) 60 for the former and ($1\frac{2}{3}$ × 50) $83\frac{1}{3}$ for the latter, so that for equal space in the vessel occupied by fuel petroleum would produce about 39 per cent. more steam. The relative weights of fuel to be carried, which is also very important, would be as 60 for the anthracite and 50 for the petroleum, or one-sixth less than the anthracite. If, however, the petroleum is stowed in barrels the above ratios change materially. In this case only about 36lb. of petroleum could be placed in a cubic foot of space, allowing for the bulk of the materials of the barrels and for the interstitial spaces between them. Then the relative quantities of steam that could be obtained from equal spaces occupied would be (1 × 60) 60 for the anthracite and ($1\frac{2}{3}$ × 36) 60 for the petroleum, or exactly the same. In either case the aggregate weights of fuel and containing vessels would not materially vary, for the weight of the barrels or of the partitions of the small compartments containing the petroleum is considerably greater than the weight of the bunkers containing the anthracite. The great economy in the use of petroleum on large vessels may be illustrated by reference to the Etruria. Shipping men say that one reason such vessels are not more profitable is because of the small space left for freight after stowing the necessary quota of coal. She burns on a passage of six-and-a-half days 2,275 tons of coal, but, to be prepared for delays, she carries 3,000 tons, leaving only 400 tons for freight. If 39 per cent. of space were economised on such a vessel it would give space for 1,170 tons more cargo of the same gravity as coal."

(I should like to say, in parenthesis, for this is a noncontroversial chapter of early history, that to-day most steamers which burn oil have been specially built for the purpose and have their bunkers conveniently arranged, not necessarily always near the stokehold, but frequently, as in the case of warships, on the double bottom principle. Oil bunkers are spacious, isolated and thoroughly oil-tight, made, in fact, on a carefully thought out scientific principle in order that the pumping work may be easily and safely done, and there is now no doubt that oil stowage is in many ways a decided improvement on the coal-carrying plan. Respecting the use of oil fuel on Transatlantic liners, nothing more need be said here than that its general adoption, favoured by arguments which are much stronger than those employed in the case of the old Cunarder Etruria, is only prevented by questions of cost and supply, there being no real opposition to the contention that in the important matter of speed it would come up to the most sanguine expectations. We are fast nearing the time when oil will be used in conjunction with turbines to secure the maximum of steaming power in the record-making leviathans of the Atlantic. In a later chapter on the oil fuel situation this year, I show that Pacific liners are using it with the greatest possible success and that two of the largest passenger steamers ever built in Japan are oil-fired.)

The fear that petroleum would not be found in sufficiently large quantities to furnish fuel to drive the wheels of American industries, and because it was thought that its enlarged use would doubtless increase its cost to an extent that would destroy its economy, prevented ship-owners and manufacturers of that country from adopting it, and in the years of which I am writing only isolated attempts in steel works at Worcester, Massachusetts, and

The tank steamer Buyo Maru (owned by the Toyo Kisen Kaisha, Oriental Steamship Company), which burned oil fuel absolutely without smoke during her trial trip off the Tyne in February, 1908.

[*To face p.* 58.

on steam ferry-boats on the bay of San Francisco and elsewhere were made to use it as a fuel.

A naphtha engine, working with the Holland patent, ran for some time on the Eirie, drawing a train of passenger cars, but nothing practical came from the experiment, and the same may be said of the experiments conducted with a Dickey furnace, a spraying apparatus, using crude oil.

In 1886 an American authority wrote—"Russia has determined a problem which is not regarded as conclusively solved in America. To-day nearly, if not all, steamers on the Caspian and the Volga, and the locomotives on the railways in that region, burn oil exclusively. In this country, with a few exceptions, the only practical utilisation of petroleum as a fuel is in kerosene stoves, in which the heat is obtained from three or four wicks without chimneys." A year or two after this, however, the Standard Oil Company started to go into the business on a large scale. The Lima oil fields, Ohio, and Chicago were successfully connected by an 8-inch pipe line, and the Standard prepared the public mind for the innovation by establishing a liquid fuel branch of its business and organising a staff of engineers and workmen capable of fitting oil fuel appliances. The result was that as soon as Lima oil began to flow into the reservoirs at Chicago numerous applications were received from local factories to fit up oil appliances and furnish supplies. The movement rapidly extended, and one report at that time stated that the ramifications of oil pipe lines were driving coal out from every quarter of the city. "As might be expected, the coal trade in consequence has been very depressed, and is not likely to undergo an improvement, seeing that public feeling is in favour of the change owing to the greater purity of the atmosphere arising from the use of the new fuel," said one report. The innovation, however, was not started in other American cities; in fact, it was soon discovered that the lighter oils of the northern fields were not suited for fuel purposes, and America had to wait for the advent of California and Texas before it could consistently claim to be a factor in the world's supply of liquid fuel.*

Considering that France is not an oil-producing country, it was early in the field with some important experiments. Deville, already referred to, experimented with his shallow tray system in his laboratory and on board Le Puebla, and Zede tested a similar method of oil burning in the Arsenal at Brest.

An apparatus tried in the French Navy by M. Ferrari, of Genoa, had longitudinal trays containing wicks, separated by screens which distributed the air, a tube pierced with holes placed beneath each wick carrying the

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* Although there never have been any specially strong commercial reasons why the Standard should push forward the idea of oil fuel in America, it rendered the Bureau of Steam Engineering and other official departments and commissions invaluable service by supplying data prepared by its oil fuel experts (Mr. W. D. Hoffman and others) and placing the oil-burning tank steamer City of Everett at the disposal of those who were commissioned to conduct official tests. This is particularly true in relation to what are known as the Boston and Maine Railway (Hoosac Tunnel) experiments, conducted on oil-burning locomotives in order to keep the tunnel clear of smoke. Mr. Hoffman made suggestions to the Government naval engineers in regard to installations on torpedo boats; these were largely the result of practical work done by him on locomotives in Florida and other States.

oil throughout its entire length. Trials were made with Ferrari wicks on the Amalia and the torpedo boat No. 139 at Toulon. On the Amalia the object was very moderate firing, two trays only being fitted in each furnace in place of the fire bars. The power developed with a compound engine did not exceed 100 h.p. per furnace, the combustion was incomplete, and flaming occurred. The consumption was satisfactory when compared with coal, and it was shown that at sea only 1·79lb. of mazoot per h.p. was required against a consumption of 3·022lb. of coal.

The trials on the torpedo boat were made with the object of obtaining very rapid firing with forced draught. The trials were made with nine trays, and fifteen others arranged at different heights. Various arrangements were tried, both with the screen full of holes and with different descriptions of wicks, but the results were most discouraging and did not at any time equal the power obtained with coal. These tests were taken to show that however suitable the liquid state might be for distribution it did not adapt itself readily to the process of combustion. To ensure the complete mixture with the air required for perfect chemical combination, the fuel had to be brought to a gaseous state.

At one time French interest in the subject was exceedingly great and promised to result in the widespread adoption of liquid fuel in the Navy. This interest, however, was not maintained, and our own Navy, taking advantage of much of the experimental work of other countries, has succeeded in bringing to maturity some of the best ideas of foreign pioneer fuel experts. This being largely a history of the progress of liquid fuel burning, I do not hesitate to give the following extract from a statement made by M. Bertin nine years ago.

"In the Leblond and Caville boiler the kerosene is forced by a pump into a reservoir, from which it flows, under pressure, through a bent tube. The oil becomes vaporised in the bend of the pipe, which passes through the flame, and escapes through a flattened jet. Two jets are sufficient to replace the ordinary grate in a furnace 3ft. 3in. wide; the combustion must take place, whether with natural or forced draught, under the system known as the closed ash-pit system. On a Du Temple boiler, tried at Cherbourg, Messrs. Leblond and Caville evaporated 11·5lb. of water with natural draught, and 9·46lb. with forced draught. In the Symon House burner the oil is vaporised in a cylindrical reservoir, exposed to the action of the flame, and follows a circuitous course. The inflammable gas escapes through a jet, the opening of which is controlled by a needle attached to the regulator which supplies air to the burner. The burner is started by heating the reservoir with a lamp. An igniter, or more properly a re-igniter, filled with fireclay has been fitted over the jet in the centre of the reservoir. The Symon House boiler, supplying steam to a compound engine of 19·7 h.p., burns 2·23lb. of petroleum per h.p.—a by no means economical result. In the Escher-Wyss motor, which uses petroleum as a vaporisable liquid, the boiler itself provides the jet of combustible vapour. Instead of vaporising the petroleum it is possible to direct it at a high pressure through orifices small enough to reduce the oil to a very fine spray closely mixed with air. This arrangement, which requires an oil of great fluidity, can only be used for small powers, and is mainly used for lighting purposes in lamps, and in starting apparatus on boilers fitted with sprayers and atomisers. In burning mazoot a strong jet is directed into the furnace through orifices large enough to allow it to escape reely and regularly, notwithstanding its viscosity, especially if care is taken to surround the oil-pipe with a steam jacket. In order to reduce the jet to a fine spray it is usual to combine a strong jet of steam or compressed air, either at an angle or more often concentrically. A steam or air jet, at a pressure of 85lb. per sq. inch, is used for spraying an oil jet under a pressure of 43lb. The spray mixes thoroughly with the air through which it passes, and, when the supplies of oil and steam or air are regulated in the proper proportions, gives a clear flame without smoke. The atomisers for the combustion of petroleum in this form are of different designs. As a rule, the orifices are circular or annular, the jet of oil being placed in the centre of the jet of steam or air. This arrangement is more easily controlled, works with greater regularity, is less costly than other designs, and renders pulverisation more complete. Occasionally a supplementary concentric nose piece is added for the supply of additional air for combustion, which, however, is not under pressure. Sometimes very narrow rectangular slits are used instead of annular nozzles, when the two escaping jets strike one another at a considerable angle. The slit for the oil requires very careful attention and adjustment to avoid a partial choking of the burner while at work. The regulation of the two jets and the varying of the power of the burner to the required intensity is a delicate operation. Suitable stop valves are provided for varying the pressure of air at the nose piece. With the petroleum jet it is sometimes preferable to keep the pressure constant and to vary the section of the oil jet by means of a needle. This method is greatly exposed to irregularities of working inasmuch as mazoot flows very badly from an annular slit, and the vibration and want of centralisation of the needle are always to be feared. It is a much more satisfactory method to construct each atomiser for a given rate of combustion and to vary the number of atomisers according to the rate of firing. In some of the best known American and Russian atomisers the oil orifice is annular and a conical screen is sometimes added to produce a further crossing of the jets and ensure more complete pulverisation.

"The apparatus generally used in the French Navy is the Guyot burner, which has been tried on board the Bouffle and torpedo boat No. 22. The steam jet in Guyot's burner is regulated by the movement of the central spindle, which also forms the oil supply. Although it is easier to regulate the steam in this manner, great care is required to keep the spindle which regulates the steam supply perfectly in the centre. It is also important that the spindle should not be too long, and that it should not project beyond the steam jet.

"The jet of pulverised petroleum forms a long column of flame. The impact upon a cold surface, like a boiler plate, at a temperature of 300° to 400° F., immediately checks its combustion and the petroleum deposited upon the plate does not become re-ignited. For this reason special precautions must be taken to ensure complete combustion. If there is sufficient depth in the furnaces the jet is directed upon a fire-brick wall, which becomes sufficiently heated up to re-ignite the petroleum spray which comes in contact with it. Mr. Urquhart adopts this arrangement on his locomotives in Russia. The two sides and the top of the masonry screen, or baffle, which receive the jet are composed of firebrick, pierced with openings, through which the gases of combustion escape, air being admitted from below. In a similar arrangement adopted on a torpedo boat boiler at Cherbourg (1893) the burners were directed transversely across the furnace and the air was admitted from below. If the furnace is sufficiently long the flame should be unobstructed, but sufficient bricks should be fitted under the jet or burner so that if the pulverisation is imperfect petroleum dropping on the red-hot masonry will be ignited. In a return tube boiler, fired by petroleum, fitted on torpedo boat No. 22, the burners in the small ante-furnace are so arranged that the air enters at right angles to the direction of the jet. With this arrangement of the air striking the jets obliquely, the quantity of steam decreases rapidly as the draught increases. On the No. 22 torpedo boat 11·06 to 10·08lb. of water were evaporated per lb. of petroleum with an air pressure of from ¾ in. to 1 in., and only 9·45 to 8·50lb. with an air pressure of 3¾ in. to 4 in.

"On a Godard boiler, with the jets parallel to the axis of the furnace and the air inlet through the ash pan only 8·25lb. of water were evaporated per lb. of petroleum under an air pressure of 3 in. to 3½ in. Air inlets parallel to the direction of the flame are the most advantageous way of ensuring good combustion; thus at Cherbourg (1890) as much as 13·25lb. of water were evaporated per lb. of petroleum on a return tube boiler."

In the latest arrangement adopted by M. Guyot (responsible for the petroleum tests at Cherbourg) the atomisers are placed in an ante-furnace composed of masonry and the air enters mainly from below. The boiler is of the return flame Du Temple type; the evaporative efficiency decreases as the air pressure increases, but not in greater proportion than in the case of coal. Under test it fell from 12·5lb. of water per lb. of petroleum at 0·31 in. air pressure to 11·3lb. at 1·77 in.

In the early trials made in France in 1887, 1·2lb. of steam were used per lb. of petroleum pulverised. Later, on the Bouffle, 0·75 to 1lb. were required, and on the torpedo boat No. 22, 1·2lb. On the Godard boiler, 0·46 to 0·12lb. were used, and 0·53 to 0·75lb. on a locomotive type of boiler tried in 1893.

In trials made by M. Guyot on his boiler in 1895, he did not exceed 0·63lb.; and got as low as 0·25lb. of steam per lb. of petroleum pulverised. In Italy, similar results from 0·5 to 0·25lb. have been obtained, and on a Schichau torpedo boat as low as 0·102lb. is said to have been reached.

French and Italian experts have found that the conditions surrounding the combustion of liquid fuel in the form of a jet are much more favourable to a complete chemical combination, even when a reduction can be made in the excess of air, which in a coal-fired grate carries off 10 per cent. of the total heat produced. They also say that the supply of liquid fuel can be easily and constantly regulated. There is no charging of the furnaces, and no cleaning or damping down the fires, which often necessitates a considerable loss and expenditure in coal. It cannot be denied that mazoot has many advantages over coal from an economical point of view, and these can only be appreciated in actual work.

M. D'Allest, who was one of the first in France to try liquid fuel, obtained an evaporation of 11·33lb. per lb. of mazoot under a high rate of forcing, producing 16lb. of steam per sq. ft. of heating surface.

Several trials were carried out in the Navy before arriving at equally good results, but in 1890, on torpedo boat No. 22, 11·36 and even 13·25lb. of water were evaporated. On the Godard boiler, which was transformed to burn liquid fuel, only 9·6lb. was obtained—that is to say, about the same as coal, if account is taken of the amount of steam used for pulverisation. M. Guyot evaporated in his boiler in 1895 12·5, 12, and 11·3lb. in a closed stokehold under an air pressure of 0·31, 0·67, 1·8 in. respectively. Thus, an evaporation of 12lb. of water seems to be as easily realisable with mazoot as 9lb. with coal, which gives mazoot a superiority of 1·33 over coal, being 1·22 for the difference on calorific value and 0·11 for more perfect combustion.

France has failed to adopt oil fuel on anything like a large scale. The few vessels which burn it as an auxiliary fuel have not accomplished anything remarkable in the way of records, certainly none that will compare with the brilliant results secured on a number of British warships.

Colonel Nabor Soliani, of the Italian Navy, one of the pioneers in the introduction of liquid fuel, found, from trials made on a torpedo boat, that the consumption with coal firing amounted to 2·13lb. per indicated h.p., while the liquid fuel was only 1·25lb. Italian experts early discovered that petroleum has other advantages besides the one of superiority in evaporative power, since the work of the trimmers and stokers is not merely simplified, but entirely suppressed; and, consequently, the expense and trouble attendant upon the personnel are reduced to a minimum.

Over and above the facility of manipulation and the economy in weight there are other very pertinent advantages. Forced draught with a closed stokehold is rendered much easier by the suppression of the stokers and even of the stokehold itself, in the ordinary acceptance of the term. The regulation of the fires and atomisers can be carried on through a bulkhead, and no opening and shutting of the fire doors is necessary. The great regularity with which the fires can be worked obviates one of the principal causes of fatigue to boilers, as it renders unnecessary the opening of the furnace doors when firing. This enables a higher rate of combustion to be obtained without danger and lengthens the life of a boiler. The fires are always clean and in good condition, which materially increases the average working power of a boiler, because in the case of coal-fired boilers the power necessarily drops as the fires get dirty and falls still lower while they are being cleaned. With the atomisers properly regulated combustion is complete and there is no smoke. Lastly, liquid fuel is very much more easily transhipped and stowed than coal.

It was found at the time of these early experiments that the greatest obstacle to the further introduction of mazoot was its price. In Italy and France it was about double the price of coal. But, then, said the experts, there are many things which justify its use; these include the reduction in expenditure on personnel, which may amount to from 50 to 60 per cent. of the difference, and, further, the gain in weight and space—meaning greater freight-earning power or armaments.

This was also the position in this country, where oil could not make progress against the economic disadvantages due to high price and unreliability of supply. The tank steamer Baku Standard, owned by Mr. Alfred Suart, went from the Tyne to New York in January, 1894, with oil fuel. She did this absolutely without any hitch whatever, burning 20 tons of oil against 32 tons of coal, and having only six stokers against ten. But the trip was not a success financially. The James Brand, of the same fleet, went to New York in February, 1894, and burned 20 tons of oil against 32 tons of coal. She had only three firemen, but as one of the men broke his collar-bone at the beginning of the voyage there were only two on duty all the way out. She likewise had no trouble whatever. Mr. Suart, however, found that the oil was too expensive to justify him in continuing the experiments.

No tests on Italian steamers have given more important results than those conducted on the Tebe, a full-powered passenger steamer, running between Genoa and Alexandria. With the Korting type of burner, Howden's forced draught, and Worthington's feed pumps, all specially installed, she gave results which were in every way an improvement on her coal performances.

Mr. Salvatore Orlando, who described the tests, wrote—"The only difficulty was the occasional clogging of the filter. The obstruction appeared to be due not so much to impurities in the oil as to a carbonaceous deposit, probably traceable to coking. The formation of the deposit was inflicted by the increased pressure necessary to deliver the oil to the burners, but it was found entirely practicable to clean the filter screens successively without interfering with the running of the engines. The result of the tests fully confirmed the experience with liquid fuel in vessels elsewhere. In comparing the cost with coal fuel, the greater advantages in handling the oil must be considered, especially the difference between the convenient manipulation of the oil burners as compared with the laborious and brutalising work of stoking coal furnaces at sea. The real question to be considered is the one of fuel cost, and, with definite data as to performance, this can readily be determined for any locality by comparing the relative local prices for coal and oil."

I must not overlook the Scotch shale oil industry in these chapters of early history.*

Some authorities consider that the shale fields of this country should yield large quantities of liquid fuel for

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* It is just possible that oil as we know it in the great fields of the world may one day be discovered in Scotland. In the early history of this industry I have come across several references to oil in North Britain. Prof. Benjamin Silliman, writing in 1833, said—"A fountain of petroleum is situated in the western part of the county of Allegany, State of New York. The oil spring or fountain rises in the midst of a marshy ground. It is a muddy, dirty pool of about eighteen feet in diameter, and is nearly circular in form. There is no outlet above ground, no stream flowing from it, and it is, of course, a stagnant water, with no other circulation than that which springs from the changes of temperature and from the gas and petroleum that are constantly rising on the surface of the pool. The water is covered with a thin layer of petroleum or mineral oil, giving it a foul appearance as if coated with dirty molasses, having a yellowish-brown colour. Every part of the water was covered by this film, but it had nowhere the iridescence which I recollect to have observed at St. Catherine's Well, a petroleum fountain, near Edinburgh, Scotland. There the water was pellucid, and the hues produced by the oil were brilliant, giving the whole a beautiful appearance. The difference is easily accounted for. St. Catherine's Well is a lively flowing fountain, and the quantity of petroleum is only sufficient to cover it partially, while there is nothing to soil the stream. There are, however, upon this water, here and there, spots of what seems to be a purer petroleum, which is free from mixture and which has a bright brownish-yellow appearance, lively and sparkling. Were the fountain covered entirely with this purer production, it would be beautiful. . . . They collect the petroleum by skimming it like cream from a milk pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon, and just under the surface of, the water, and is soon covered by a coating of petroleum, which is so thick and adhesive that it does not

naval purposes, and this subject gathers additional importance from the fact that attempts are being made on a large scale to develop shale deposits with liquid fuel potentialities in remote parts of the Empire.

Admiral Selwyn, who conducted oil fuel experiments at Woolwich in 1865-7, only a few years ago expressed the following opinion—

"In this country we have reliable and large sources of heavy oil in the shape of oil shale, and if the whole of our shipping, naval and mercantile, took to burning oil fuel, some experts think, it could be found for them within our own country at a far lower price, considering the evaporative value, than could ever be thought possible for coal. The enormous sources of shale lie under the whole of Portland and go across to the shores of Brittany. The seam, which is 10 miles wide and 60 ft. thick, can be worked from the grass roots right across to the Wash, where it splits up into two partitions, one going to Northumberland, where there is a 40ft. thick deposit. It goes by one stretch to Hanover from the Wash, then away through Germany and Russia, but there is not a bit of it that contains as much as British shale, which yields from 60 to 120 gallons of heavy oil to the ton."

In the early years of this important industry the tars from the acid and soda treatments in the refineries were waste products and as such were deposited in the hollows of the spent shale bings. But the drainage from these

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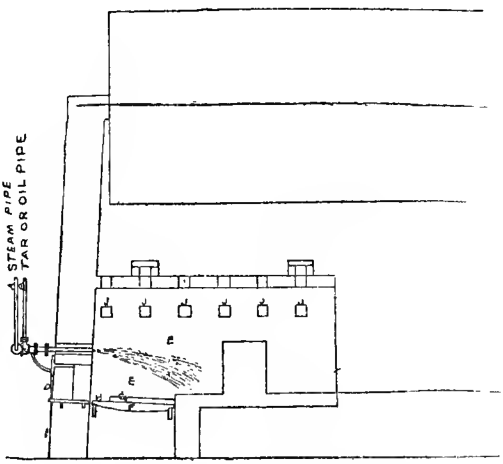
fall off, but is removed by scraping the instrument upon the lip of a cup. It is used by the people of the vicinity for sprains and rheumatism and for sores upon their horses." After I started on this work I received interesting evidence that there are two very similar cases on the properties of farmers in New Zealand.

polluted the streams, and other means had to be adopted to get rid of them. Although they were burned, no attempt was made to use them as fuel, but subsequently




SCOTCH TAR BURNING APPARATUS.

A. Steam inlet pipe.
B. Tar inlet pipe.
C. Injector.
D. Furnace door.
E. Furnace.
F. Furnace bars.
G. Tiles laid upon the furnace bars, to form bed upon which tar fuel is burned.
H. Part of furnace bars left uncovered for air admission.
I. Sliding door on front of ash pit for regulating the air supply.
J. Air inlet ports to furnace.

they were consumed in furnaces employed to evaporate the waste water of the works.

About 1871 tar was burned under the stills at the Oakbank Oil Works. Behind the coal fire bars a bed was formed, some four feet square and six or more inches deep, with the bottom gradually sloping up to the front. The tar was run on to this bed in a gentle stream and burned, and the carbon residue was raked forward at intervals and burned with the coal on the fire bars. Sometimes the tar bed was placed on a level with the fire bridge and the flame led over its surface, but in others the tar bed was supported on an arch under which the flame passed.

About 1875, probably under Mr. Beilby's supervision, the vitriol tar was washed with water, and vitriol thus recovered, while the fuel value of the tar was greatly improved.

In 1879, Mr. N. M. Henderson,* at the Broxburn Oil Works, carried out a number of experiments with steam and air injectors, which have been in use ever since at the Broxburn Works. The tar is thus injected as a spray into the furnaces under the stills, this method giving far greater fuel value than the tar beds produced. One ton of tar is equal in calorific value to about two tons of ordinary coal fuel.

Before use the acid tar is washed for the recovery of vitriol, and the soda tar is neutralised with a little acid tar, the aqueous solution of sulphate of soda being allowed to settle out.

All the tars produced in the Scotch oil refineries have been profitably utilised in this way for years. Mr. Beilby

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* My host when I inspected these famous shale works eight years ago. One of the most popular and experienced of our shale oil authorities, an inventor whose name will be associated with Scottish oil as long as there is a shale industry in the land, and a courteous and broad-minded manager, serving one of the most honourable combinations of business men connected with any branch of this world-wide industry.

has stated that Scotland can produce gas tar oil and coke oven oil much more cheaply than any oil imported from abroad. The blast furnace oil, however, has not as high a value as good petroleum.

These early results, covering a period of considerably more than a quarter of a century, conclusively prove that oil fuel burning came into the realm of applied science very soon after the steam engine was invented in this country. The experiments of the present century prove that, scientifically, the system is practically perfect, both for marine and manufacturing purposes, and that the production and use of oil fuel must now be counted one of the world's most useful and promising industries.

"EVERY year the petroleum industry becomes more and more important. Liquid fuel, a novelty when described in 1884, is now (four years later) largely used on steamers, on railways, and in manufactories in the United States, and has become one of the commonplaces of engineering. That it will supersede coal in countries where coal is cheap and oil is dear may be doubted, but a wide sphere of usefulness may be predicted for it wherever the reverse is the case."

MARVIN (1888).

"CRUDE obtained from Scotch shale is substantially a mixture of the paraffin and olefine series, with a small admixture of naphthenes and benzenes, which constitute the finished products. . . . The tars extracted with chemicals, together with dregs and residues not fit for any other purpose, are used as liquid fuel for the stills. Our ordinary products are too valuable to be used for fuel. Crude petroleum and petroleum residues are largely in demand throughout the world for firing steamships and railway engines, and our own oils might partly be used for that purpose in time of war. The thermal value of oil fuel is more than one-and-a-half times that of coal, and it can be burned without producing smoke."

D. R. STEUART,
Of the Broxburn Oil Company.

# CHAPTER III

## OIL FUEL AND NATURAL GAS QUESTIONS OF AMERICA AND ENGLAND. THE POSITION TO-DAY

"The Navy Department made an exhaustive report on liquid fuel in 1904, and while other countries have accepted its conclusions we lag behind. We may wake up some day, as we did in 1898, and find we have no smokeless powder. There have been millions of passengers carried during the last five years on American ferries, river boats and ocean steamers, without a single accident attributable to the use of liquid fuel. . . . Commercial wisdom and patriotism suggest the conversion of warships into oil burners."—CALIFORNIA PETROLEUM MINERS' ASSOCIATION TO PRESIDENT ROOSEVELT IN SEPTEMBER, 1906.

WHAT other countries with navies, particularly Russia and Japan, are doing is of vital importance to us; what America has failed to do is a source of amazement to fuel experts who make a study of international petroleum subjects.

Although, as I have shown, the mechanics of liquid fuel burning were studied in both countries as early as 1862—three years after the discovery of oil by Col. Drake at Oil Creek, near Titusville, Pa., and the year when the first refinery was erected at Baku—it was some years later before a regular commerce in oil fuel was organised. Baku went into the business commercially in advance of Pennsylvania; the refiners in the Caucasus were practically compelled to search for markets for the astatki surplus of a huge output of petroleum. There was no doubting the permanent character of Baku's oil supply in 1860–1, and even to-day theories of exhaustion are unpopular.

Compared with the oil fields of Baku, the earliest producing regions of America were of ephemeral value. In what were known in early days as the oil circuit counties of Pennsylvania, oil towns flashed into prominence and vanished in a year or two. Pithole,* the Magic City, Cashup, Top-top, Balltown, Shamburg, Petroleum Centre, Pioneer, Summit City,† Schaffer and Miller Farms, in Venango, were all meteoric creations of oil which have been removed from the map of America's oil regions. Clarion County produced Antwerp, Beaver City, Pickwick, Jefferson, Fern City, Slambaney, and Elk City, but these also are only a memory.

Pennsylvania never gave birth to an oil city like Baku, and that is why America failed to take the lead in the establishment of regular fuel oil markets.

Against the early popularity of liquid fuel in Russia, America was able to put her natural gas industry.‡

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* Described, in its day, as "the most wicked city of modern times."

† Typical of some of the dead oil centres of America. When oil was struck operators fought their way into this field, and in a month it had a bank, hotels, stores, drinking dens and gambling hells, and one writer (Mr. J. L. Hunter) speaks of one "gilded palace of sin which lured men and women on to eternal ruin." One road leading from Summit City to Dean City was christened "The Devil's Lane," or "The Road to Ruin." It was a mile of gambling dens.

‡ Other fuels need some preparation to fit them for combustion, but with natural gas none is necessary. It has a

Natural gas was first used in the United States in 1824, where it was piped from a well to illuminate the village inn at Fredonia, N.Y., in honour of the visit of General de Lafayette. In 1841, William Thompkins struck a large flow of gas just above the burning spring in the Kanawha Valley, and used the gas for heating salt furnaces. In the earliest year of oil well drilling (1859) the waste gas which escaped from the wells was used for firing the boilers of the drilling engines and lighting the fields. In 1872 the first natural gas plant was formed; a 2-inch line was laid from the Newton well to furnish gas for domestic use in Titusville, but it was not until 1874 that its great value as a manufacturing fuel was demonstrated. In that year, Messrs. Rodgers and Darchfield began to burn it under boilers and for all puddling and heating furnaces in their plant at Leechburg, Armstrong County, Pa., while later (in 1885) Mr. Andrew Carnegie used it in his steel works.

In a single year America has been known to market 171,875,000,000 cubic feet, equivalent in value to fully 40 per cent. of the output of crude oil, or 8,500,000 tons of coal.

In many fields natural gas and oil have a common source, the gas occupying the higher portions of the arched rock-sealed reservoirs, while the oil, of greater gravity, seeks the lower levels. The production of natural

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high calorific power. It is composed of 93 to 97 per cent. of Marsh gas ($CH_4$). One cubic foot of gas has evaporated 1lb. of water from and at 212° F., which gives 966 B.H.U. to the cubic foot, or 16 cubic feet of natural gas equal to 15·456 B.T.U., the calorific value of 1lb. of petroleum. Therefore, 16 cubic feet of natural gas have the same value as 1lb. of petroleum, or 16 cubic feet will equal the calorific value of 30 cubic inches of petroleum.

gas is one of the most important mineral industries in America (sixth on the list according to value), and also in Canada, where it is burned under boilers as a manufacturing fuel and used for domestic purposes in many oil-made towns.

In this country important discoveries of natural gas have been made in Sussex. The first was at Hawkhurst in 1836, when, at a depth of 240 ft., "the auger bit disappeared into a cavity and a rush of gas burned two workmen to death." During the drilling operations in different parts of Sussex in the seventies there were frequent explosions of gas. In the Wealdon area a fine quality of gypsum impregnated with petroleum has been discovered.

What are known as the Heathfield discoveries were made during the drilling of a water well on the site of the Heathfield Hotel, fifty yards from the station on the London, Brighton and South Coast Railway. In several shafts the workmen found inflammable gases, and the railway company, as early as 1898, found it advantageous to light the railway station with natural gas. In what is known as the Mayfield natural gas area quantities of crude oil have been brought to the surface, and Mr. Richard Pearson, managing director of the Natural Gas Fields of England, has stated that the workmen could easily get a barrel or two per day out of a single shaft.

Oil men visiting this country from foreign fields have investigated the natural gas phenomena of Heathfield, and quite a number have expressed the opinion that a properly drilled well, carried down to more than 3,000 ft., would most probably result in a strike of oil.

When America started to use oil as fuel the general verdict was that where only economy was to be considered it must take a second place, but where economy of storage space and convenience of handling stood first no fuel could be placed in competition with it. Where the cost was not so important as convenience and actual steam-raising results, appliances for the use of the liquid fuel came gradually into demand. On the other hand, where large supplies of cheap coal were available, petroleum failed to compete at the prices of twenty-five years ago. When the glowing accounts of Russia's extensive adoption of liquid fuel for steamers, locomotives, and stationary engines reached America the oil men would not admit that the problems of the international use of petroleum as a fuel had been solved, preferring to believe that success was limited to the oil regions of the far-away Caucasus. Besides, their pessimism was in a way justified by exhaustive and costly experiments conducted by three national commissions appointed to investigate the practicability of using oil as a fuel under marine boilers. The reports were adverse on the ground of cost.

Furthermore, American oil men feared an exhaustion of the supply, and in 1888 Jacob Harris Paton, in his book on the Natural Resources of the United States, wrote these lines of unjustifiable lamentation and caution—

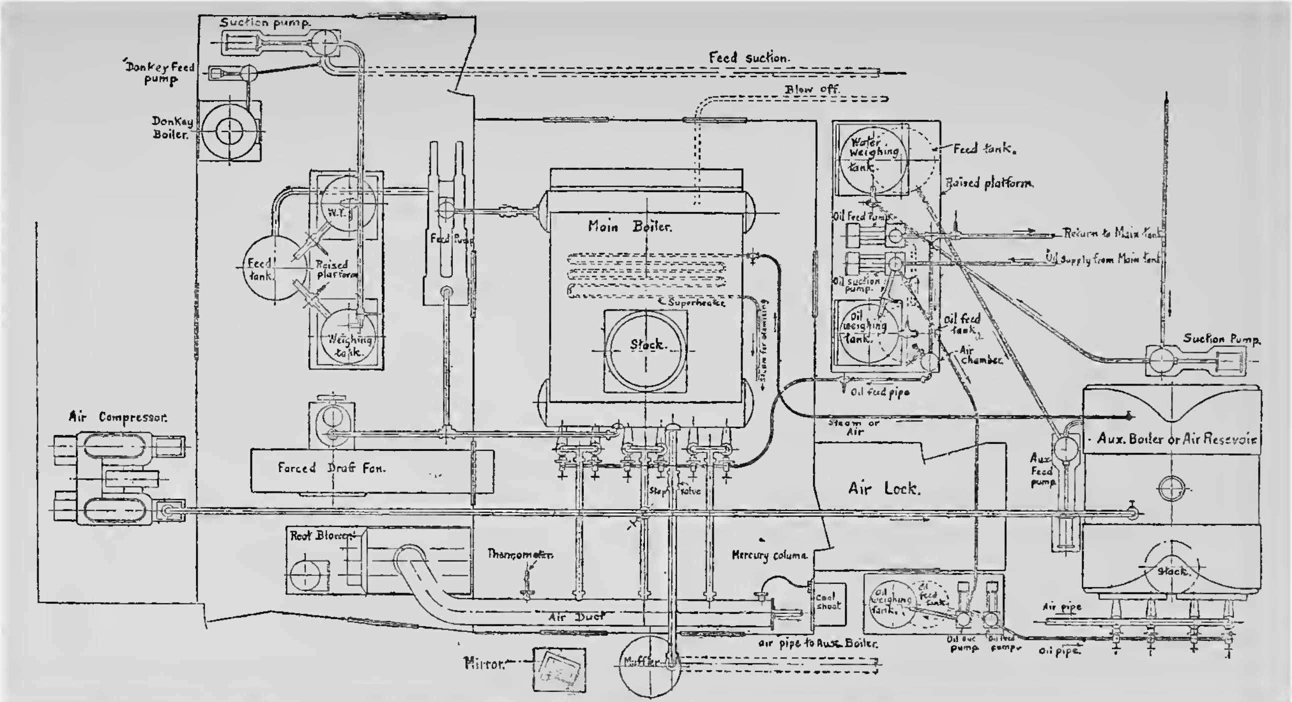
"The production of oil in West Virginia has been pushed to such extremes that the glutted market will perhaps induce more discretion hereafter, and thus leave some for the use of succeeding generations; in this case, excessive greed has wrought an injury that must be felt in the future."

In the chapter on the earliest experiments I have referred to American methods of using oil as fuel; in this one I have to bring the subject up to date, certainly up to the important developments of the first years of this century, and, this being a chapter on American attitude towards oil fuel, I come, quite naturally, to the opinions of high naval authorities who have studied this subject and the records of the tests conducted by the Naval Fuel Board of that country.

Although none of the American oil fuel tests will compare in importance with those conducted by the British Admiralty, it is a fact that the most valuable reports extant have issued from the Washington office of the American Navy Department. The reports contain much more information than any of the statements prepared by other Government experts, and a reason for this is found in the fact that America, being the largest producer of petroleum, is more than any other country interested in the dissemination of information likely to be of benefit to the industry. In this country, where there are no oil fields, we have everything to gain by keeping secret the results of experiments conducted by our naval engineers.

American naval opinion at the time when the 1901–2 tests were being conducted was pretty correctly represented by Rear-Admiral G. W. Melville, then Engineer-in-Chief to the Navy, when he said—

"The present problem of the modern battleship is not that of the gun and its mount, but the boiler and its installation. While the warship may be nothing more than a gun platform, it requires considerable power to move a platform of 14,500 tons at a high speed in a heavy sea. This platform is not only expected to be manœuvred rapidly, but to steam uninterruptedly for a distance of one-fourth the way round the world. The battleship that cannot make the enemy's coast the first line of defence is limited in the field of its usefulness, and when operating at such distance the value of the boiler factor comes




Shows the general arrangement of the Hohenstein experimental boiler plant used by the United States Navy Board for the liquid fuel tests in 1904. On this boiler nearly every well known make of American oil burner was tested with results which were given in detail in a report of 450 pages.

only second to the value of the factor of the gun. The efficiency of the warship of the several naval powers is simply proportionate to the efficiency of their boilers and the character of their personnel. Neither in armour, armament, or machinery is there any vital difference between the battleships of the several nations. In these respects, the last ship, wherever designed, is the best, for as regards draught, tonnage, thickness and extent of armour, character and distribution of guns, and design of machinery, every nation has settled upon a type of vessel that meets its particular requirements and each navy has therefore secured the best warship for its particular purpose. The experience of the next five years with the ships nearing completion will conclusively show that in coming naval conflicts the question of victory may be quite as much dependent upon the battle of the boilers as the contest between the guns."

These points are so aptly put that favourable comment would be superfluous and criticism obviously hypercritical.

In order that my object in dealing with these tests should not be misunderstood, I should explain that the extracts given in this chapter are not only freely condensed but have the further disadvantage of not appearing in the same sequence in which they are given in the voluminous reports of the Navy Board. I do not give them in order that I may criticise them, but, rather, for the purpose of showing the progress that has been made by our own naval engineers since these tests were conducted.

The tests, undertaken to show the relative evaporative efficiencies of coal and liquid fuel under forced and natural draught, were conducted and completed while Rear-Admiral Melville was Chief of the Bureau of Steam Engineering, but the report was not finished until Rear-

Admiral C. W. Rae succeeded Melville as Engineer-in-Chief of the Navy. At that time the department was justified in claiming that the expense of conducting these tests probably represented the largest outlay ever incurred in the investigation of the important problem of determining the possible future field for the use of crude petroleum; but to-day the record for experimental work culminating in practical results and the permanent adoption of oil fuel in the Navy of a first-class power is undoubtedly held by the British Admiralty.

The Navy Board, on the question of the similarity of conditions and requirements of oil fuel installations for locomotive and torpedo boat work, found that the following advantages were practically obtainable in both cases—

Economy of space reserved for carrying fuel.

Ease in filling tanks.

Rapidity of time in meeting a varying load in boiler.

Ability to force boiler to extreme duty in case of emergency.*

Absence of smoke under light normal working conditions.

Short height of stack.

Superior personnel available for the operation of the burners.

Discussing the smoke evil, the Navy Board said—

"There is a possibility of torpedo boats at reduced speed burning oil without smoke. It must be understood, however, that the smokeless burning of oil fuel in a torpedo boat can at present be effected only when there is a limited consumption of fuel. The efficiency of such boats may be vastly increased when improved baffling is

* In the next chapter I deal with Rear-Admiral Evans' denial that oil is an emergency fuel.

secured, and it is hoped that the smokeless burning of oil may be eventually obtained even with a marked increase in fuel consumption. The Board considers that the eradication or mitigation of the smoke nuisance in torpedo boats is intimately connected with the question of baffling. In the small or bent-tube type of water-tube boilers the most important problem confronting experts is a systematic arrangement of baffling whereby combustion can be effected within the tubes instead of within the smoke stack. A special design of baffling will have to be arranged for each distinct type of water-tube boiler."

While it is true that, during these early trials, and even at the time of the first British (Surly) experiments, the smoke trouble existed in an aggravated form, there is now no possible objection to oil fuel on that ground. When there is a proper adjustment of oil and air or steam, and with the ordinary conditions of good boiler practice, even on a full-powered warship, the combustion chamber shows a clear white incandescence with hardly any flame apparent, and no smoke or foul-smelling ejection.

One of the principal reasons advanced for the general use of oil as a fuel for naval purposes was the advantage that would accrue from the abolition of smoke. It seemed to be regarded as a matter of certainty that with the use of oil complete combustion of the fuel could be secured before the gases reached the base of the funnel. Possibly three-fourths of those who advocated the substitution of oil for coal had not the slightest doubt but that the prevention of smoke would be as certain as the obliteration of refuse in the ash pan. There was scarcely a naval writer who, in discussing the probable advance in naval construction, did not dwell upon the prospect of dispensing with coal, and of the advantage that would ensue if a fleet could manœuvre or establish a blockade using such an incomparable smokeless fuel as crude oil. In the earliest experiments, when the oil had passed through several stages of refining, and wherever a limited quantity was burned in a regular and uniform manner, no smoke appeared; whenever an attempt was made, under severe forced draught conditions, to secure an exceedingly large evaporative capacity, the smoke nuisance was encountered.

Careful and long-continued observations convinced the Board that with the use of water-tube boilers, as compared with the fire-tube boilers, the difficulty of effecting complete combustion before the gases reached the base of the stack had enormously increased, and the result of these American naval investigations confirmed the opinion of Rear-Admiral Melville that the weakness of the modern water-tube boiler lay in its inefficient system of baffling.

In the report it was stated—"In the attempt to prevent smoke on board warships it should be kept in mind that the installing of the boilers in different compartments produces different steaming conditions in the several stokeholds, owing to the greater ease with which air finds its way into some compartments as compared with others. Every marine engineer of experience knows that by reason of their location certain boilers steam more freely than others. That there is a difference in the natural air supply of the several fire-room compartments is evidenced by the fact that the fire-room force always find when the ship is under steaming conditions that certain compartments are more habitable than others. By reason of the structural arrangement of the ship, it will probably be found impossible for the water tenders in the various compartments to observe whether or not smoke is issuing from the funnel of the several boilers under their charge.

Where several boilers discharge the products of combustion into one funnel the problem is still further complicated. In view of the extended experience acquired in the conduct of these oil tests, it can be safely affirmed that in warships fitted with protective decks, with an installation of water-tube boilers under forced draught conditions, the smoke nuisance is likely to prove more obnoxious with the use of oil than with the use of coal as a fuel. It is hopeless to expect an improvement in this respect until naval experts are ready to sacrifice some of the luxuries or a small amount of the armour, so that the gain in weight secured thereby will permit the lengthening of the ship to a degree that would not only permit more floor space, but allow additional weight for the installation of a battery of boilers. A simple change in the form of the arch of the protective deck might, in some cases, greatly improve matters, since this change would permit a much desired increase of height for installation of boilers and also render possible the introduction of some form of economiser that might be fitted in the uptake. In brief, the smoke question will exist proportionately to the limitations which are placed upon the design and installation of boilers, and thus the problem of obliterating smoke in land boilers ought to be comparatively easy of solution in contrast to the eradication of the evil in boilers of naval vessels."

The economical consumption of fuel in large quantities can only be effected in boiler or furnace installations designed by technically-trained experts possessing a knowledge of the practical mechanics of combustion. Hundreds of oil burners have been designed, and these, viewed from a chemical and theoretical standpoint, should have operated efficiently; but when the Board subjected them to actual tests they proved unsatisfactory.* There are practical conditions as well as chemical principles that must be considered in the solution of the liquid fuel problem. Everyone is aware that with a charcoal or coke fire it is possible to maintain very intense combustion within a comparatively small space and with very little smoke. This sort of fire was known to the smelters of the bronze age and is still used in blast furnaces and other operations where great concentration is required. The explanation lies in the fact that the fuel is solid, even at the highest temperature. The solid particles in the smoke are probably particles of ash, but whether they are ash or unconsumed carbon they are exceedingly small as shown by the bright blue colour of the smoke.

Complete combustion requires that for every atom of carbon and for every two atoms of hydrogen there shall be at least one atom of oxygen brought in close proximity and then and there subjected to a temperature sufficient for ignition. In other words there must be a thorough mixture and then ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where

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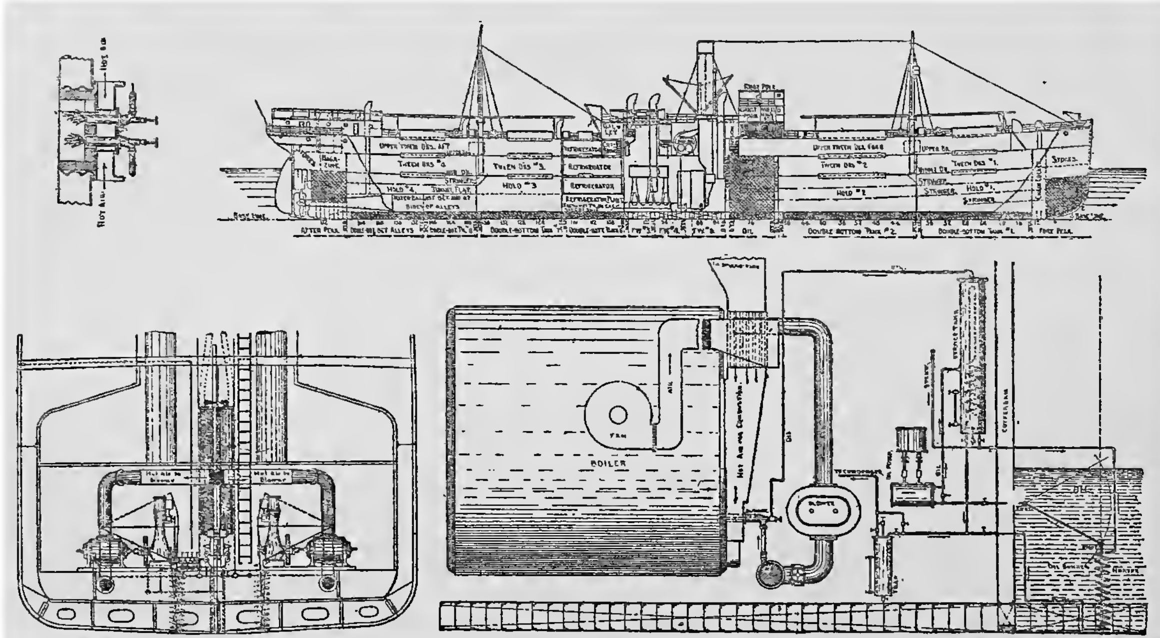
* During the past two years some well known types of burners owned by many well known private concerns have been brought up to a high pitch of perfection and work to the complete satisfaction of those who have installed them on modern tank steamers and other vessels of the mercantile marine. I make references to some of these elsewhere. It is also known that the British Admiralty has played an important part in the evolution of oil burners for naval purposes.




THWARTSHIP SECTION THROUGH FURNACE ROOM.

DOUBLE BOTTOM WATER BALLAST.

DISPOSITION OF FUEL OIL BUNKERS.

In the diagram of the Nebraskan the cross-sectioned portions indicate position of oil storage.

SOME of the earliest tests of the modernised system of burning liquid fuel on American steamers were made on the Nebraskan and Nevadan, owned by the American-Hawaiian Steamship Company, during voyages from New York to San Diego, California. The Nebraskan left New York, touching at St. Lucia, British West Indies, and Coronel, Chile, for coal. She reached San Diego in fifty-seven days, five hours, and forty-three minutes. On that voyage 2,267 tons of coal of poor quality were used, and a fire room crew of fifteen men was found necessary. The ship was kept at full speed during the entire voyage. On the voyage from San Diego to New York, with a greater cargo in her hold, the voyage was completed in fifty-two days, seven hours, and twenty-six minutes. There were consumed in the furnaces 8,826 barrels, or 1,260 tons, of California oil. Only six men were required in the fire-room. On the outward passage from New York to San Diego the ship steamed 13,280 miles, while on the homeward passage between San Diego and New York the ship steamed 12,760 miles, the increased distance on the outward passage being due to the fact that the ship called at both St. Lucia and Coronel for coal. Four hundred and fifty-seven tons of measured space for cargo was saved by reason of the oil fuel being of less bulk. While five days were saved on the Eastward journey, it must be remembered that the voyage was 520 miles shorter.

The Lassoe-Lovekin type of burner (an improved type of a burner used by the Standard Oil Company some sixteen years ago) and the Howden draught system proved a decided advantage in the burning of the Texas as well as the California product.

[*See facing page.*

we have a mechanical mixture, with the combustion of the so-called smokeless powders, in which the mixture is so thorough and minute that similar proportions of oxygen, carbon, and hydrogen occur in each separate molecule. In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is attained. As to the real nature of diffusion it is known that at ordinary temperatures the particles of oxygen in the air are moving about in every conceivable direction at velocities averaging over 1,600ft. per second. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom. So that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an inappreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large quantity of combustible in a small space.

In the combustion of hydrocarbons we have the following conditions: The fuel is already on its way to the chimney before it is even partially burned. The first effect of the heat is to disassociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents and also the products of combustion of hydrogen are alike transparent colourless gases. In any case, the carbon, left alone in the form of an impalpable dust, is much less favourably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this, it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

In the case of a liquid fuel which is incapable of vaporisation the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises with this sort of fuel from the action of capillarity or surface tension. Thus, no matter how finely the liquid is pulverised, each tiny drop assumes a spherical shape and so presents the least possible surface for the impact of oxygen atoms. Obviously, then, a liquid fuel like crude petroleum requires ample combustion space, more indeed than almost any other sort of combustible material.

The relative dimensions—length, breadth, and depth—of the combustion space are of minor importance; the primary requisite is volume, and that alone, provided all parts of it are traversed by the same quantity of gas in a given time, or, in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others.

Before I carry my quotations from this report over to another chapter a brief comment on the paragraphs I have already taken will not be considered out of place here. Many of the facts are of great interest to students of liquid fuel burning systems and the fuel problems which have been successfully solved by our own Admiralty. There is no longer any need to apply the language of qualification to questions of its scientific use. We have reached a time when some of the highest authorities on naval fuel subjects declare that the use of liquid fuel is an ideal method of raising steam, while others, more interested in its adoption for marine and manufacturing purposes, confess that the only difficulty standing in the way of its widespread adoption is the inability of oil men to guarantee an adequate supply at a reasonable price. No one who thoroughly understands the subject can be found to deny that amongst the fundamental economic benefits resulting from its use are those which rest upon the undoubted fact that it is much more easily handled than coal, that it can be stored at less cost, that it does not deteriorate when stored, that the fires are perfectly steady, that the steam pressure is regular, that the temperature of the stokehold is lower, and that there are no hot cinders and ashes to be pulled by hand labour to the deck or mechanically ejected.

Numerous authorities have attached their names to lists of the merits of liquid fuel, and this chapter may be suitably closed by the following one, for which Mr. J. A. F. Aspinall is responsible—

1. Diminished loss of heat up stack, owing to the clean condition of the tubes and the smaller amount of air which has to pass through the combustion chamber for a given fuel consumption.

2. More equal distribution of heat in combustion chamber, as doors have not to be opened; consequently, higher efficiency. The heat is easier on the walls of the boiler, since the steam from one part is hotter than from any other.

3. Reduction in the cost of handling which is done by pumps.

4. No firing tools or grate bars being used, the furnace lining suffers no damage.

5. No dust or ashes to cover or fill tubes and diminish heating surface, nor to be handled or carted away.

6. Petroleum does not suffer when stored, while deterioration of coal under atmospheric influence is well

known, not to mention the expense and shrinkage in handling, labour of feeding fires, removing clinkers, &c.

7. Ease with which fire can be regulated from a low to a most intense heat in a short time.

8. Reduction of manual labour in the case of firemen.

9. Great increase of steaming capacity, as we have conclusively proved by many factories in Pennsylvania and Ohio having had to increase their boiler capacity by about 35 per cent. when returning to the use of coal on account of the high cost of oil.

"THE time will come when oil will be used in the place of coal. The saving in freight room by the use of oil on a passenger steamer on one trip between England and Australia will be about £6,000."

W. H. GUION,
Head of the Guion Line, in 1879.

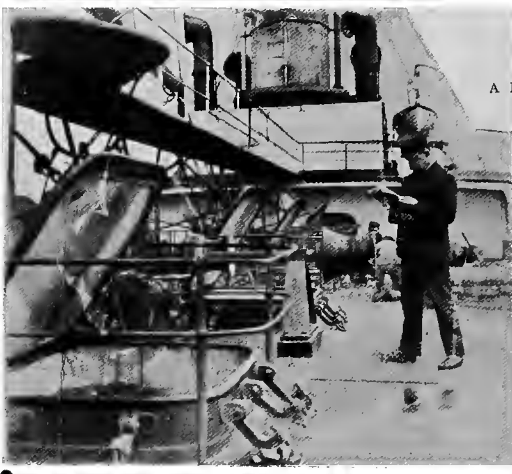
"THERE has been in the past considerable fault found with the use of oil as fuel because of the burning of the boiler tubes nearest the flame. I desire to say that boilers under which oil is burned in a proper manner will last a great deal longer than with coal. In firing under the boilers of a liner using coal the firemen have to open the furnace doors to put in fuel and 'lift' their fires. When this is done the cold air rushes in, the heat drops, and the shock to the surface of the boiler and tubes causes an immediate contraction, with attendant injury to the heated steel. With oil the doors are not opened during the whole voyage, and the heat is constant."

MR. VALELEMAR F. LASSOR,
In connection with the 12,000 mile voyage (San Francisco to New York) of the American-Hawaiian Steamship Company's oil-fired passenger steamer *Nebraskan.*

THE ANGLO-AMERICAN OIL CARRIER POTOMAC.

DECK VIEWS.

STORMY WEATHER.



A FINE DAY AT SEA.

[*To face p.* 95.

# CHAPTER IV

REAR-ADMIRAL EVANS AND OTHER OPPONENTS OF OIL FUEL. IS IT SAFE?

IN the introductory chapter I refer to the relatively small production of crude as compared with coal, and the admission is made that, from a naval standpoint, the coal fields are more advantageously located than the oil regions. When the American Navy Board conducted these tests they did not pay serious attention to the subject of supply, but studied the relative evaporative efficiency of oil and coal as fuels. They did their work on the assumption that the thermal efficiency of a pound of oil is the same in the case of crude or refined. While the crude contains sulphur and other chemical elements of low thermal efficiency, these have substances particularly rich in hydrogen. In the process of distillation not only the sulphur but the rich hydrocarbons are lost, and it therefore follows that in the commercial burning of oil the evaporative efficiency of the same weight of fuel from every field or district is practically the same. In noting the comparative economical efficiency, for naval purposes, of oil and coal, there must also be taken into consideration the fact that a ton of oil can be stowed in less space than a ton of bituminous coal, while there is the further fact that in the carrying of oil the compartments can be more completely filled. The relative efficiency of oil and good steaming coal from the naval standpoint of fuel supply in warships may be regarded as in the ratio of 18 to 10 *; but in the case of some qualities of coal the difference in favour of oil is very much more pronounced. Shipmasters and engineers who have been afloat with Indian coal, used largely east of Suez, know that as a steam-raising fuel it is smoky, dirty, and costly, and that it takes two tons to get the same working results as a ton of Welsh anthracite. It chokes the flues, and no vessel can possibly steam well with it. Against this inferior fuel, oil has every advantage, and if the supplies were reliable it would quickly take its place in hundreds of passenger steamers in Eastern trades.

"The Board is of opinion (and I am here quoting from the report) that, in regard to the evaporative efficiency, a long ton of the best quality of coal, such as Cardiff or Pocahontas coal, is equivalent to four and one-half barrels of oil, and that, in a long ton of an inferior quality of coal, the evaporative effect will be that obtained from only three to three and one-half barrels of oil. This comparison is based upon the assumption that, until greater volume is permissible for the installation of naval boilers, it will not be possible to secure, in actual naval practice, an evaporation from and at 212° F. of over 14lb. of water per pound of oil fuel. Increased efficiency, however, may be secured by heating the air requisite for combustion, as in the Howden or some similar system, whereby the heat of the escaping gases is utilised for raising the temperature of the entering air requisite for combustion."

The Board, agreeing that the mechanical or engineering feature of the oil fuel problem had been practically solved,

* I believe it has been found from actual results that 1lb. of oil is equal to about 1·75lb. of coal.—Mr. W. E. Farenden (1906).

stated that the financial features should not be regarded as of serious importance in the solution of any naval fuel problem, "seeing that it would be just as logical to fill the magazines of a warship with an inferior quality of powder as to stow the bunkers with a poor steaming fuel." This question of cost should not receive undue consideration. In 1902 it was the structural, transport, and supply features which presented the only serious difficulty to the adoption of liquid fuel by the navies of the world, and, as I show elsewhere, at least two of these problems have been solved by the British Navy. In regard to the transport and supply features, which may be regarded as the commercial side of the problem, the Engineer-in-Chief of the United States Navy said—

"It may be regarded as a certainty that, excepting where unusual conditions prevail, the cost of oil for marine purposes will generally be greater than that of coal. The cost of oil, however, is less for vessels departing from the Gulf and California seaports, but the rule will probably hold elsewhere. While the question of cost should be of secondary importance in military matters, it must be taken into consideration in industrial matters. It is the expense of transport that now prevents the oil from being a cheap combustible for marine purposes, but this disadvantage ought to be soon removed. . . . It can certainly be expected that when a large fleet of vessels* are used

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* In the building of more than twenty new tank steamers we have the best possible guarantee that, unless the world's production increases beyond expectations, the transport of oil will be reasonably cheap for several years, although we cannot hope that the cost of liquid fuel will be sufficiently low to enable it to successfully compete with coal on a purely *L. s. d.* test. These orders for new

for carrying oil, and when terminal storage facilities are provided, there will be a material decrease in the price of oil. This is a very important commercial phase of the question, and should be carefully considered in determining the probable relative value of the two combustibles in the early future. It is undoubtedly a fact that the transport charges per mile for oil are excessive compared with the freightage for coal. As regards the question of supply, it may be more expensive if not difficult to transport and to store oil than coal. The fumes of all petroleum compounds have great searching qualities, and therefore extreme precaution will have to be taken to guard the storage tanks. If it be true that for military purposes it is best in time of war to keep all reserve fuel afloat, then liquid fuel is at a disadvantage in this respect. The mining and railway companies have invested so heavily in the coal industry and the transport facilities have been so perfected that it is possible to quickly deliver a cargo of coal at any point in the world. There has been, likewise, a development in the method of loading and unloading cargoes of coal. Since it will require progressive development to perfect the transportation and the storage of oil, and as the world's supply is still an unknown quantity, it will be some time before there is a reserve supply of oil at the principal seaports. The question of oil supply for battleships and cruisers may prove to be a military problem, since the oil requirements of naval vessels for service conditions may only be met by the Government establishing oil fuel stations. The military aspect of the establishment of fuel stations

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tonnage also show that we may anticipate an increased movement of the more highly explosive grades of refined oil.

may prove to be a serious problem, since it may not only necessitate heavy expenditure, but may involve the greater political question as to the wisdom of maintaining a complete chain of fuel stations between country and colony."

Times have changed since the Navy Board expressed these opinions. Oil is now being powerfully backed, not by puerile theories or speculative sophistry, but by the convincing facts of successful tests, and we have passed the period when the arguments put forth in support of oil are weakened by apologies and qualifications. Oil as fuel is most thoroughly believed in, and it is satisfactory to know that the confidence of those who advocate its use is to a great extent the outcome of the hard work done on British warships by our own naval engineers.

> "Any Government which adheres to the exclusive use of coal as a fuel for its navy when oil is obtainable is simply shutting its eyes to manifest efficiency and progress and must sooner or later break away from a practice which the British Navy has already made obsolete. . . . In the United States Navy not a single battleship is equipped for the use of oil as a fuel notwithstanding the fact that America is the greatest oil-producing country among all the nations. It is incomprehensible that our naval authorities should be so far behind in a matter of such vital importance, and the fact that they are so lends some colour to the criticisms persistently and conspicuously made against our naval construction."—MR. REAVIS, March, 1908.

As a cardinal principle in naval warfare is preparedness and swiftness of action, and seeing that the determination of the range at which an engagement shall be fought will lie with the fleet which possesses the fastest speed, one naturally expects the question of fuel oil to be considered one of vital importance in the case of the navy of the United States, particularly in view of what Great Britain has actually achieved and what Japan and other foreign powers contemplate doing. Nothing of the kind; America has really not moved beyond the experimenting stage; her fleet in the Pacific is coal-fired, and oil fuel does not appear in the catalogue of its needs, although reports are current in California—America's most prolific oil-producing State and the one in which most British capital is invested—that some of the warships will be converted into oil burners before they leave San Francisco. On the Pacific Coast coal is scarce and expensive compared with the output and cost on the Atlantic coast, and it will be on the Pacific coast that oil will find its most important use for naval purposes.

We find one explanation of this neglect of liquid fuel in the fact that Admiral Evans has no great faith in it. For naval use oil fuel, in his opinion, has not one of those exceptional advantages which some authorities claim for it; he prefers coal, and bluntly says so, and takes the extraordinary stand, so hostile to widespread and growing naval opinion, that oil is even incapable of beating coal in an emergency test of speed. What authorities on steam-raising subjects in Great Britain, Russia, Japan, and Roumania declare to be hard facts, the actual results of extended and costly experiments on every class of warship, appear to have no weight with the gallant Admiral who has taken America's coal-fired armada to the Pacific—to the very spot, in fact, where he must find himself up against irresistible arguments and trade conditions showing that local oil of an A1 liquid fuel grade is incomparably better than the inferior steam-raising coal of the Pacific States, or even the best foreign coal transported by colliers chartered by the American Admiralty.

The arrival of the fleet in the Pacific converts an ordinary power and speed question into one of strategy. Has Japan not her oil fields and refineries (recently recovered from foreign companies) and will these not provide her with valuable and inexhaustible supplies of liquid fuel for the Navy?

Any one acquainted with the geography of the oil fields on the American coast must be surprised that the convenient sources of fuel supply and the means of cheap and rapid transport have so long been overlooked by the Naval Department, which, more or less, condemned liquid fuel by refusing to have anything to do with it on the cruise to San Francisco, where, curiously enough, oil is being burned with the best possible results on both passenger and cargo steamers.

One problem of the cruise along the eastern coast was the renewal of the coal supplies, and oil fuel experts were not surprised to hear that the bunkering arrangements worked badly and that the Admiral complained of the poor quality of the coal. Oil tank steamers could have performed the feat of bunkering the fleet very much better than the numerous and widely-scattered fleets of coal carriers. The Texas-Louisiana and Indian Territory oil fields, near tidewater, in the Gulf of Mexico, could have supplied the fleet with fuel oil for the cruise, and additional supplies, if required, could have been secured at other points on the Atlantic and Pacific coasts. Not only do pipe lines make the movement of oil simple and effective, but it is transported in a fraction of the time consumed in moving coal, it being possible to pump direct from the oil fields into the fuel tanks of the warships.

Admiral Evans has asked, "Where will it be possible to secure oil at foreign stations to maintain the necessary supplies on our warships?" and expressed the opinion "that at most of the ports its price would be prohibitive." The American fleet can go to no part of the world where it cannot be accompanied by tank steamers. Moreover, wherever it can get coal it can get oil, and that, too, with the minimum of risk because fewer steamers would be engaged in the work of carrying the liquid fuel. In war time all fuel stations, coal and oil, on neutral territory would be closed, so that, after all, it is not a question of foreign supply, but a question of marine transport, and I should certainly say that America could maintain an oil supply better than a coal supply.

There appears to be much misunderstanding as to the word contraband, but it may be accepted as an axiom where a fleet is supreme, able to lock up all possible enemies and fight marauders, nothing is contraband, for the fleet is strong enough to protect its own floating interests.

Then there is the reference to the prohibitive price of fuel oil. It is significant that the Admiral who expressed this opinion found it advisable to establish a coal economy competition in the fleet under his command. America's navy is small compared with ours, and as America is a petroleum-producing country and England is not, I should say that the fear of the prohibitive price is shown to be unfounded by the adoption of oil by the power which has the greatest fleet and absolutely no oil—only an oil-producing Empire in embryo. Besides, it is admittedly a question of efficiency and only remotely one of economy in the case of the navy of a first-class power.

The Admiral thinks that, as only a certain quantity of fuel can be consumed under each boiler, the burners are limited in number, and the steam pressure cannot be increased, a ship is limited in its speed and there can be no emergency rush. Oil, he says, will burn very well under the boilers and meet any demands of marine engineers, especially of the merchant service, but there are grave objections to its use as a naval fuel. For instance, he thinks it can be burned with advantage in a ship that is required to jog along at a certain uniform speed, but it will not admit of forcing in naval use. To quote the Admiral—"There are cases where the naval captain must be prepared to drive his ship at top speed regardless of the consequences and forget economy. He may be chasing a blockade runner, or he may be flying before a greatly superior force, when forced draught must be applied in closed stokeholds, and that is where oil fuel fails."

There are few interested in naval engineering subjects who do not remember that in the British naval manœuvres Admiral May's ships equipped with oil as an auxiliary steam-raising power outstripped the coal-burning fleet commanded by Admiral Wilson. In the memorable race up the English Channel to the North Sea it was found that three tons of oil were equal to four tons of coal in steam-raising capacity, so that the King Edward VII. and three other battleships were able to draw away from Admiral Wilson's ships, which, in the course of the sternest part of the chase, showed signs of having dirty fires, coal difficult to get at, and engine room staffs tired out with ceaseless labour.

It is just in the emergency test that oil displays its greatest power, and it is difficult to understand why any

American authority should take the contrary view. The fuel efficiency of a naval boiler is more likely to be secured with the use of oil than with coal.*

One of Admiral Evans's most serious arguments against oil fuel reads—"The storage on board ship of thousands of gallons of fuel necessary for a long cruise alongside tons of high explosives would be exceedingly dangerous; the ship's company would be living on a volcano, so to speak, and in battle a single shell from the enemy might fire the whole ship." The structural problems of a fuel oil installation are difficult and complicated, and the storage of oil on warships undoubtedly acts against its free use for naval purposes. Oil must be carried below the protective deck, as far below the water line as possible, and as considerable space must be found in the lower portions of the vessel for ammunition and equipment, it is exceedingly difficult to secure beneath the protective deck adequate space for oil storage purposes. Moreover, crude oil is admittedly a great searcher, and some of the gases from the volatilisation of liquid fuel are poisonous and explosive; but, while oil is dangerous where there is careless or inefficient installation, experience shows that the danger can be reduced to a minimum when the apparatus, designed by men of acknowledged expert knowledge, is operated by intelligent and observant engineers working

* Back of all the factors which lead to success in naval warfare is motive power—steam. Back of steam is fuel. Naturally, the most valuable combustible for steam-making purposes is desired; therefore, in the present age, it is either coal or liquid fuel. Liquid fuel has been declared by naval authorities to be vastly superior to coal, not only in evaporative efficiency, but trials have shown that at many parts of our vast coast it costs less.—Mr. Reavis, Texas.

under the rules recently drawn up for use on British warships.

It can be taken for granted that there are descriptions of commercial fuel oil which, properly isolated and stored, would not be a source of danger during a battle at sea. Take the case of the fire on the Heusatonic when she went ashore on the Irish coast last year. A rocket exploded in an accidentally-created vapour zone with the result that a fire took place. If the same rocket had been shot through an open hatchway into a tank of ordinary Russian mazoot there would have been no explosion and no fire. On these questions of the volatility of different kinds of oil many of the world's most famous petroleum and explosive experts agree that even under war conditions the storage and use of liquid fuel cannot be considered more than an ordinary war risk. It is a risk which the British Admiralty is evidently prepared to take, and there are thousands of experts in the handling of oil who support the Naval authorities in this policy of a fearless adoption of oil fuel.

Admiral Evans refers to the liquid fuel products of the northern fields of his own country and condemns oil as a dangerous combustible without looking at it from the standpoint of the world's most suitable products, and particularly those of Russia. The earliest practice in Russia demonstrated that petroleum refuse was a perfectly safe fuel, being, indeed, safer even than coal. One or two scientific men, among them Prof. Lisenko, of St. Petersburg, have declared crude oil to be dangerous. "Petroleum dregs (he said) constitute, owing to the difficulty of setting fire to them, a material perfectly safe for river steamers. This, however, cannot be said of crude petroleum, which ignites more readily, and hence, owing to its dangerous qualities and the irrationality of making use of it when dregs will do as well, its use ought to be prohibited on rivers."

Goulichambaroff, combating both these opinions, asserts that it is quite safe after it has stood a little while in the air. He considers that if there is a strong demand for the article as fuel, and if the crude oil is forthcoming in large quantities, the question of "irrationality" ought not to be made a cause for official prohibition.

Every combustible material is more or less dangerous in use and requires certain precautions in handling; there is, however, a difference in their respective degrees of inflammability. This danger is chiefly of a twofold description: it may either be the result of the fuel coming in contact with a flame or of spontaneous ignition. To obtain a clear idea regarding the degree of liability to spontaneous ignition it has to be compared in this relation with a solid fuel like coal. The latter ignites on coming into contact with a flame, but such ignition necessitates more or less prolonged contact. Some coal, considered from this point of view, represents while fresh from the pit a serious danger owing to the amount of inflammable gases retained in it. In addition, coal, like many other solids, has the property of condensing on its surface considerable quantities of gases, several times exceeding in volume the one of coal itself. Thus freshly prepared charcoal freely absorbs various gases—90 volumes of ammonia, 68 of sulphuric acid, 35 of carbonic acid, 9 of oxygen, &c. Given certain atmospheric conditions, the absorbing power is considerably increased. The gases are so firmly bound by the coal as to defy their removal even by submerging the coal under water. The condensation of gases on the surface of coal is always accompanied by a rise of temperature which frequently results in spontaneous ignition, and many steamers have been lost owing to this cause. However, nobody ever thinks of abolishing its employment as a fuel.

Petroleum, on the other hand, does not ignite spontaneously under ordinary conditions; instead of attracting or condensing gases it gives these off, or, more correctly, evaporates, even at the usual temperature. The result is the reverse of what has been observed in connection with coal, which becomes heated owing to the condensation of gases, while the temperature of petroleum is lowered under similar conditions owing to evaporation. There is only a single possibility of petroleum igniting spontaneously, namely, rapid oxidation at a very high temperature or under high pressure.

At Baku, when the excise duty on kerosene was paid on the time occupied in distilling, when every refiner tried to handle as much crude as possible in a certain period, distillation was carried out at a fast rate and very high temperature; once the distillation was completed, no time was lost by allowing the astatki to cool, and it was immediately run off into ambars. The astatki, having a temperature of at least 400° C., when it came into contact with the cold air, underwent rapid and energetic oxidation, with the result that the whole mass immediately took fire. Not only petroleum, but even iron, ignites spontaneously under these conditions; a red-hot steel or iron wire plunged into a receptacle containing oxygen immediately ignites.

Nowhere has there been a case of petroleum or its derivatives taking fire except by coming in contact with a flame.

Bolley affirms that "petroleum can neither ignite spontaneously nor explode until part of it is converted into vapour," but, Mr. Goulichambaroff thinks, this opinion may lead to erroneous conclusions, as petroleum is not explosive even when evaporating, unless its vapours come into contact with a flame. "In London and Liverpool," Bolley continues, "where there are always large stocks of petroleum, the municipal bodies, experimenting on a large scale, have proved that spontaneous ignition or explosion can only ensue in the event of the petroleum vapour mixing with at least 8 per cent. of air." Prof. Eaton, of New York, arrived at the same conclusion.

That petroleum vapours or gases can neither burn nor explode except in the presence of air and that a certain volume of air is required in either case are well-known facts; but neither the one nor the other could ensue without contact with a flame. The air forming the gaseous hydrocarbons of petroleum makes an explosive mixture which can be stored for any period without the slightest possibility of explosion.

In the Russian records it is stated that the question of the spontaneous ignition of petroleum was raised in Russia in 1870, when an explosion occurred on an oil-carrying lighter moored at Kronstadt, and the Committee of the Ministry of Marine submitted the question to the Academy of Science, when Zinin and Butleroff, members of the Academy, reported as follows—

1. We are not cognisant of a single authenticated instance of the spontaneous ignition of petroleum.

2. There is not the slightest justification for assuming that the subsequent ignition of the petroleum was preceded by an explosion of a barrel filled with petroleum.

3. All the components of petroleum do not absorb oxygen from the air, are with difficulty oxidisable on its

account, and in general withstand the action of powerful re-agents, so that, if the possibility of spontaneous ignition is admitted, it could only have happened provided a fairly large heap of porous material like wadding or sawdust saturated with petroleum had been exposed to the action of the atmosphere.

4. Petroleum contains substances which are more easily vaporised than kerosene, and for this reason kerosene does not ignite so easily as crude, but not to such a degree that one can, under every condition, bring it close to a burning body or throw a lighted match into it.

5. Owing to the volatility of petroleum its ignition by a burning or highly-heated body from a distance could only take place when the vapours given off by the petroleum reach the flame. If the vapours happened to mingle with a volume of air the ignition would be followed by an explosion.

6. As appears from the Commander-in-Chief of the Port of Kronstadt, the explosion on the lighter preceded the outbreak of fire, which was, most probably, caused by the petroleum vapours (which either filtered through the staves or leaked on to the deck from a broken barrel) mixing with the air and coming in contact with a flame. A spark would have sufficed to ignite the mixture and cause an explosion and conflagration.

Numerous investigations in different countries show that petroleum is not liable to spontaneous ignition and that it will only explode when its vapours or gases come under high pressure or get in contact with fire. Richardson, an English engineer, thought that if a red-hot cannon ball were to drop into a petroleum tank the contents would not explode but simply evaporate.

Experiments made in St. Petersburg during 1887 had for their object the determining of whether petroleum would be ignited if struck by an explosive bomb. Bombs were fired from 37-47 mm. Hotchkiss guns and a four-pounder into tanks filled with petroleum, and not only was there no ignition when the bombs exploded, but the rise of temperature was only very slight. Similar tests made at Toulon with projectiles of 47 mm. diameter gave equally satisfactory results, and Mr. Goulichambaroff tells me that on several occasions he has seen Balakhani labourers extinguishing burning stumps of wood by throwing them into crude petroleum instead of into water.

In explanation of these facts, Mr. Goulichambaroff refers to data relating to the temperature at which crude petroleum ignites and to its variations dependent upon a change in the specific gravity of the crude. The following table refers to the Balakhani qualities of crude—

| | | | | |
|---|---|---|---|---|
| Petroleum of ·866 sp. grav. | ignites | at | 21·5° C. |
| ,, ,, ·876 ,, ,, | ,, | ,, | 25·0° C. |
| ,, ,, ·871 ,, ,, | ,, | ,, | 25·0° C. |
| ,, ,, ·877 ,, ,, | ,, | ,, | 28·5° C. |

Petroleum from other Russian sources, although of higher specific gravity, have a much lower flashing point, due, of course, to the chemical composition of the petroleum. For instance,

| | | | | |
|---|---|---|---|---|
| Kuban petroleum of ·814 sp. grav. | ignites | under | 11½° C. |
| ,, ,, ,, ·895 ,, ,, | ,, | ,, | ,, ,, |
| Grosny ,, ,, ·873 ,, ,, | ,, | ,, | ,, ,, |

Exposed petroleum rapidly loses its more volatile and inflammable constituents, and its flashing point rises to 40° C., after fourteen days at 70° C. As regards astatki this temperature varies between the wide limits of 80° and 170° C.

Some Pennsylvania crudes are highly dangerous if kept near a fire, and this accounts for the products of the Northern fields of America rarely being used as a fuel in the same condition that they come from the wells.

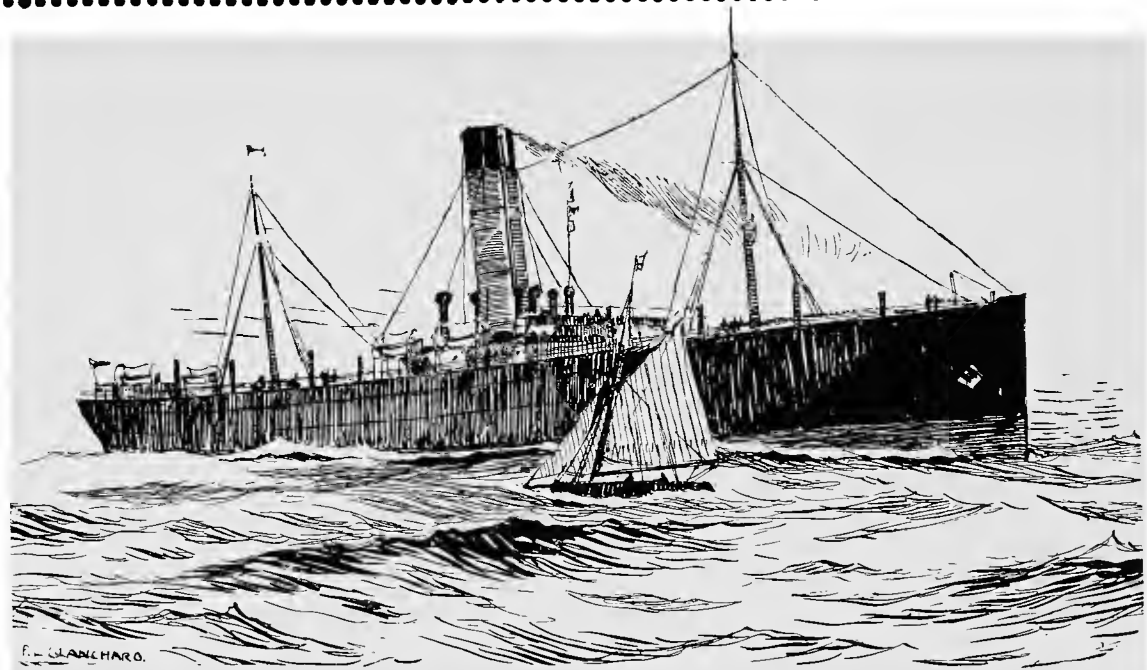
On this subject of the alleged danger of using oil fuel, Marvin said—"Thousands of tons of oil, thrown up by the fountains and allowed to spoil in the surface lakes, have been used as fuel without any mishap. For years also the locomotives on the Transcaucasian have been running from Balakhani to Baku, with trainloads of crude freshly drawn from the wells, and there has not been a single case of explosion. So much for the crude article. As for the safety with which the dregs may be carried and used on any kind of steamer there should be sufficient proof afforded by the fifteen years' practice in the Caspian to set all fears at rest. What test could be severer than its employment on steamers loaded from stem to stern with hundreds of tons of inflammable kerosene? Yet hundreds of voyages have been performed by the floating oil-cisterns of the Caspian without a single case of destruction from the ignition of the vessel by its liquid fuel or its refined petroleum cargo."

No less an authority than M. Bertin, in 1899, when he was investigating the question of oil fuel as the Chief Constructor of the French Navy, stated that Baku mazoot formed an ideal fuel for naval purposes. His investigations enabled him to say that a Russian mazoot, which did not give off vapour below 248° F., and would not flash under 302° F., might be exposed with impunity to the explosion of a shell. It could certainly be stored and handled with very little risk.

Then there is the smoke trouble, referred to by Admiral Evans. Combustion and black smoke difficulties are the result of imperfect fuel equipment, and it has been demonstrated in the latest trials of all types of torpedo boats and torpedo destroyers that by the use of oil with the latest Admiralty-owned burners and atomisers and others by well-known makers the maximum power can be obtained from a water-tube boiler absolutely without smoke. Where there is regularity of pressure and supply—secured by the employment of properly designed pressure regulators—we have complete smokeless combustion in ordinary steamers and small naval vessels, if not in full-powered men-of-war. As I have already made clear, this much cannot be claimed for ordinary steam coal. During the early stages of combustion of any fuel, highly volatile gases distil at a low temperature, rise rapidly, cling to the boiler, get into the tubes, and pass out unconsumed, and it is only too obvious that the secret of success lies in combustion chambers being properly and scientifically arranged so that the air may be heated to the required temperature and the flame properly retarded, diffused, and distributed.

But, after all, what the British Navy has actually accomplished is the best proof we can have that oil is the steam-raiser which holds the records for speed in all kinds of warships, that it is easy and safe to handle, and that it saves labour.

The United States Navy has never been menaced by fear of a coal famine. Neither in the Civil War nor in the Spanish-American war were the operations of the navy interfered with by opposing force, and the blockades of the South Atlantic and Gulf States, as well as of the Kuban ports, were carried on with the vessels using a minimum quantity of coal. That is why the fuel problem




[*Specially drawn by Mr. Blanchard.*

A tank steamer of the type of the Narragansett and Tuscarora, owned by the Anglo-American Oil Company.

[*To face p.* 112.

in the conduct of naval operations has never been seriously studied in America. The acquisition of the Philippines and Hawaiian Islands and the defence of the Isthmian Canal make it likely that the scene of probable future naval operations will be at points less favourable to the United States than have existed in the past. It may be in the Pacific rather than on the Atlantic where the greatest naval battles of the future will be fought. California, Oregon, and Washington coal is of inferior quality, and both the Australian and Japanese fuels are far superior to the product of the Pacific coast of the American Continent.

With her fleet on the Pacific coast, America will now probably see the advisability of studying the question of utilising the vast oil fuel supplies of California for naval purposes.

To conclude my reference to America's objections to liquid fuel, I should say that, while it is perfectly true that country has been content to stop at experiments and the publishing of a report, it is satisfactory to see it stated that the Navy Department officials are this year going to give attention to the matter of using fuel oil in place of coal in torpedo boats. It is predicted in authoritative quarters that the next torpedo boat destroyers will be oil burners. Although those now building will be fitted to burn coal, the Department is convinced of the desirability of using oil and is only held back by commercial considerations. There is no longer any question in the minds of the naval officers, who are familiar with the tests of oil and who know what is being done in the English and other navies, that oil is the best fuel. As one officer has put it—"The question is simply a commercial one. It is no longer doubted that oil is more desirable than coal, but the problem is, where are we to get our supplies of oil? In the case of coal, we have a number of sources from which to obtain it. The advantages of oil are numerous. The chief one is that a third more fuel can be carried in the same space. Then, too, the oil can be put on board at sea in rough weather much more easily than coal."

Commenting on this view, a Texas correspondent, who sends me the report, says—"In view of the fact that the British Navy is getting supplies of fuel oil from refineries on the Texas Gulf coast there seems to be little weight in the argument of the officer quoted in the foregoing interview. If England can transport its oil supply four thousand miles or more the United States naval authorities, with a plentiful supply of liquid fuel on the Atlantic coast, the Gulf coast, and the Pacific coast, certainly cannot plead insufficiency or uncertainty of supply. No other nation has such tremendous advantages in the matter of oil supply."

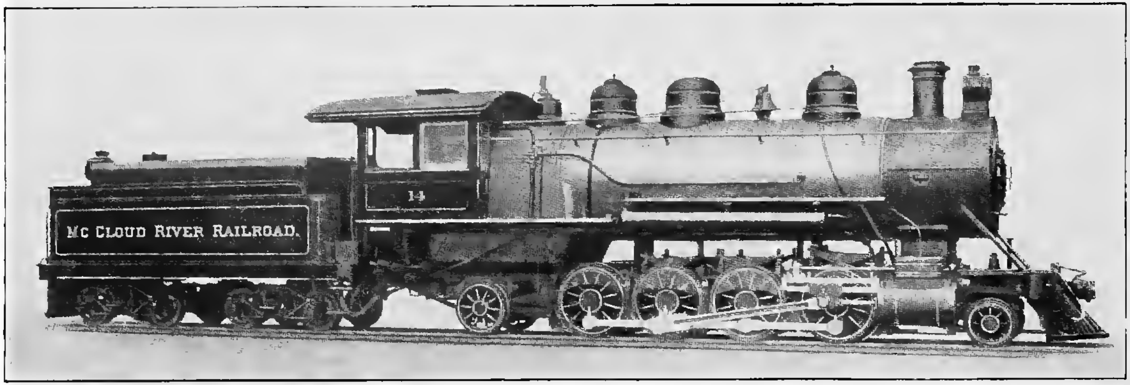
"CRITICS are apparently ignorant of one of the things that was proved almost more emphatically than anything else in the Surly trials—that with the new arrangement oil or coal can be used at will. Those who have seen the invention at work require no convincing in regard to that proposition. Among the acknowledged defects of coal are its bulk and consequent heavy demands for labour and space, its unevenness of quality and imperfect combustion, beyond which comes the very material objection of smoke production. On every one of these points oil is infinitely superior, and there remains only for a solution of the problem such a utilisation of the liquid fuel as will take full advantage of these points without introducing faults that will outweigh or even detract from these desirable features. In regard to the Navy, the introduction of oil fuel makes for speed, a wider range of action, and the reduction of the number of stokers, who could be added to the fighting strength. It will lighten the task of the stokers, and remove the smoke column, which is so menacing a thing for a warship, and the fuel will keep without serious deterioration (in any climate) for an indefinite period. In regard to taking in fuel, a hosepipe and oil-pump will do more than an army of coal loaders."

J. J. KERMODE.

In regard to the effect of oil on boiler plates, this advantage is certain: the furnace doors do not require to be open throughout a voyage.

Burners should be designed to permit rapid and easy examination, overhauling and renewal of special parts by inexperienced men, and an ordinary fireman should be able to take out a burner and renew it.

SPEAKING in 1899, Mr. R. Traill (Armstrong, Whitworth and Company, the builders of many oil-burning steamers) said his company found that the calorific value of liquid fuel was 24,000 units as compared with 15,000 units for the best Welsh coal. In burning oil the combustion was so perfect that instead of getting one-third more steam they actually evaporated twice the quantity of water. In a marine boiler they evaporated from 15lb. to 16lb. of water per pound of oil fuel against 8lb., which was the best achievement on steamers using Welsh coal.




THIS work shows that in most of the oil regions the locomotives which draw the tank cars burn liquid fuel. It is also burned in numerous industrial centres. In the lumber industry in many parts of the United States the locomotives are of the usual American "dinky" type, but as the grades are often steep and the lines roughly laid, various geared designs (the Shay and Heisler, and others) are frequently used. For the heaviest work locomotives of considerable size are employed, and the Baldwin Works, of Philadelphia, recently turned out a remarkable oil-fired locomotive for the McCloud River Railway Company. One of the "Mikado" type, it has eight coupled wheels with a pair of carrying wheels at each end. The combination of cylinders 20 in. diameter with a stroke of 28 in., steam pressure of 180lb. per square inch, and a total heating surface of more than 3,000 sq. ft., ensure very great tractive effort. The boiler is of the straight type, 6 ft. 2 in. diameter, and constructed of steel plate $\frac{3}{4}$ in. thick. The fire-box is of the wide type constructed of steel plates of $\frac{5}{16}$, $\frac{3}{8}$, and $\frac{1}{2}$ in. thicknesses, and is 7 ft. 6 in. long and 5 ft. 6 in. wide. There are 350 iron tubes of 2 in. external diameter and 15 ft. 6 in. long. The fuel is oil, a special spraying burner being fitted in the fire-box.

[*To face p.* 117.

# CHAPTER V

SIR BOVERTON REDWOOD, MR. THOMAS URQUHART, AND MR. JAMES HOLDEN GIVE EVIDENCE BEFORE THE ROYAL COMMISSION ON COAL SUPPLIES ON THE ADVANTAGES OF OIL FUEL FOR MARINE AND LOCOMOTIVE PURPOSES.

OIL fuel benefited by the evidence given before the Royal Commission on Coal Supplies in 1903. A considerable part of it dealt directly with the advantages of petroleum for power purposes, and even to-day, when we have it published verbatim in the form of a Blue Book, it is eminently readable and useful. Oil fuel was under a cloud of smoke in 1903, but the black trail of the Surly, Mars, and Hannibal tests is scarcely seen in the printed evidence of Sir Boverton Redwood, Mr. James Holden, and Mr. Thomas Urquhart, three of the world's foremost fuel experts, who represented the oil industry before the Royal Commission.

Sir Boverton Redwood gave lengthy evidence, in which he dealt not merely with the use of oil as a substitute for coal in the furnaces of steam boilers, but also with the employment of petroleum in internal combustion motors of the gas engine type. In steam engines of moderate dimensions, he said, only 12 per cent. of the total heat given to the boiler in the form of coal appears in the engine as indicated work, whereas in gas or oil engines the proportion of heat rendered effective is in some cases more than double this percentage. On the basis of existing experience it is evident that there is scope for the advantageous employment of oil engines as substitutes for the very large number of independent steam engines of moderate power required for the working of the machinery on ships of war. Success has attended the use of petroleum spirit in small engines for motor launches.*

Sir Boverton stated that he was convinced that no one could travel on an oil-burning steamer on the Caspian Sea without being struck with the saving in labour of stoking and the effectiveness of control, and to these advantages there may be well added the ease and celerity with which the bunkers can be replenished.

In his evidence on the differences in the mechanical appliances used on the Caspian and those used in this country Sir Boverton said—" I think it is a question of the construction of the combustion chamber. The arrangements for the burning of the oil on the steamers plying on the Caspian Sea are such as to afford opportunity for thoroughly satisfactory combustion of the hydrocarbons, whereas in the attempts that have been made to carry out the combustion of liquid fuel on our ships of war in this country, as far as I can judge from the results, they have

* Petrol launches are coming extensively into use on warships and passenger steamers. Some of these travel as fast as 20 knots, while crack racing boats have records of over 30 knots. Perhaps one of the most interesting innovations of the present year is the employment by the Anglo-American Oil Company of a large petrol launch on the steamer Iroquois. This launch is intended to keep up communication with the Navahoe, the oil-carrying barge which the Iroquois tows in the Transatlantic oil trade. The small craft will be used in good weather to make journeys between the two vessels.

not adopted means which admitted of satisfactory combustion."* It is mainly a question of the arrangement of the furnace, the provision of a necessary supply of air, which, however, of course, must be admitted in such fashion as not to bring about too much cooling.

The following questions were asked—

Sir Clement Le Neve Foster †: Has oil fuel been found to be smokeless in the burning of it in the Navy?

Sir Boverton Redwood: I am afraid it has not in the Navy. I think the combustion has been badly arranged, and badly carried out, and there have been serious complaints of the difficulty of getting, not merely smokeless combustion, but anything approaching to it.

The Chairman: Have you been on an oil-fired steamer where there was absolute freedom from smoke?

Sir Boverton Redwood: Yes, on the Caspian Sea, several times.

The Chairman: Then, in your view, it is rather a question of the construction of the furnace than of the material?

Sir Boverton Redwood: There is no doubt about it.

Mr. Brace: But with the furnaces as they are at present arranged, smokeless steam coal has been quite as smokeless, or more so than oil, has it not?

Sir Boverton Redwood: Oh, yes. I think you may say

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* This evidence was given before oil was smokelessly burned on fast warships.

† The death of Sir Clement, whose unrivalled practical knowledge of the coal-mining industry, coupled with his high scientific ability, had rendered him a most valuable member of the Commission, occurred during the later stages of the inquiry, and his colleagues were, therefore, deprived of his assistance in the preparation of their report.

that the worst coal, the coal for instance that is used on some of the Clyde steamers, which is most objectionable in regard to the quantity of smoke given off, is very much better in that respect than oil as the oil has been burned in some of the Navy experiments.

(It should be pointed out that the foregoing discussion took place at a time when the Admiralty were striving to overcome the difficulties attending the use of liquid fuel under special conditions in respect of which no previous experience was then available for guidance, and it is satisfactory to find that the hopeful view expressed by Sir Boverton has been fully justified, for the problem has been successfully solved, the combustion of oil fuel in the British Navy now effected by means of the new Admiralty burner, with improved furnace construction, being absolutely smokeless.)

Continuing, Sir Boverton said, where considerations of safety in respect of storage, transport, and handling may be ignored, there is no difficulty in burning the crude oil as fuel, and accordingly this is commonly done in the oil fields, not only in Russia, but generally. Moreover, in some of the Baku refineries the benzine which cannot be readily sold is used as fuel. For ordinary purposes, and especially for employment on passenger steamships, it is no doubt desirable to have a liquid fuel which does not readily ignite or give off inflammable vapour at any temperature to which it is likely to be subjected before it enters the burner, and accordingly standards of flash point for such oil have been fixed. The limitation of flash point is a matter of importance, for it is evident that the higher the standard the more restricted the available supplies. Safety in storage, transport, and use must be the first consideration, but the limit of flash point should be as low as is consistent with this. On the Russian railways the minimum standard is, I believe, 70° C. (158° F.) by the Abel-Pensky close test, but in this country a disposition to exact a higher standard, at any rate for marine work, has been exhibited. As regards transport and storage it cannot be contended that a standard of 150° F. (close test) is insufficiently high. In use on board ship, if leakage occurs in the stokehold, no practicable limit of flash point, however high, would render the oil safe, but leakage can and should be guarded against, and if escape of oil does not occur a standard of 150° F. may be regarded as adequate. Any unnecessary requirement as to flash point would tend to make liquid fuel more costly, and would diminish the supply. In California, where the use as fuel of the oil produced in that State is increasing rapidly, it is generally considered that a flash point of 150° F. is high enough, and in India the import duty on petroleum having a flash point not below 150° F. has been reduced to 5 per cent. on proof being furnished that the oil is intended to be used exclusively as fuel.

Apart from the use of petroleum in internal combustion engines, which on the score of comparative economy may be expected to be very largely extended (though only gradually as regards high powers) as improvements are made in such motors, it may be said that at the present time in all civilised countries there is a general recognition of the merits of liquid fuel for steam generation and furnace work generally, including such operations as cement manufacture and glass making, and that nothing but the assurance that adequate supplies will be continuously available is needed. Hitherto, or until recently (1903), the liquid fuel industry has been an offshoot of, or the outcome of, the pre-existing industry of the manufacture of the ordinary commercial products of petroleum, and deposits of petroleum not yielding the latter products in sufficient quantities have been regarded as comparatively valueless and have remained unworked. This has been notably the case in the United States, but within the last few years there has been a largely increasing output of fuel oil in California, and the copious yield for a short time given by the flowing wells on Spindle Top, in South-Eastern Texas, raised hopes that very considerable supplies would be obtainable in a district most conveniently situated for export. This has unquestionably contributed materially to direct public attention to the liquid fuel question, but, so far, these anticipations have not been realised, for the cessation of flow of the gushers has brought about such a rise of price as prohibits delivery to this country in competition with coal, and until further producing areas in this State are developed America may be expected to use all the Texas fuel oil that can be produced.

It, however, by no means follows that the Texas wells will have flowed in vain, for it may be hoped that, interest in the subject having been aroused, other known sources of supply of oil suitable for fuel may be brought into development.* There has been too much disposition for the potential producer of such oil to postpone operations

* The anticipations of Sir Boverton Redwood have been abundantly realised. Away up behind Texas, in the great Mid-Continent region, prolific sources of supply have been discovered with the result that the shipments of liquid fuel at Port Arthur are steadily increasing. We are also on the threshold of important developments in our own Colonies.

until there was an assured market for it, and, on the other hand, for the fuel user to apathetically await the creation of adequate supplies.

That there is ample scope for energy and the employment of capital in opening up fresh sources of supply if petroleum is to be largely and generally used as a source of power must be evident. Those who talk lightly of petroleum replacing coal cannot realise what is involved in such a change. Hitherto, exported petroleum products have been chiefly used by the pint as a source of light, or in small quantities for the lubrication of machinery, and to supply the markets of the world with a commodity which is to be burned by the ton is another matter. . . . Weight for weight, the output of petroleum is only 2·8 per cent. of that of coal. Assuming that the present output of petroleum in the world were doubled, and that the whole of the surplus thus created were used as fuel, this would only be equivalent (taking into account the relative thermal efficiencies) to about 5 per cent. of the world's output of coal.

Mr. Thomas Urquhart * was the first to practically and commercially use oil fuel in locomotives in Russia. He did this in 1883, although certain tests had been conducted ten years earlier. Mr. Urquhart's work was done on the Grazi and Tzaritzin Railway (South-East Russia), and, when he was before the Royal Commission (in 1904), he stated that over 4,000 locomotives burned liquid fuel on the railways of Russia. The locomotives are of the

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* Mr. Urquhart died at Dalney Castle, Ross-shire, in 1904, just one year after he gave this evidence. He was a brother of Mr. Andrew Urquhart and uncle of Mr. Leslie Urquhart, both of whom have held important positions in the Caucasus.

ordinary type, but have their fire-boxes fitted with liquid fuel appliances which can be removed in a few hours and replaced by furnace bars.* Russian experience proves that liquid fuel is less injurious to the boiler than the use of coal. During Mr. Urquhart's experience on the Russian lines the cost of oil was brought down to about half the amount paid for Russian anthracite (very much like Cardiff coal, but a little harder), which came from near the Sea of Azov. Russian engines burn 43lb. of anthracite per train mile as against 25lb. of petroleum refuse. Coal cost on an average for the year *7s. 6d.* per train mile against *4s. 4d.* for petroleum.

Asked to describe the advantages of oil fuel, Mr. Urquhart said—"It occupies much less space than coal, about half the coal space, and it is much cleaner on the engine, in fact one man could manage the whole train. We were obliged to have two men on the engine because the Government did not allow us to have only one, but an American, who came all the way from Pennsylvania to see what was doing in Russia with petroleum fuel, said he could do with one man in America. I do not know whether the law will allow him to do it there or not. All the factories about Moscow burn petroleum; it is used for metallurgical purposes, melting brass and welding iron, and at some scrap furnaces iron is rolled into bars by the use of petroleum fuel."

On the subject of smoke Mr. Urquhart said—"We could always keep it down, and if there was any smoke it was simply through the carelessness of the engine-driver.

* The Russian Government will not allow the railway concerns to adopt liquid fuel unless they prove that the engines can be made at any moment effective for burning coal.

While the brickwork was green, not hot enough, smoke resulted, but when the brickwork reached a certain temperature there was absolutely no smoke."

At one part of his evidence the following questions were asked and answered—

In winter time does the oil get so thick that it will not run ?—It gets so thick that we cannot get it to run to the spray injector, he replied.

Then how do you start a locomotive in winter time ?—We simply heat up the oil, to begin with:

But how do you heat it up ?—By having a steam spiral pipe into the tender.*

But supposing the locomotive is cold, how do you start it—you have no steam ?—We have the steam from a neighbouring locomotive.

Ah, if you have the neighbouring one ?—Yes, we always have that at the engine depôt ; there is always one engine in reserve in steam for general use, and all the engines are fitted with the necessary appliances for heating up.

Mr. Urquhart expressed the opinion that, with a locomotive in first-class order and in the hands of a skilful driver, 50 tons of liquid fuel were equal to 100 tons of first-class coal.

After this evidence on Russian liquid fuel, there came the statements of the foremost British expert on its use in

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* This was a difficulty on the London, Brighton and South Coast Line, where, three years ago, on a change of management, oil fuel was discarded and coal reintroduced. No one denies that while it was used it worked efficiently, but there was trouble in raising steam at points remote from New Cross, where there was a steam boiler for starting the firing in the engines. The oil was sprayed on to chalk, there was practically no smoke, and the system was popular with the engine-drivers and firemen.

locomotives in this country, Mr. James Holden, for twenty years Locomotive, Carriage, and Waggon Superintendent of the Great Eastern Railway and the inventor of the Holden burner.* He stated that of the 1,200 engines owned by his company, running 22,000,000 train miles per year and consuming about 650,000 tons of coal, about 80 were oil burners. He introduced oil fuel on the system one year after he joined the company, and his experience, directed to the improvement of the means of applying and dealing with oil fuel, enabled him to say that he could get quite as much, if not more, out of oil now than at any previous time.

Asked if he would use oil if he could get it at twice the cost of coal, he answered—"Yes, if we could get an assured supply at twice the price of coal, I would recommend my directors to fit up a larger number of engines." He burned residuum because he thought it was cheaper and

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* "This gentleman," said Mr. Bell on one occasion, "when confronted with a difficulty as to the disposal of some objectionable waste tar from the oil gas works at the Stratford works, set himself to devise an apparatus which, whilst being able to spray sufficient oil for practical purposes, should be quite independent of extra brickwork, and, further, should be available for use in conjunction with coal when desired. In other words, he instituted a system by which it becomes possible to fire a boiler under any one of the three following conditions—(1) with coal alone as ordinarily used, (2) with coal and oil combined, or (3) with oil alone. Manifestly, such an arrangement possesses great advantages over all those requiring special treatment of the furnaces, for, as the ordinary grate remains, steam can be raised with wood or coal; a coal fire can be made up and used should any mishap occur to the oil pipes or burners, and coal is always available if prices or supply are in its favour." In that way came the introduction and perfecting of the Holden burner.

quite as safe (he should not like to say safer), and much more convenient in the sense that (to quote his own words) "it is much easier to take it on board the tender, it gives no labour to the fireman, it gives him practically the whole of his time to look out for signals and to attend to other work on the engine, and it is very much more conveniently stored." He added—"Liquid fuel is so much more valuable for fast work that I use it almost exclusively for our fastest expresses. When we have to convey Royalty, or when we have any special function on, one always selects a liquid fuel engine; there is never any difficulty in maintaining steam and never any difficulty by reason of getting a dirty fire."

Asked if there was any smoke, he replied that if there was, it was because of the mismanagement on the part of the driver. "There is not the slightest reason why there should be any smoke," he added. At the time he gave this evidence Great Eastern engines were constantly running in and out of Liverpool Street, and the company had never been fined because liquid fuel engines made smoke.

The following questions were put to Mr. Holden—

You use, of course, all the tar that you make at your own works?—Yes, and we purchase a great deal. I purchase coal tar from country stations; I have used shale oil, furnace oil, creosote oil, and a good deal of astatki and Texas oil; I have used Borneo oil—anything in the shape of liquid hydrocarbon.

Do you mix them together?—It is very rare that one can mix them because of the different specific gravities.

Will they not mix?—No; if they are allowed to stand the heavier oil sinks to the bottom.

Do you use them indiscriminately or alternately?—We use the best for the best work. If we had Russian astatki or Texas oil we should certainly use that for our fastest and heaviest trains.

Do you find that, weight for weight, the liquid fuel has approximately twice the calorific value of coal?—That is so.

And that it can be advantageously used either alone or as an auxiliary to the coal?—Yes; for the last eight or nine years I have been using it in a very large way independently of coal. We use a small quantity of coal to light up, covering the bars with broken firebricks. We have a lot of firebrick *débris* from brick arches which are used in the fire-box of the engine. We crack them up, and, covering the bars with the pieces, we get an incandescent base quite sufficient to use the liquid fuel upon. I do not know that it would be necessary to do that if we had an assured supply of fuel, but I started with the assumption, and I still feel it incumbent upon me to assume, that I may be called upon at any moment to discontinue the use of liquid fuel and fall back upon coal in consequence of the market failing us.*

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* Mr. George Montagu, M.P., who made a trip on one of the Cromer expresses, said—"The economy in working will be realised when it is remembered that liquid or coal fuel can be used, either together or separately, so that, if coal is dear, liquid can be used, or vice versâ, and it is quite practicable, if required, to run an engine one day with coal and the next with liquid fuel. The importance of this fact cannot be over-estimated at times when the country is at the mercy of a great strike, such as it has undergone of late, when the price of steam coal has risen from 15*s*. to something like 30*s*. per ton. The market price of coal tar is 23*s*. per ton as against coal at 14*s*., but the average amount used per mile is only about 16lb. as against 30lb. of coal, so that it will be seen that the balance in

Mr. Holden said many years ago he used oil fuel on a ferry boat at Woolwich, but, unfortunately, the Board of Trade were so alarmed at the idea that they insisted upon surveying her twice a year. That was so inconvenient that at the end of five years he said they must either give them a twelve months' certificate or they would take her off. They refused to do this, and he took her off. Having so much difficulty with that little installation they never thought of applying it to the main fleet.

Does that cautious habit of mind still continue in the Department? Mr. Holden was asked.—I am not aware whether it does or not, my Lord, was his answer.

Might I ask a question with reference to the Fleet; did you happen to see in either the *Graphic* or the *Illustrated News* a picture of one of His Majesty's armoured ships propelled by liquid fuel?—Yes.

The picture showed that the air was enveloped in an enormous cloud of smoke as a consequence of the use of that fuel.* You saw that picture?—I did.

What do you think of that?—I thought that there had been some grave mismanagement to make so much smoke.

Either on the part of the engineer or the draughtsman? —I should not like to apportion the blame.

It might have been on the part of both, but it was a striking picture, we must admit?—Yes; of course, that

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cost is in favour of liquid fuel. Liquid fuel has other advantages, such as the maintenance of a clean fire throughout a long trip (no small advantage in fast running), and also clean tubes, and, last but not least, as I take it, a shorter bill for compensation to farmers for injuries to their crops."

* The photos of King Edward's new turbine (coal-fired) yacht show that when she ran her trials in March, this year, she was simply enveloped in clouds of smoke.

was taken from a photograph, and I presume it was *bonâ fide* smoke. I was rather thinking of the case of a locomotive, but it would not be so with a steamer; with a locomotive it depends upon whether you take your photograph from the light side of the issuing stream or from the dark side; if you took it from the dark side, of course, it would have all the appearance of smoke.

On a question of whether there is any danger with an oil-fired locomotive in the case of a collision, Mr. Holden said he rather thought there would be more danger with a coal-fired locomotive. He went on to explain that in the one case they would have a large quantity of burning coal, and in the other in all probability the fuel would be shut off; but if it were not, he did not think it would go on burning; the fuel itself, even supposing the tank was destroyed, would not burn except it was sprayed or heated up to a considerable temperature.

But, as a matter of fact, was not the bad Abergele accident due to oil? queried Mr. Le Neve Foster. Mr. Holden's reply was—" Ah, that was petroleum, practically an explosive spirit, the oil that is used for lamps, and we do not burn that in the engines.*

(The Great Eastern, North Eastern, London, Brighton

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* The question of the safety of oil fuel on the tender of a locomotive hauling a passenger train was frequently raised when it was thought that the Great Eastern intended to go in for oil on a large scale. Regarding the inflammability of oil fuel, the exact nature of the product used should be considered. The flash point (close test) approximates to 205° F., and the ignition temperature is very much higher. This high flash point practically guarantees the bulk from ignition, and it is only by atomising it and introducing atmospheric air that combustion can be promoted. A train was derailed on the main line of the

and South Coast, and other companies have all shown a desire to adopt oil as a permanent fuel for their locomotives. They only gave up the idea when they realised in 1902-3, just after Texas failed to come up to expectations, that the sources of supply were unreliable and the price in

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Transcaucasian (Batoum-Baku) railway at a point a few miles out from Baku and just where the train crosses a sandy desert region. The passenger cars were telescoped on to the tender with the fuel tank exposed, and yet there was no fire. When a coal-burning locomotive is in collision and derailed, sometimes the burning contents of the fire-box are thrown over the *débris* with more or less disastrous results. With an oil-burning locomotive the effects of the accident are considerably modified ; the shock of the collision and the almost certain snapping of the oil fuel pipe between the engine and the tender instantly extinguishes the fire, and, even if the oil fuel tank is damaged, the only trouble caused is the bespattering of the rolling stock with a heavy liquid which is practically non-combustible. When the Chief Officer of the London Fire Brigade conducted experiments with river and land steam engines to ascertain whether it would be advisable to use oil fuel in place of coal with fire brigade appliances, he reported that, although the economy was not so great as he anticipated, the advantages derived made it absolutely certain that it would be well for land fire engines at all events to be so constructed that oil fuel might be used. He found that the principal advantage was "that with oil fuel a working head of steam was obtained much more rapidly than with coal." The Fire Brigade Committee of the County Council reported—"The Chief Officer is desirous of using on the land engines low flash oil, because it is much better for the purpose than high flash oil. The latter is very liable to carbonise and the tubes consequently become clogged. The Chief Officer is of opinion that no danger will result to the men riding on the engines inasmuch as the fire in the engine is shut off by a tank from the reservoir containing the oil. Under these circumstances we consider that low flash oil may be used for heating purposes on fire brigade appliances."

no way fixed. Lieut.-Col. the Hon. H. W. Campbell, in the chair at a meeting of the London and South Western Railway, said the locomotive department had during the half-year of 1902 made some very careful experiments in the use of oil fuel for their engines. They were naturally anxious to see whether, so far as the working was concerned, the use of oil would be more economical than coal. The experiments satisfied the board that with oil and coal at the relative prices, the coal, so far as they were concerned, was most economical; but there was no doubt that oil might form a useful alternative fuel in the event of there being an alteration in the price of either article. It was just about that time that Mr. J. A. F. Aspinall fitted several Lancashire and Yorkshire locomotives with Holden's oil-burning apparatus for use on the Liverpool Dock lines, the chief object being to get rid of sparks and smoke, which were most objectionable and dangerous when the engines passed some of the Liverpool streets. The announcement was also made that the North-Eastern, with a main line system that reaches from York to Newcastle, and thence on to Scotland, had practically decided to employ oil as fuel instead of coal in a number of their engines; indeed, I believe, a start was made to lay down the necessary liquid fuel supply plant at the Gateshead locomotive sheds. Nothing came of it. If Newcastle—the industrial heart of the coal fields of the North—were to become the scene of a series of successful experiments in the use of oil it would exert an influence for good in connection with this industry that could not be equalled by the tests and performances of any other city. It would be a triumph of gigantic importance and significance for oil on the banks of the coaly Tyne.)

In the final report of the Royal Commission, and under the heading "Possible Substitutes," I find the following paragraphs of interest in a work of this description—

"For high powers on land and water, as well as for railway traction,* oil has for many years been used effectively and economically as a substitute for coal in steam raising, especially in Southern Russia, and this application of petroleum is rapidly extending wherever supplies can be obtained at a cost per ton not exceeding double that of steam coal in the locality at the time. The merits of liquid fuel are now generally recognised, and the only thing lacking is the assurance of an adequate and regular supply at a low enough price.

"For use in steamships the advantages of liquid fuel are marked. Weight for weight it occupies less space than coal, and when effectively burned has about double the calorific value. Moreover, it can be easily controlled, while there is a considerable saving in stoking and the bunkers can be replenished with ease and rapidity. Oil can also be used to advantage in conjunction with coal or with a base of inferior coal, lignite, peat, or wood.

"The employment of petroleum in internal combustion engines of the gas engine type is a comparatively recent

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* This being a chapter in which a great deal is said about oil fuel on locomotives, I may point out that it harmonises with the trend of construction, which is in the direction of building engines of higher boiler power. Oil is also especially adapted for use in electric current generation stations, and many who make a close study of the subject believe that in this country small branch lines will be worked by electrical locomotives operated from fixed generating stations, and it is being pointed out that there is no better means of generating electricity than by employing liquid fuel as the source of heat.

development. In their earlier forms oil engines were practically confined to the use of a highly volatile description of petroleum such as is now used under the name of petrol for motor cars, motor launches, and submarines. For stationary engines, especially of large power, ordinary petroleum or paraffin oil, such as is burned in lamps, has long since replaced the volatile products above referred to. The use of these heavy oil engines, as they are called, is rapidly extending, and the still more recent invention of Mr. Diesel shows that a very heavy oil, even crude petroleum, can be successfully employed as fuel in an internal combustion engine. To sum up, briefly, any description of petroleum products or crude petroleum itself can now be made available as a source of power, provided that suitable appliances are employed.

"There has been much disposition in recent years to speak of oil fuel as if it were a serious competitor of coal and a real substitute for it. The facts before us do not bear out that view. Sir Boverton Redwood in his evidence has given us a valuable account of the present and prospective sources of supply of petroleum and its allied products, and while he thought there was ample scope for energy and capital in searching for and opening up fresh sources of supply, he expressed himself very strongly against the possibility of any largely extended use of petroleum as a substitute for coal. He pointed out that the world's production of coal in 1901 was 777,000,000 tons, and that in the same year the world's production of petroleum was 22,000,000 tons, or only 2·8 per cent. of the weight of the coal.

"The conclusion we have arrived at as regards the use of oil fuel in this country is that which is expressed by Sir Boverton Redwood when he said, 'I think there will be certain selected applications of liquid fuel where the advantages of employing such a fuel are especially obvious, but for anything like general employment I cannot see where we are to look for adequate supplies.' Mr. Beilby was also very definite on this point, and he thought that no extensive use of oil fuel is likely to take place in this country, as the home supply is inadequate and the prices fluctuate too greatly; nor could he see how it would be possible to import oil in bulk at a price sufficiently low to compete with coal."

This Commission treated oil fuel as one of the etceteras of the Empire's great fuel problems. Before long we may expect to have a Royal Commission treating it as a subject of first importance owing to the fact that it has become an absolutely indispensable fuel in the case of the Navy. As an Imperial subject it is certainly important enough to be set down on the programme of the next Colonial Conference. After that we should be ready for a Royal Commission.

"THE proper design and construction of the furnace is of the very greatest importance in its effect on the efficiency of the oil-burning plant; and, just as the burner was found to be the key to the control and regulation of the fire, so the furnace more than all else determines the efficiency of the fuel combustion. The furnace design, therefore, will be controlled by the requirements for perfect combustion. And these requirements for perfect combustion are very simple. They are—that every particle of fuel shall come in contact with no more and no less air than it theoretically needs for its combustion; and that it shall come in contact with this air before it reaches a part of the furnace which is below the temperature of ignition. Therefore, there are three ways in which the furnace may fail of perfect efficiency:—

"1. It may supply to some of the fuel more air than is needed, wasting heat by increasing the temperature of air which does not take part in the combustion.

"2. It may supply to some of the fuel less air than is needed, thus allowing some fuel to pass up the stack unconsumed.

"3. The temperature in parts of the furnace where the air and the fuel come together may be below the temperature of ignition, which means that that fuel will be unconsumed.

"In designing a furnace, all these conditions must be carefully considered, and, if possible, fully met. The realisation of them is far less difficult with liquid fuel than it is with any form of coal, and the experience of the last few years has clearly demonstrated that perfect combustion can be very nearly reached with almost any burner, provided proper care is taken in the furnace design; and without this, I am convinced that it is impossible for any burner to burn oil efficiently in large quantity."

A. L. WILLISTON.

THE NAVAHOE.

TYPE of barge which may one day revolutionise the oil fuel transport business. Carrying huge cargoes of from 10,000 to 12,000 tons, they can be towed by tank steamers at the rate of ten knots, and the performances of the ocean-going oil-carriers of the Standard Oil Company show that they are economical and safe.

[To face p. 137.

# CHAPTER VI

OIL FUEL IN THE NEW CENTURY. EUROPEAN SURVEY IN PARAGRAPHS. BRITISH EXPERIMENTS, RUSSIA'S WASTE OF FUEL, AND ROUMANIA'S ENTERPRISE AT THE OIL PORT OF CONSTANTZA

THE evidence given before the Coal Commission, and summarised in the previous chapter, practically brought the business of production and distribution and the science of its employment up to the threshold of the present century. Before 1900 oil fuel had no real fascination for the shipbuilders and manufacturers of this country, and it was known that the Admiralty was averse to its adoption on anything like the lines followed by Russia, France, Roumania, and even Italy.

With the advent of the century, however, there came a decided change in the attitude of the Admiralty and those interested in the engineering branch of the mercantile marine. Makers of American burners sent the extravagantly-worded literature of their trade across the Atlantic, the daily papers started to give the subject a first-class news value, oil men were interviewed regarding developments in the Texas oil fields, and papers were read before several of the technical societies. The subject grew in interest, particularly when the old Shell Company put into the controversies of the first two years of the century a mass of useful data worked up by those who were responsible for the introduction and use of the new fuel on many of the steamers. Practically all the history written around oil fuel takes its best facts from the performances of the tank steamers of this company. The Shell steamers and Texas gave oil fuel its first boom this century; the British Admiralty has done even more than this: it has made it an engineering success in the Navy.

For several years, chiefly during 1900-3, it was the custom of the Shell Company to use their oil-burning steamers for exhibition purposes; they did this in all parts of the world with most gratifying results, and it is generally acknowledged that in this way they greatly increased the popularity of the system amongst ship-owners, engineers, and others.

The company met with a certain amount of expert opposition. When the Strombus was launched she was expected to steam ten knots on a liquid fuel consumption of 21½ tons per day, a result which a number of well-known anti-oil engineers declared to be impossible, and the confession must be made that few, if any, oil-burning steamers have come up to this expectation of so high a percentage of advantage. As a matter of fact, the daily consumption (Texas oil) of the Strombus was 28 tons against 40 tons of coal. The Shell Company went on and did still better work, much of which is described in Oil Transport.

I recall the fact that the Bullmouth—one of the medium-sized oil-fired and oil-carrying steamers owned by this company—was used for exhibition purposes at Hull Docks in 1902. On the Sunday and the Bank Holiday of that year the crowds which inspected her contributed £20 to a public charity. She was also visited by a company representative of the trawling and shipowning interests of the chief port on the Humber.* The interesting and highly instructive character of the proceedings was the result of the excellent local arrangements made by Messrs. Sanderson and Company, local agents of the Shell Company, Captain Stratton, and the firm's representative, Mr. M. S. Abrahams, who explained the engineering features of the steamer.

There are about 1,000 steam trawlers sailing from Hull and Grimsby, and the Hull fleet alone consumes 500,000 tons of coal annually. This represents a huge business transaction between the owners of the steam trawlers and the Yorkshire colliery proprietors, and it is not difficult to see that if liquid fuel is used on the trawlers trading on the fringe of the south-eastern coal fields of Yorkshire there are few places in this country where it will be likely to fail. Steam coal is cheap in Yorkshire, cheaper even than it is on the Tyne or in South Wales.

Going down the Humber, the company paid a

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* Present: Mr. John H. Robins, British Steam Trawling Company, Ltd.; Mr. E. B. Cargill, Cargill Steam Trawling Company; Mr. L. Spring, Kingston Steam Trawling Company; Mr. John Watson, St. Andrew's Engineering Company; Mr. Jas. L. Read, Earle's Shipbuilding and Engineering Company; Mr. W. Townhill, Cooper Company, engineers; Mr. Walter Scott, A.C.A.; Mr. J. G. Runton, superintendent engineer, Humber Mutual Insurance Company; Mr. H. McInnes, superintendent engineer for Messrs. G. R. Sanderson and Company; Mr. G. Mills, Great Central Railway, Grimsby; Mr. R. Innes, analyst, Mr. R. L. Kemplay, Mr. W. B. Marshall, and Mr. Parker Brackenbury, Hull; Mr. A. Greaves, surveyor, and Mr. F. W. Hobson, Hessle; Mr. Abrahams, Shell Company; Mr. E. R. Cockrill, Messrs. Flannery, Baggallay, and Johnson, superintending engineers to the Shell Company; Mr. J. D. Henry, London, and other gentlemen holding representative positions on the Humber.

preliminary visit to the stokehold. A Chinese assistant had charge of the oil fuel burning apparatus, and the scene in the stokehold, where there was no dirt or commotion, was very different from the noisy and dirty spectacles witnessed in an ordinary tramp when she is steaming down a busy river. There was practically no noise, and the company could hear plainly everything Mr. Abrahams had to say. It was not claimed for the Bullmouth that she was a smokeless burner of oil. Her furnaces, built for coal, were too short, and the results were not so satisfactory as those secured on board the latest oil-burning vessels built to consume oil without making black smoke.

Mr. Abrahams, questioned on this point, explained that at the start of the run, after the fires had just been lighted, the furnaces were not thoroughly hot, and the combustion was not perfect. He also offered the original explanation—far from surprising to any one who has entered a stokehold with a crowd of visitors—that the Celestial fireman in charge of the burners was sometimes tempted to display his industry and knowledge of the job by "tinkering about" with the valves. As a matter of fact, the valves, once set by the engineer, should require no further attention until the steamer reached port, but it was not even then claimed for the Bullmouth that she was a perfect up-to-date job, though her success as an oil-fired steamer has been most gratifying to the owners from a financial point of view.

When off Grimsby a second visit was paid to the stokehold, and the company had an opportunity of seeing oil fuel burned with the engines going at varying speeds. Through the small apertures in the furnaces it could be seen that the fierce white heat glowed over the entire surface of the boilers, and that the heat action was not only great and steady, but that the evaporative efficiency of the burners appeared to be of the most perfect description.

Mr. Hollingsworth (chief engineer) told me that on the voyage from Kurrachee the vessel had consumed a little over 17 tons of liquid fuel a day against 33 tons of Indian coal. Besides this, the speed was faster, the pressure being as good as with the best Welsh coal. The substitution allowed them to dispense with ten firemen, although the engineers had slightly more to do. One of the greatest advantages was that with liquid fuel there was no cleaning out of fires, and in that way not a second was needlessly lost on a voyage. The heat was much steadier than with coal, and this enabled the vessel to travel at an average speed of 10·6 knots an hour, or two knots faster than vessels of the same class using coal. On the voyage from Kurrachee they encountered all the trade winds and some very bad weather, whilst from Gibraltar it had blown a gale, with high seas and head winds. In spite of all this they had accomplished the journey in twenty-eight days, instead of the thirty-one usually taken by steamers in this trade, and had beaten the Birdoswald, from the same port, by twelve clear days, while the Caspian, which left Kurrachee four days before them, had not arrived.

Asked at what speed they could take in liquid fuel as compared with coal, Mr. Hollingsworth said the rate of oiling differed at various ports, but at Port Said, the quickest oiling port, they could oil at the rate of 100 tons an hour. They could discharge a cargo of 5,500 tons in 16 hours. Their fuel supply lasted twice as long as coal was carried in less space, and they were not bothered with having to stop to clean fires.

Introduced by Mr. Abrahams, Mr. J. D. Henry, the only other visitor from London, gave the company a number of facts about the Texas, Russian, Borneo, and other oil fields. On the question of the supply of liquid fuel, he described the discoveries at Spindle Top, and the opening out of Sour Lake, Saratoga, and other oil-producing areas in Texas and Louisiana. He bore testimony to the keen character of the search that was being made for new oil fields in different parts of the world. If the power of oil fuel to raise steam had not been so widely acknowledged as experts thought it ought to be, he certainly considered it would ultimately secure a position of supremacy amongst the fuels of the new century. He regretted that the company were not on board one of the largest vessels of the Shell fleet; on one of these, he said, they would have seen a system of steam production practically beyond criticism, being financially satisfactory to the owners, mechanically reliable under all conditions, free from smoke, and suitable for both large and small as well as for fast and slow vessels in both the Navy and the mercantile marine.

Mr. Abrahams went into the details of the construction of the oil fuel burning apparatus in a manner seldom attempted on an occasion of this kind, and there was no point raised by any of those present that he did not discuss in a most thorough manner. One of the important points raised had to do with the application of oil to the furnaces of steam trawlers. It would be possible, he said, to equip any trawler with an oil fuel tank, and if the tanks were not built into a vessel they could be lowered into her without any great difficulty. Fuel oil in trawlers could do no damage to the iron work; in fact, it would act as a preservative, and in the event of any of those present wishing to use the coal bunker space it would be possible to make them oil-tight by means of strapped seams. The diameter of the pipe used to convey the oil depended on the quantity of the oil which they wished to use. In the Bullmouth he thought the pipes were 1½ in. Crude oil, when burned, left no sediment, and every particle was consumed. They got a third more work out of the furnaces than they did under coal; they could work the Bullmouth with two boilers, and get the same speed as with coal, whereas if they worked the three boilers they steamed 1½—2 knots faster. Oil fuel gave them a spare boiler. In their first boats they had a great deal of trouble, but that was due to the inexperience of the engineers. Answering further questions, Mr. Abrahams said the life of a boiler was increased by seven years by the use of liquid fuel.

Mr. Cargill, speaking as the vice-chairman of the gathering, thanked the Shell Company for giving them such an excellent opportunity of viewing an oil-carrying vessel like the Bullmouth. Along with the other Hull gentlemen present he represented a very large and growing industry. They claimed to be progressive, and what they had seen had set them all thinking more than they had hitherto done—indeed, he felt that the result of their investigations would be the conversion of some of their trawlers into oil-burners, and they would have nothing to regret if it brought down the price of coal.

Mr. Abrahams said what they had learned he hoped they would think over when they returned to Hull, and that they would, as practical men, be so enamoured of the new fuel that they would ask his company to build the necessary reservoirs for the storage of oil to supply the steam trawlers trading from Hull and Grimsby. Those present represented a number of progressive commercial enterprises, and if they could see their way to do business which would be mutually advantageous to them as business men, and beneficial to the port of Hull, he knew that Sir Marcus Samuel, acting in the spirit which he had displayed ever since he started the business, would gladly give them the same benefits which others had derived from the building of tanks in the Far East and at other places nearer home. Liquid fuel was a successful steam-raiser from a money point of view, and gave better results than coal. They must not think that they used liquid fuel merely as an advertisement; they used it in their vessels because it was an economical commodity. They had to pay for it no matter whether they got it from their own extensive fields in Borneo or from oil fields in other countries. They had to buy and transport it in their own steamers to the centres of industry, and they would be only too glad and ready to foster a trade for liquid fuel at Hull and other places on the Humber.

Mr. Robins thanked Mr. Abrahams and Mr. Henry for their information. Some of them believed liquid fuel had come to stay, and the fact that so many had gone off in the Bullmouth on Coronation Day showed how deeply they were interested in the subject.

The Hull steam trawlers are still coal-fired, and here again, I fear, it will be many years before oil fuel will be sent to the Humber at a price and in sufficient quantities to compete with the product of the Yorkshire coal fields, although I am personally aware that certain oil men in this part of the country think that the ideas of 1902 will be realised, not only in the case of the Humber, but also in the case of the Tyne and some of the rivers further north.

If the price can be brought down (and this can only be done on a reasonable transport freight) and the sources of supply multiplied, there is no reason why some of these early predictions about the ousting of coal should not be realised in the case of the mercantile marine, in some parts of the British Empire at any rate.

During the years covered by this chapter numerous new burners have been invented, some of the old standard makes have been greatly improved, and quite a number of eminent engineers are at work on ideas to use oil fuel in conjunction with the turbine on fast warships and liners.

Russia, which gave us the first lessons in liquid fuel burning, has not made progress this century. My readers will have formed the opinion that it is impossible for any one to correctly gauge the oil fuel situation in that country at any particular time. The industry has in it inherent evils of artificiality, secret dealings and Government pipe line and railway anomalies. In a work entirely devoted to the history of the progress of the Russian liquid fuel industry one might be able to set forth in orderly fashion the mysterious methods of marketing and the scientific principles of its utilisation for a large variety of purposes all the way from Baku to St. Petersburg; but in this work, in which I have to take a world-wide survey of the subject, I am prevented from embodying more than a few of the numerous interesting and important facts about the great liquid fuel industry of Russia.

There is, and always has been, a great wastage of oil fuel at Baku. The prodigality of Baku managers and workmen in the matter of the natural products of these famous fields is proverbial, and it was just this fact which told against British-made burners when an attempt was made to introduce them into the Baku fields six or seven years ago. They saved oil and gave better results than the Russian burners, but, then, Baku is the one place on earth where economy of fuel counts for practically nothing. The annual consumption of oil fuel in the Baku fields—that is fuel used in running the industry—reaches some 2,000,000 tons, worth some £2,500,000, and it has been shown by Mr. A. Guchmann, well known for his able work at the International Congresses and contributions to Russian oil literature, that the annual wastage, due to negligence, is, in money value, several hundred thousand pounds. It has been asserted by this authority, corroborated by Mr. Pogosoff, Mr. Khatisoff, and Mr. Piterski, that a saving of 30 per cent. would be possible without remodelling the methods of consumption and merely by a more intelligent handling of the oil and the burners. Imperfect combustion, resulting in the day-and-night escape of dense clouds of smoke, and a reckless wastage of oil at the points of storage, cost Baku £500,000 a year. In numerous instances there is no proper regulation of the air and the many different burners at work are neglected and roughly handled, while many of the furnaces are defective in construction, imperfectly designed, and, frequently, of a tumble-down description. Many of the furnaces have been described as "eccentric and wasteful," while in those cases where something like perfection of design exists the workmen are neglectful and the fire-boxes are kept in a dirty condition.

I mention these facts, peculiar to Baku, for a purpose; they provide us with one more reason why we should despair of ever seeing Russia develop a large foreign export trade. Russia has no ambitions in the direction of supplying cheap fuel for non-producing countries, and, of course, the nature of her home markets makes it impossible for our British-owned companies to independently organise a fuel oil export business. There was a time when some of us thought it would be reasonably sound business to put liquid fuel f.o.b. Batoum at 20s. per ton. That is out of the question to-day, when this figure is less than that charged for the oil at Baku, and when a new set of conditions makes it impossible for oil men to take advantage of the improved tank car facilities on the Transcaucasian Railway resulting from the completion of the Baku-Batoum pipe line.

In an earlier chapter I have referred to the possibility of Russia supplying her own men-of-war and mail steamers on the Black Sea with liquid fuel, and my references to the imperfectly developed state of the liquid fuel branch of the industry are only intended to show that the country is not in a position to materially assist in the solution of the problem of the supply of the world's markets. The oil fuel of Russia cannot, for commercial reasons, and, also I should say, for labour reasons, flow over the Transcaucasian tariff wall (constantly moving, but always in the region of 14 copecks per pood) into this or any other foreign market.

Neither our Navy nor our mercantile marine can reckon on the oil fields of the Apscheron Peninsula for liquid fuel supplies even in peace times, and in using the word "peace" I perhaps ought to explain that I intend it to apply in both a local political as well as in an international sense.

Moreover, the Russian business is made dangerously unreliable by the quick changes of market prices. The fluctuations frequently paralyse the inland oil fuel business.* In

* "A factor that one can never be sure of is the treatment meted out by the Russian Government. They will raise the transport rate when one least expects it."—Sir Marcus Samuel.

the eighties astatki was cheap; if it had been permanently cheap it could have been put into competition with coal in almost any country in the western part of the world. Below I give the astatki prices of a year in the eighties, 1894, and those of last year—

| 1894. | | | | 1907. |
|---|---|---|---|---|
| January | $2\frac{3}{4}$—3 | copecks | ... | 23 |
| February | $2\frac{3}{4}$—$3\frac{7}{8}$ | „ | ... | $25\frac{1}{4}$—$25\frac{3}{4}$ |
| March | 3 —$3\frac{1}{2}$ | „ | ... | $26\frac{1}{4}$ |
| April | $3\frac{3}{4}$—$4\frac{1}{2}$ | „ | ... | $26\frac{3}{4}$ |
| May | $3\frac{1}{4}$—$3\frac{7}{8}$ | „ | ... | $27\frac{1}{2}$ |
| June | 4 —$4\frac{3}{4}$ | „ | ... | $30\frac{1}{4}$ |
| July | $4\frac{3}{4}$—5 | „ | ... | $31\frac{1}{2}$ |
| August | $4\frac{1}{4}$—$4\frac{3}{4}$ | „ | ... | 32 |
| September | $4\frac{1}{8}$—$4\frac{1}{2}$ | „ | ... | $32\frac{1}{4}$ |
| October | $3\frac{3}{4}$—5 | „ | ... | $31\frac{3}{4}$—$32\frac{1}{4}$ |
| November | 4 —$4\frac{1}{2}$ | „ | ... | $23\frac{1}{2}$ |
| December | 5 —$5\frac{1}{4}$ | „ | ... | $24\frac{1}{2}$ |

These prices show that a Russian supply of oil fuel for this country is out of the question, and the Roumanians, who make a close study of the Russian situation, expect to make capital out of the troubles of their Caucasian competitors.

Nevertheless, when we come to the question, can oil fuel be used on steamers? Russian experience and practice provide us with the answer. It is only necessary to take a journey on the Volga or Caspian Sea to be able to give a most emphatic affirmative answer. There the engines are managed by engineers, their assistants and stokers, of whom, according to the late Admiral Mikaroff, hardly 54 per cent. have received even a superficial technical training, while others are only turned into engineers in the stokeholds of the vessels. Amongst the number there are about 13 per cent. who are entirely illiterate. Still it does not matter; somehow everything works smoothly on the Caspian Sea. Into the hands of these men are entrusted the powerful, complicated, and expensive engines of passenger steamers and the lives of hundreds of passengers. From this it is easily seen how well they have been able to adapt oil fuel to the firing of Volga and Caspian steamers, and also how simple is the application of liquid fuel when the question of cost is not of vital importance.

Roumania takes a well-sustained interest in oil fuel. It would probably be possible to say the same of Galicia if that country of magnificent oil fields had better transport facilities and ports of shipment. Roumanian oil men have long contended that any disadvantage arising from the high price of oil fuel, due to a huge home consumption, should not be allowed to militate against its adoption for naval purposes. A high authority in that country recently gave me some forcible reasons why liquid fuel should be substituted for coal on the warships of this country. He said—"With oil fuel we would get invisibility at sea by reason of our torpedo boats using smokeless oil, rapidity of steam raising, quick and noiseless oil bunkering in the roughest sea and on the darkest night, and many other advantages arising out of the ease and safety with which liquid fuel can be handled, to say nothing of the undoubted humanitarian advantages which would spring from the abolition of the hardships of the stokers when our ships are rolling in a heavy sea or steaming in tropical climates."

Roumanian shipowners were induced to devote attention to the subject by the successful employment of oil fuel on

British tank steamers. The Emilia was the first vessel flying the Roumanian flag to abandon coal in favour of oil, and her success gave the Roumanian Service Maritime Company the lead which they required to test its merits on the nineteen-knot twin-screw passenger steamer Regele Carol I. This vessel has engines of 6,500 i.h.p. Running between Constantza and Constantinople, she beat her records with coal, and what is known as the Wolff pulveriser gave most excellent results. Working with half oil and half coal (separate boilers) it was found that the steam pressure could be maintained with the greatest ease, and she attained a higher speed than was secured when she burned coal exclusively. It was found that from 60 to 80 tons of oil took her from Constantza to Constantinople and back, whereas when she burned Westphalia coal the consumption was 150 tons, and, of course, to this obvious advantage we must add the important one of a reduction in the working staff. It must be admitted that the failure of Roumania to use oil fuel on a large scale is a somewhat telling argument against its adoption in a country like Great Britain. The reason, however, as I have already pointed out, is found in a large and increasing inland consumption. One cannot refer to this phase of the Roumanian oil fuel question without remembering that the oil fields of the country are possible contributors to the liquid fuel needs of the world. If up to the present the exports of Roumanian residuum to this country and different parts of the Continent have not developed on a large scale we find a reason in the fact that, in addition to the inadequate transport facilities, there has hitherto been an insufficiency of storage accommodation at Constantza. In the past it has been commercially impossible to make shipments of residuum in bulk. Now, however, the Government, recognising the importance of foreign markets, is building a number of up-to-date tank storage installations, and I am informed by the head of a leading company in the country "that there is every prospect that during this coming autumn the port of Constantza will possess the necessary facilities for storing and shipping large quantities of residuum."

If the fuel oil industry of Roumania has not made any real progress since the beginning of the century I should say that there is every prospect of some exceedingly interesting developments taking place in the early part of next year, when a real attempt will be made by some of the leading companies to make regular shipments of oil fuel.

In this Chapter of fragments showing the attitude of foreign Governments towards oil-burning the case of the Dutch Navy must not be overlooked. During 1901, when an oil torpedo destroyer was permitted for the first time to take part in the British naval manœuvres, the Dutch torpedo boat Ophir, built at the Jarrow shipyard, proved "that oil was a brilliant success as a supplementary fuel." Running on coal she did 24½ knots, but when Borneo crude (Holden burners) was added, her speed was increased by two knots. But here again we have a case where the naval authorities have not adopted oil to any great extent, although the country has some of the most prolific oil-yielding Colonies in the world.

What Germany does with oil fuel must always be of interest in this country. Not only has she oil fields of her own—fields which have been visited by the Emperor and in which he is known to take a very keen interest—but at the present time she can get oil from foreign sources with greater ease and at less cost than ourselves. Until this year the German Navy did not favour oil fuel any more than the navies of other European powers. That is fortunate—for us, certainly; but it is just as well not to overlook the fact that the latest German armoured cruiser will get her great speed of twenty-four knots by using turbines developing 44,000 h.p. and burning oil fuel as well as coal. Germany will follow the example of Great Britain and use oil fuel in her navy.

Take the case of the Italian Navy at the beginning of the century. At that time Signor Charles de Grave Sells (Messrs. Ansaldo and Company) and other Genoese authorities were able to declare "that it was the only navy that had adopted oil fuel throughout and had standard burners and fittings." The Italian naval authorities had all the advantages of a good start and they were able to adopt it with every hope of success, because as far back as 1890 they conducted a series of trials which proved that oil could be used with advantage in the furnaces of warships. Several torpedo boats were equipped to burn oil fuel, but in the case of a number of large vessels it was used in conjunction with coal, and the acknowledgment was officially made that the only reason why the system was not adopted throughout the fleet was because there were no large oil fields in Italy and experts feared that in the event of a declaration of war foreign fuel supplies might be cut off at the moment when they were most needed.

Concerning the naval experiments of that time, Signor Sells wrote—"In the smaller vessels with oil fuel exclusively an increased power was obtained with a relatively smaller consumption of fuel, the work in the stokehold was easy, and the speed could be maintained for any length of time. Two or three hours was the limit at which a torpedo boat could be run at full speed when fired with solid fuel." The increase of power in some of the older ships, when oil was substituted for coal, amounted to as much as 25 per cent. He also stated that "an immense advantage had been found to result from the change," in that "in larger installations the stokehold staff could be considerably reduced."

At the present time the Italian Navy has its own colliers, which run regularly to Bristol Channel ports for Welsh coal for the fleet. I learn on high authority that the naval authorities, seeing that the British Navy has secured Fleet auxiliary tank steamers, will shortly purchase or build a large steamer to carry American and Russian oil for the oil-fired warships and Government-owned oil depôts ashore. The Italians are practically following the lead given by the British Navy.

No country on this side of the Atlantic is really pushing oil fuel for mercantile marine purposes, and its progress is limited to its great and increasing use on railways. The lesson we should learn from the European situation is that, in the matter of oil fuel, the future belongs to the Empire with the greatest number of widely-scattered and sparsely-populated islands on which it is possible to produce and store supplies for the Imperial Navy and the industrial needs of the Mother-country and her Colonies.

AN enormous future lies before this fuel, even if it only depends upon its relative cost compared with coal, but when we come to the collateral advantages it enjoys, the benefits of using it, as compared with coal, are simply overwhelming. The first great advantage to vessels of war, especially to torpedo boats, in using liquid fuel, as compared with even the best coal, is *the entire absence of smoke arising from its employment. When combustion is complete, not a trace of smoke issues from the funnel of a vessel using it. How important this is to torpedo boats the least initiated can understand, but it is not less so to cruisers, or even to battleships, which, when using liquid fuel, could shadow an enemy's fleet without being detected.*

SIR MARCUS SAMUEL, Bart.

IF the manœuvres of 1906 did nothing else, they at least demonstrated the importance of speed in battleships as well as in cruisers and the value of liquid fuel. The main point to be borne in mind is that in the circumstances laid down by the Admiralty, Admiral May captured a considerable quantity of shipping, that he drew the whole of the British force away from the British Isles, and then turned and passed up channel, leaving Admiral Wilson's great fleet, twice as strong as his own, far away in the Atlantic. He had time to work his will, as he circumnavigated the British Isles, and having far superior speed to the British ships and plenty of fuel—coal and oil—could have got back to his base at Berehaven, and with the three battleships dropped in the chase, but not captured, he would have been free to begin the game afresh.

*Daily Telegraph* correspondent in *H.M.S. King Edward VII.* (oil-fired).

# CHAPTER VII

## WESTWARD HO! OIL FUEL ON THE ATLANTIC AND IN AMERICA

HAVING discussed new century developments in the Eastern Hemisphere, I come in this chapter to the subject of the possible use of oil on Atlantic passenger steamers and its increasing popularity in different parts of America.

It has not been employed on the Atlantic because companies have been unable to secure supplies at a reasonable price on this side, and the owners of passenger steamers are not convinced that the plan of bunkering in American ports for the round voyage has the remotest chance of being worked to their financial advantage under present conditions.

A number of the Belgian and German steamship companies took a practical interest in oil fuel seven years ago, when it was thought that its adoption on a commercial basis was possible. Unfortunately, the result of its employment in the Transatlantic passenger trade was discovered to be a financial failure, sufficiently serious to necessitate its rejection and the reintroduction of coal. On the other hand, the steam-raising results were highly satisfactory. As a matter of fact, the merits of oil fuel were not in doubt seven years ago, because fifteen years before oil-fired vessels were successfully employed in the Atlantic trade.

In 1902 much interest was taken in the trips made by the C. Ferd. Lacisz, Segovia, and Sithonia, owned by the Hamburg American Company. In the case of two of these steamers the results * of the use of oil were—

| | System. | Oil per i.h.p. per hour. lb. | Coal per i.h.p. lb. | Heating Surface. sq. ft. | I.H.P. | Percentage of gain by use of oil. |
|---|---|---|---|---|---|---|
| C. F. Lacisz | Korting | 1·408 | 1·93 | 7,560 | 2,200 | 27 |
| Sithonia . | Howden | 1·065 | 1·49 | 6,924 | 2,500 | 28·6 |

We also have the testimony of Mr. C. A. Griscom, of the American Line, that when the Kensington went from Southampton to New York on oil fuel her performance was quite satisfactory.

Quite a number of calculations have been made to show what an immense saving there would be if oil were adopted in the record-breaking leviathans of the Transatlantic passenger trade. Mr. Ernest Foerster, speaking recently at the Technical High School, Charlottenberg, Berlin, warmly advocated its use on the modern mail steamers of the Fatherland. One calculation made by this authority was that in the case of the Deutschland twelve engineers and forty-eight stokers would be a sufficiently large staff if oil were used. The present staff consists of 180 men. Instead of carrying 1,287 passengers the vessel would have accommodation for 1,619.

Since the Lusitania and Mauretania have been placed in the Atlantic service a number of speculative estimates have been prepared in connection with the suggested use of oil fuel in the world's greatest passenger steamships. One of

* By Mr. Orde in the Transactions of the Institution of Mechanical Engineers.

the most interesting calculations has been worked out by Mr. Kermode. Taking the case of the Lusitania, he says the 192 stokers and 120 coal-trimmers would be replaced by 27 intelligent men of the greaser class, while a water attendant and a burner tender per stokehold per watch would meet all needs, and there would be accommodation for, say, an additional 250 third-class passengers. Some 600 tons of oil fuel per day would accomplish more than the 1,000 tons of coal per day now used, and 2,000 tons less fuel would be necessary per trip from land to land.

Presumably the Lusitania carries coal for the round trip, and in that case 4,000 tons less fuel might be carried if oil were used, and the cubic space represented by this saving of weight could be utilised for cargo and the earning of dividends. This would be the result if the vessel utilised her present bunkers for oil fuel; but, as a matter of fact, the oil could be carried in her double bottom, serve as ballast, and preserve the trim of the ship, because as one compartment was emptied of oil fuel sea water could be admitted. In that way the existing bunker space could be made available for cargo.

The Lusitania has 192 fires to produce 68,000 i.h.p., and on the assumption that 32 fires are cleaned every watch, it will be seen that about 10,000 i.h.p. is lost every four hours through the operation of burning down and cleaning fires alone.

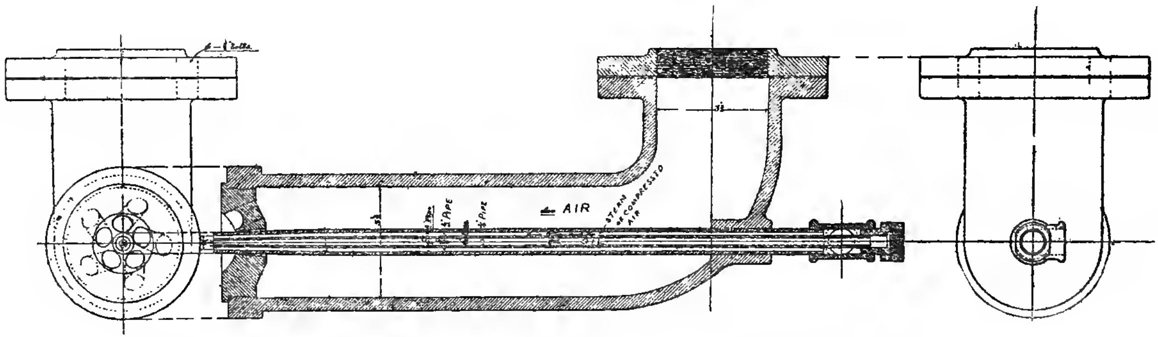
Mr. Kermode considers that irregular stoking accounts in some cases for as much as 10 per cent. loss of steam throughout a voyage, and, added to this, there is the steady lowering of the efficiency of the boilers through soot deposit in the tubes.

Liquid fuel and automatic stoking would ensure steady steam from land to land. From an approximate estimate of the several factors which go to determine a quick voyage, it is safe to say that the use of oil fuel would diminish the time of a single trip by eight hours.

It takes 35 men two-and-a-half hours to put 80 tons of coal on board a liner from lighters. As against this, a steam pump can put 300 tons of liquid fuel aboard in one hour, silently and cleanly. The whole army of lightermen, coal-heavers, firemen and coal-trimmers, the bane of an engineer's life, would be dispensed with for sea-going purposes and could find more congenial employment under better conditions of life by handling the extra cargo that the ship would land on every voyage.

It is only too clear that oil fuel will not replace coal on first-class passenger steamers for a number of years; it will be prevented from doing this by the foolish timidity of inexperienced passengers, the unreliable and limited character of the foreign fuel oil markets, and the aversion of the companies to risk a loss of patronage by making an innovation the advantages of which, while they may be obvious to the managers and engineering staffs, are not seen by ordinary passengers. The situation is a curious one. Oil can do the work better than coal, but there is not enough of it to justify its permanent adoption by the great passenger steamship companies of the world, excepting in such cases as California and Japan.

Of all the exclusive information that I have succeeded in collecting for this work, none is so strikingly convincing as the results of the running of the Col. E. L. Drake and Captain A. F. Lucas (two oil-fired steamers owned by the Standard Oil Company) on the Atlantic coast. From the time these vessels were launched (the Drake in 1903 and the Lucas in 1904) up to the middle of last year the results with oil fuel were extremely




One of the first devices for burning petroleum, used by Standard Oil Company.

satisfactory. Running between New York and Texas, at which point they were able to secure it at, approximately, 25*s.* 3*d.* ($6.30) (with coal at $5 per ton), these steamers were operated on oil fuel. They gave considerably better results than with coal. Not only was there an increase of 10 per cent. in the speed, but the oil fuel did not in any way damage the boilers. The stokehold staffs were reduced from 15 to 4 men in each vessel, and practically the one and only disadvantage was discovered in (and I am quoting a high authority) "the initial necessity of educating the engineers in the economical use of oil fuel." Last year oil was abandoned owing to the increased cost of the fuel at the Gulf ports and the lower cost of coal at Northern Atlantic ports.

Here I come to an interesting fact which illustrates the now familiar point that when a vessel is trading near an oil region coal cannot possibly compete. When the Drake was recently sent to trade on the California coast she burned oil with every possible advantage. The favourable conditions at San Francisco will be seen from the following figures—

| | Per ton. | |
|---|---|---|
| Fuel oil costs . . . | 28*s.* | ($7) |
| Coal ,, . . . | 40*s.*—44*s.* | ($10) |

The reason why it is found to be cheaper to run the Lucas on coal in the Transatlantic trade (and the vessel is now engaged in towing oil-carrying barges between New York and this country) is shown by the following table—

| | New York. Per ton. | United Kingdom. Per ton. |
|---|---|---|
| Oil | 33*s.* 8*d.* ($8.40) | 41*s.* ($10.20) |
| Coal | 12*s.* 8*d.* ($3.17) | 10*s.* 6*d.* ($2.61) |

While oil fuel is very much cheaper at New York than it is in this country it does not pay to take it on board for the round trip, as it displaces an equal quantity of cargo on which the vessel loses freight. The performances of these Standard steamers, while they prove that oil does not damage the boilers, that there are none of those rapid changes in furnace temperatures encountered when coal fires are being cleaned and that a material saving is effected in grate bars and fire tools, show that the economical use of oil fuel is only possible at those points where oil is readily obtainable and coal is comparatively scarce.

In the chapter dealing with the opposition of Rear-Admiral Evans to oil fuel I have made it clear that the Pacific Coast provides us with an excellent example of what oil is capable of doing in a region of its origin. California has the largest fleet of oil-fired steamers, more oil-burning locomotives than any State in the country, and the largest oil-fired locomotive.* The oil and coal prices which I have just given prove that there is no place on earth that can beat it for cheap oil fuel markets. Oil fuel is the premier branch of the petroleum industry of the State. Although oil has been known to exist since the early fifties, there were no developments of any consequence until twenty years later, when the Pacific Coast Oil Company, the parent concern of the present Union, struck oil in Ventura County and ran it through by pipe line to the coast, where it was shipped to San Francisco.

The real father of the oil fuel business in the State was Mr. Doheny, who, in 1892, drilled a large number of wells

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* This oil burner draws the Owl special between Los Angeles and Bakersfield, two of the greatest oil cities in the State.

in and around Los Angeles. He pioneered the industry which gave the chief oil city of California nearly three thousand wells in the first few years of its existence.

Obviously, the marvellous growth of the oil fields of the State does not make suitable material for this work, but there is no reason why it should not include the interesting statement that, although California has produced 197,000,000 barrels of oil to date, pumping 35,000,000 barrels in 1907, and promising to increase that output this year by 6,000,000 barrels, geologists and oil experts declare that the development of its petroleum fields has just begun. Great schemes are on foot for the development of vast tracts of oil land, and American and foreign capital is being freely put into various new enterprises. During the past few years British capital has done exceedingly well in California, and there is no reason why our companies should not share liberally in the increasing prosperity and extension of the oil fuel business of the Pacific Coast.

Thirty-two refineries are in actual operation in the State, and oil as a fuel is as valuable to the Pacific Coast as the coal fields are to Pennsylvania. Steamships, railways, smelters, machine shops, gas works, water works, brick kilns, lime and cement factories, down to the kitchen range, are run with oil. Local practice shows that as compared with coal oil only takes up 51 per cent. of space, while a single fireman with oil will do the work of eight coal stokers and passers.*

The distribution of oil to the manufacturing and industrial enterprises of the coast is provided for by three large pipe line and transportation companies, whose combined

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* *The Oil Industry*, Los Angeles.

investment in pipe lines, tank steamers, and storage facilities aggregates over £20,000,000.

The Santa Fe Company, as the result of a long series of carefully made tests, has found that a ton of coal will run a train 26·7 miles, while a ton of oil will run it 38·46 miles. In the matter of cost the advantages are also on the side of oil. Take, for instance, oil at 4*s.* 8*d.* per barrel as compared with coal at £1 9*s.* per ton, that being about railway price. Six barrels of oil (42 gallons to the barrel and 8lb. to the gallon) are equal to one ton of oil, making, at 4*s.* 8*d.*, £1 7*s.* 9*d.* per ton against £1 9*s.* for a ton of coal. But, as a train can be run on a ton of oil 12·39 miles farther than on a ton of coal, the cost of the oil is practically brought down to 19*s.* 6*d.* per ton.

The advantages of oil do not end here. A large engine tender can carry eight tons of coal, which, at the rate of 26·7 miles per ton consumed, will run a train 213·6 miles. As oil only takes up 51 per cent. of the space the same tender will hold 16 tons of oil, which, at the rate of 38·46 miles per ton, would run the same train 615·36 miles. It is these results which have led the Santa Fe to use oil on all its lines in California, and similar tests by other railways and manufacturing firms have been productive of equally satisfactory results.

Californian oil statistics are amongst the best and most reliable published, and I should say that there is no State that has produced so much information in support of the efficiency and economy of fuel oil. The State Mining Bureau records that in the heating furnaces of the Los Angeles Steel and Iron Company one ton of good Wellington coal equals three barrels of oil for steam purposes, while for furnace use one ton of Wellington coal equals 3·50 barrels of oil. At the Los Angeles Railway

Company's works one ton of Wellington coal equals 3·62 barrels of oil for steam purposes, while at the Los Angeles County Court House one ton of good coal equals 3·10 barrels of oil.

Speaking of the cheapness of oil fuel as compared with coal on railways, a prominent engineer recently said—"Petroleum as a fuel is more easily handled than coal since it can be pumped into the receiving tank in a couple of minutes, whereas coal has to be shovelled into the receptacles. Oil is safer than coal. There is no possibility of starting fires from sparks along the line, and the expense of clearing a wide strip of ground on each side is done away with. Then, it gives a steadier fire. The burner is automatic and practically does away with the work of the fireman. No cleaning of furnaces is necessary, and the labour on the locomotive is greatly reduced on that account. The pleasure and convenience of passengers are materially increased on a train where oil is used for fuel, as there are no flying ashes or cinders and practically no smoke."

The production for last year was over 33,000,000 barrels, and a conservative working estimate for this year is 35,000,000 barrels. The oil converted into refined by-products by the refineries is a little over 8,000,000 barrels. Still, to be conservative, the quantity can be taken as 10,000,000 barrels, leaving out of the total production 25,000,000 barrels for fuel.

These 25,000,000 barrels of oil will, allowing three-and-a-half barrels to the ton, displace, approximately, 8,000,000 tons of coal. As £1 8*s*. is the average price of coal this will be £11,200,000 worth of coal. The 25,000,000 barrels of oil displacing it brought the producers £1,500,000, allowing 1*s*. 3*d*. as the average price. This, then, means between £9,600,000 and £9,800,000 actually saved by users of fuel in California. This is outside the value of the refined products.

According to estimates of the Independent Producers' Agency the consumption of fuel oil by Pacific Coast railways in the five years (1902-1906) amounted to 40,000,000 barrels, or 8,000,000 barrels a year. The average net cost of the liquid fuel is put at 10*d.* a barrel, or £1,600,000 for the five years. It is figured that 10,000,000 tons of coal would have been required if oil had not been available, and the net cost of 10,000,000 tons of coal is placed at £8,000,000. It is argued that by the use of California oil the railways have saved £6,400,000 in five years.

The actual saving of money is not the only benefit of the oil refinery business. The Pacific Coast has practically no coal. Near Seattle, a poor grade is mined, and the other deposits are not worth speaking of. The coal used in California comes mainly from New Zealand, Australia, and other foreign points. Thus, foreign producers would make the profit on the coal that is not used on account of oil, while American consumers would lose it, and, of course, the expense of development and the producers' prices remain and benefit the industry, and, indirectly, the State.

The following table shows the demand among the various industries using oil to be as follows—

| | Estimated bbls. |
|---|---|
| Railways (steam) . . . . . | 15,000,000 |
| Point Richmond refinery (Standard Oil Company) . . . . | 3,000,000 |
| Union Oil refinery (at Oleum) . . | 1,750,000 |
| Carried forward . . . | 19,750,000 |

| | Estimated bbls. |
|---|---|
| Brought forward . . . | 19,750,000 |
| All others (23 in number) . . . | 4,000,000 |
| 360 steamers that have been granted permits to burn oil fuel . . | 2,750,000 |
| Japanese and Chilian contracts . . | 3,000,000 |
| Panama pipe line, eastern trade, together with the Government requirements for canal construction | 3,000,000 |
| All other requirements, California, Oregon, Washington, British Columbia and Alaska . . . | 8,500,000 |
| Total . . . . . | 41,000,000 |

If we compare this table with the one of production we will see that there is a shortage of 6,350,000 barrels, or 266,700,000 gallons.

There is oil in some of the islands of the Pacific, and the same statement may be confidentially made in regard to the Philippines. Some of these islands form a by no means insignificant part of Californian oil commerce. The industries of the Hawaiian Islands afford unusually favourable opportunities for the substitution of oil for coal. The high cost of coal, the relatively low cost of California crude, the demand for large quantities of fuel in the sugar mills and other thriving industries, and the necessity for a fuel that can be employed night and day with a minimum amount of supervision, combine to emphasise the value of oil as a substitute for coal. Oil is working satisfactorily on many of the plantations, with a uniform reduction in cost of, approximately, 30 per cent. Any machine, device, or process which enables one man to do the work of two, even though its operation costs as much as the two men, is a distinct advantage, as it reduces the requirements for labourers by 50 per cent. for that particular work. It is a clean fuel; instead of a grimy, dusty, and disagreeable spot, like the regulation coal-firing room, wherever oil fuel is used we have perfectly clean fire rooms. It is smokeless, not comparatively so, but absolutely smokeless; if any smoke issues from the smoke stack, it is proof that there is some defect in the burner or in the arrangement of the furnace. With cheapness, economy of labour, cleanliness, and the abolition of smoke in its favour, there does not seem to be any reason why oil should not supersede coal as a power-producing fuel in some of the islands of the Pacific.

These facts show that in Pacific oil fuel trade we have a convincing argument in favour of the great things which can be done in Peru, Mexico, and, indeed, in the British Colonies and wherever oil fields are known to exist near tidewater.

"IF the nineteenth century was the coal age, the present one will be the age of oil. As a steam producer coal is out of date, and it is my belief that in a few years there will not be a single vessel leaving the Port of San Francisco using anything but oil. If the Bay of San Francisco can float the navies of the world, the oil fields of California can move them."

DR. C. T. DEANE.

THERE is a sharp distinction between Eastern and Western (American) oil, which shows itself in the variations in price. A difference in values is also determined by the geographical locations of the various fields and the difficulties in the way of marketing the product at the nearest refinery. The product of the Eastern fields has a paraffin base and yields a greater percentage of the lighter and more valuable products. The Western oils are of heavier gravity, have an asphalt base, and, although yielding a small percentage of illuminating oils, are chiefly valuable for fuel purposes. The price which they bring is measured by the relative cost of coal. About four barrels of heavy oil are considered equivalent, for power producing purposes, to a ton of coal.

# CHAPTER VIII

## THE TURBINE AND OIL FUEL

*"Owing to the great reduction in the stokehold staff and the freedom from flame at the funnels when the boilers are being pressed, a most important feature in torpedo craft, there is no doubt that liquid fuel will be very largely adopted by nearly all countries in the near future who are not already using it."*

J. E. THORNYCROFT (to the author).

THIS year has witnessed the triumph of the steam turbine and oil fuel over the obsolescent reciprocating engine worked by a coal-fired boiler. The turbine is not more firmly established in the engine rooms of British battleships than oil fuel is in the stokeholds of modern torpedo boats, destroyers, and the smaller class of swift cruisers. If the turbine has superseded the reciprocating engine in the battleships, oil fuel has been equally successful in ousting the hard fuel in the case of numerous types which constitute the scout and torpedo destroyer flotillas. Public attention is focussed on these most modern methods of increasing the speed of our warships, and as recently as April, this year, expert opinion was voiced by Mr. J. E. Thornycroft when he said—" It is now generally known that in conjunction with oil-fired boilers, the turbine engines have given results which could not have been obtained without their adoption."

After what has taken place in the case of the Tartar type of destroyer (referred to in the burner section) no one will deny that we have reached a time when authorities must cease advocating the use of oil as an auxiliary to coal. Oil must be used independently and exclusively. The injection of oil over a bed of incandescent coal may augment the steam-raising capacity of the fires of a warship, but now that the mechanical features of the problem of an exclusive use of oil have been satisfactorily met in their every detail it is only too evident that all warship installations should depend absolutely upon oil and not on a combination with coal.

In this work I have given the opinions of many high authorities. Those which have come latest into my hands are expressed in Mr. Thornycroft's paper, read at the recent meeting of the Institution of Naval Architects. He speaks as an acknowledged authority, and what he says is so extremely interesting that I do not hesitate to give the following verbatim quotation of his references to oil fuel—

"Apart from the coal capacity of a destroyer, the duration of time for which full speed can be maintained depends on the length of time it is possible to run without cleaning the fires, which at full speed, with average coal, is not more than three or four hours. With liquid fuel, stoking is reduced to a minimum, and full speed can be maintained as long as the fuel lasts. The importance of the most skilful attention to reciprocating engines is well known. With turbines, both the number of men and the closeness of attention are very greatly reduced, and it is considered that the difference which has been made by the use of turbines and liquid fuel in these vessels has had as great an effect as the introduction of the water-tube boilers in the first destroyers. The extent to which destroyers of this power will be adopted by foreign navies is uncertain in view of their very great expense, and in their programmes it will be found that vessels of what may be described as an improved British 30-knot class are being adopted.

"While the destroyers have been shown to have increased in size and power very greatly from the original type, the torpedo boat has developed almost to an equal extent. In each succeeding order for the British Navy torpedo boats have been made rather larger than their predecessors, until the last reciprocating engine boats, ordered in 1903, which were of 200 tons displacement and 2,900 i.h.p., gave a speed of 25½ knots; they carried three 18 in. torpedo tubes and three 6-pounder guns. The latest types of torpedo boats were ordered in 1905, and were at first called 'coastal destroyers.' They carried the same torpedo armament, were of slightly greater dimensions, but were fitted with turbines and oil fuel, and as far as power and speed are concerned they are practically the same as the first 27-knot destroyers. The adoption of oil fuel, however, has given them a much greater radius of action at full speed.

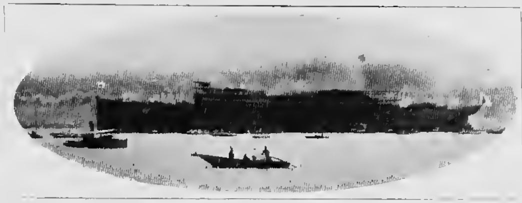
"While the turbines have given excellent results in these vessels, it is a question if equally good results would not have been obtained with twin-screw reciprocating engines and oil fuel, as while the merits of turbines for larger vessels are admitted on all hands, there is considerable doubt, when powers of less than 3,000 or 4,000 i.h.p. are required, if the greater simplicity of reciprocating engines is not to be preferred.

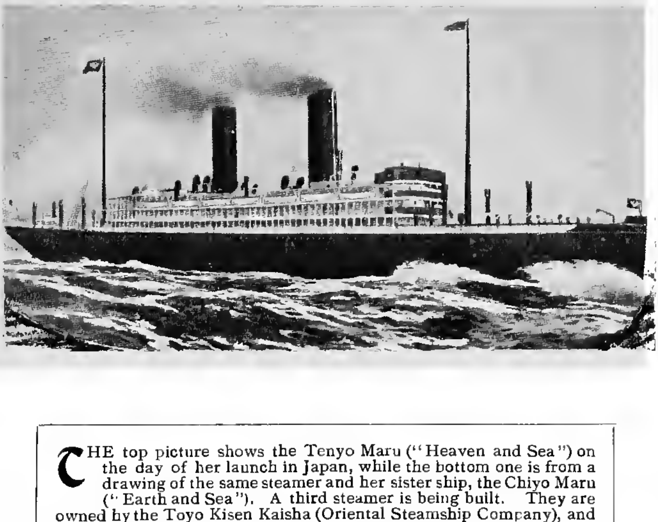
"When considering the advantages of employing oil fuel for this class of vessel, its comparative high cost, and the difficulty in obtaining it, must not be overlooked. The features that strike those who are actually working the vessels most forcibly are the absence of dirt and cinders, and the saving in stokehold staff, the moving of the fuel and stoking being effected by steam pumps and pipes instead of stokers and trimmers. With coal-fired torpedo boats it may be taken that the stokehold staff will be quite three times as great as with oil-burning boats, and while with coal firing at full speed it is usually difficult to maintain sufficient steam, in practice it is found that oil-fired boilers are blowing off, or are on the verge of doing so, and when the vessel is eased up the boilers are under such perfect control that the safety valves do not lift. The necessity of easing down gradually to avoid blowing off with coal-fired boilers is of course thoroughly appreciated.

" The evaporative value of oil may be taken as one and a third times that of coal, and while 43 cubic ft. of bunker space are required to stow a ton of coal, 38 cubic ft. of space are required to stow a ton of oil, so that the equivalent amount of oil fuel can be stowed in 70 per cent. of the space required for coal.

" The consideration of cost is not of the first importance in fuel for warships, but it is worthy of note that the most recent tank steamers have not been fitted to use oil fuel on account of the cost,* although some years ago, when Sir Fortescue Flannery read a paper on the subject at the

* This statement is not altogether correct ; a number of the 1907-8 tank steamers have oil-burning equipment, and there are some which, although fitted to burn oil, do not do so because they run to ports where steam coal is cheap and plentiful.





THE top picture shows the Tenyo Maru ("Heaven and Sea") on the day of her launch in Japan, while the bottom one is from a drawing of the same steamer and her sister ship, the Chiyo Maru ("Earth and Sea"). A third steamer is being built. They are owned by the Toyo Kisen Kaisha (Oriental Steamship Company), and are the largest oil-burning vessels in the world. They have triple screws and Parson's turbine engines and steam 20 knots. The reports of the first trip of the Tenyo Maru show that by the use of oil fuel absolute cleanliness is secured; it does away with the dirt, delay, and annoyance of coaling, and its successful adoption on these queens of the Pacific (between San Francisco, China, and Japan) proves a strong argument in favour of its early use on all passenger steamers running to ports near centres of petroleum production. The tank steamers of the Toyo Kisen Kaisha also burn oil.

*To face p. 172.*

Institution, it was expected that many vessels would soon be so fitted.

"It is interesting to compare the radius of action of the coal and oil-fired torpedo boats and destroyers, but it is difficult to draw any definite conclusions in view of the coal-burning boats being generally fitted with reciprocating engines and the oil-fired boats with turbines."

Like all honourable authors who have dealt with this subject Mr. Thornycroft gives away no Admiralty secrets, certainly not on the subject of the increased radius of action, though he has introduced sufficient facts to corroborate many of the statements made by me in earlier chapters and actually in type before he made public his views in April.

* * * * *

There is one phase of this subject which is seldom, if ever, touched upon by oil field authorities; it is the one of the immense amount of British money which has been invested in the business of petroleum production. During the past ten years I should say that something like £15,000,000, a low estimate, has been lost in oil field ventures, and I am aware that our present investments reach a figure far beyond that sum. There is scarcely a foreign centre of oil production in which British capital has not been placed, and the pity of it is that this cannot be said to be an asset of any real value to the Empire.

Moreover, excepting in the case of India, this country has never distinguished itself in oil; it has a record of disgraceful disasters and humiliating failures in practically every oil field in the world.

No one can impartially discuss the liquid fuel question or the investment of British finance in foreign oil fields without making some comment on the unexpected withdrawal of Borneo's contribution to our naval supplies. It is surprising how many naval authorities and well-informed oil men have made up their minds that we have irrevocably lost control of the Borneo oil fields. The Borneo controversy is part of the history of this country's use of oil fuel, and it is just this question of whether the Dutch oil sources of the island are actually lost to the Empire that leads me to take it up again in this work. No one denies that the oil fields of the island have a great future, and, that being so, they must be of immense value to the country which controls them through the medium of the companies in occupation. To-day they are for the most part owned by the Dutch. Our financial interests are too small to count for anything in a contract transaction, and we have to face the fact that these sources of supply have passed out of British hands. The history of how we lost control of an important part of the oil-bearing territories of Borneo has been written in fragments, and I have always taken pains to make my own contributions free from bias and as lucid as possible.

In 1901, when everything was right with the finance and patriotism of the Shell Company, Sir Marcus Samuel made this statement with evident and justifiable pride—

"It only remains for England to make the use of liquid fuel world-wide, and I am very glad indeed to know that the Admiralty are making extensive operations to give it a thorough trial. I am very pleased and very flattered that we have been invited to help the solution of this great question as far as the Royal Navy is concerned, and we do not think there is any doubt that it will be solved; in fact, it is surprising it has not been done long since, because, when the comparatively uneducated engineers of our own and other steamship companies have found that they can burn liquid fuel successfully, there cannot be any reason why the Royal Navy cannot do so as well. Its advantages are so obvious that we may congratulate ourselves that the supply from these sources has fallen into British hands, and we shall naturally do all that we can to assist our own nation."

This was a year of great hopes. Unfortunately, they were fated not to be realised, certainly not in every particular. Seven years later, following on the trouble with the Government and Admiralty, these sources of liquid fuel and petrol supply passed out of British control, and are to-day managed by the Bataafsche Petroleum Maatschappij (the new name given to the Royal Dutch Company), which constitutes 60 per cent. of the Anglo (Shell)—Royal Dutch combination.

This fact has been publicly deplored by Sir Marcus Samuel, and naval authorities and oil men, reading his statements as the obituary of Anglo-Bornean hopes and aspirations, have jumped to the conclusion that the island has no further interest for us as a source of liquid fuel supplies. Never was a greater mistake made. If Borneo oil is worth anything to us in the future—and, of course, it will be worth less when we once start to open up the oil fields of the Empire—it might be a good thing to encourage certain British oil interests already in the island. There are independent oil interests in the hands of experienced British oil men at work in Borneo, and if these are properly handled they should in time replace whatever some of us consider has been lost by the fusion of the Royal Dutch and Shell companies. In other words, there are unadvertised British oil interests in Borneo, and of these we should hear something in the near future.

Certainly, Borneo is a first-class oil island, and it possesses the undoubted advantage that it is in the centre of a ring of liquid fuel markets in the Orient. A description of these would make this reference to Borneo unnecessarily lengthy.

What is wanted in the future is the enterprising employment of British capital, labour, and skill in the numerous unproven territories in different parts of the Empire. No time should be lost in developing these Imperial resources because there is much truth in the statement that, the oil era having dawned, the Admiralty has every reason to complain that British enterprise has done so little to pave the way towards the satisfactory solution of the problems of a truly Imperial liquid fuel supply. Now, however, when oil, both its production and its use as a power producer, has become a question of real Imperial and commercial significance, the Colonies and Dominions may be depended upon to supply it in huge quantities.

A word on the subject of whether facilities for the storage of a truly British Imperial supply of oil can be provided. It is not a matter of great cost, either with respect to tanks or sites, and there is not a first-class oil port, oil field, or refinery region that does not provide ample evidence of how suitable naval depôts or tank farms could be economically and safely provided in any part of the Empire. Already, on the Thames and at many other shipping centres, as well as on the chief waterways and lines of ocean traffic in distant parts of the Empire, there are British-owned oil storage tanks, and if the Admiralty desired to organise and control a system of widely-scattered oil fuel depôts before the end of the present year it could, relying on the loyalty and enterprise of some of the oil-producing and storage companies, do so without any great difficulty. The Admiralty is not without ideas on this important phase of the subject, but, there again, the secret is being well kept.

In the day of Imperial oil the problems of storage will be easily settled, for oil tank building is one to which many British makers have devoted a great deal of attention and for which they have a world-wide reputation. Other countries know that oil-carrying steamers and storage tanks are world-famous British specialities.

"REMARKABLE as the changes have been it is a fact that, excepting that the man with the shovel has been done away with and we have the necessary apparatus for getting the oil fuel to the fires, the internal arrangements of the stokehold remain practically unchanged. In an oil-fired warship the man with the shovel has had his place taken by the oil fuel pumps. This is a tremendous advantage. Compare the human stoking on the coal-fired Albatross with the mechanical use of oil fuel on the Tartar, and you will have all the difference between an inferno and a holiday trip. . . . It is a well-known fact that some eminent shipbuilders in the North of England will equip a full-powered tramp steamer with a turbine installation under a definite contract as to consumption. Now it is only another step to the introduction of this much improved type of engine worked with oil-fired boilers. I believe the day is coming when some shipbuilders will contract to secure definite results on a guaranteed consumption of oil fuel."

JOHN DOUGLAS, A.M.I.C.E., M.I.N.A.

"THE only countries in the Empire worthy of a place in the Board of Trade Returns as producers of petroleum are India and Canada. Hitherto our traders have been too well occupied in conveying Russian oil to the East and American oil to Europe to think about latent Imperial resources. In New Zealand and Australia, South Africa, and the Canadian North-West the promise is great; indeed, everywhere under the Union Jack Nature has given to us as bountifully of the fuel of the future as of the fuel of the present. How little we appreciate our good fortune is painfully evident in the value of our imports of petroleum. When one remembers that the Dominions and India are also dependent on foreign sources of supply it is easy to measure the extent of our folly. That England should be slow to depose coal from its place as a power producer is natural, since she would then become dependent on the Crown Colonies and Dominions for her sources of supply. Fortunately it is not yet too late. If England herself loses the advantage she at present possesses in Welsh steam coal, the Empire as a whole is in an enviable position whatever happens."

C. DE THIERRY, in the *Morning Post*, Nov. 26th, 1907.

"AUSTRALIA has need of the oil field drill. Oil to this Colony of great distances means cheap and concentrated energy for combustion and transportation; to her growing industries in the cities it means better light, heat, lubricant, motive power, wealth, and a revival of the days of the gold boom which started her on the road to industrial prosperity. . . . Beneath these silent Australian wastes, sandy stretches with here and there a timbered hillock, there is oil. When the hidden stores are tapped. . . ."

J. D. H.

# Oil Burner Section.

(The information about oil fuel burners is scattered through different works on oil and the petroleum Press, and there is nothing approaching a complete record outside the Patent Office publications. Goulichambaroff collected the earliest facts for one of his Russian works on oil; Brannt reproduced some of these with a few additions of later years, and Booth, the latest writer on the subject of burners and tests, made a feature of the voluminous records of the first three American boom years of the present century. The following pages make a record for the number of burners mentioned and illustrated.)

1862 to 1907.

THE following records of the imports of liquid fuel into this country profess to be authoritative—

| | First Paper. | Second Paper. |
| --- | --- | --- |
| | Gallons. | |
| 1905 | 10,687,172 | 12,298,381 |
| 1906 | 11,570,170 | 13,819,091 |
| 1907 | 6,153,150 | 8,737,179 |

As a matter of fact, there are no reliable records of oil fuel imports, and even those which are published are misleading on the subject of the quantities handled during a single year. No one can estimate the stocks held by importers, and this is one reason why the annual statistics are unreliable.

# FORTY-FIVE YEARS OF OIL BURNERS

BEFORE the present century, authorities said that the oil burner had furnished almost as much work for the Patent Office as the waggon coupler; now, since the advent of the petrol engine, vaporisers and burners have increased in such a way that it is absolutely impossible within the scope of a single work to give a readable epitome of the Patent Office records of the world's burners.

The British Patent Office is famous throughout the world of invention for its perfect system of collecting material and its undoubted usefulness. Mr. Goulichambaroff is the one eminent oil authority who has acknowledged this in the Russian language. Of our Patent Office he says—

"If any one desires to follow the history of a certain idea let him consult the English patents, the very best historical records of human invention and thought. When a certain idea finds an exponent, glance through the hundreds of volumes and you will be almost certain to come across some evidence of the same idea brought gradually forward by persons in no way associated with the original inventor. You will be struck with the continuity of its evolution, and that, too, in spite of the differences of periods and nationalities. It would almost seem as if the seeds of these ideas were in the atmosphere and were carried by the wind across the seas for years and centuries until they become imperishable—indestructible—either through the influence of time or distance. Certain ideas may not be followed up for years; they seem to have become defunct; but, no, persevere in your search, and you will find that they crop up again—the old ideas in a new guise. Cases are on record where an idea, started in Germany, has been elaborated in France only to be made perfect in the East Indies or even in Switzerland. These phenomena are not discovered in any one nation; they are common to the whole civilised world."

Many persons have given to liquid fuel heat-producing and other values—the results of laboratory tests—that have never been obtained commercially; they have attributed to it merits which are chimerical and cannot be commercially realised, and very much the same may be said of many of the burners invented to improve its combustion. No substance under the sun yields such a number and diversity of useful articles as oil, and none has been more prolific of mechanical inventions.

Even to-day, very few of the patents are designed in accordance with the fundamental principles of an oil burner, because, after all, the simplest piece of mechanism using the least amount of atomising agent is the best, and it is only too obvious that numerous schemes for superheating the atomising agent, or converting the oil into gas before leaving the burner, do not add to the efficiency of the fuel, but, on the contrary, reduce the evaporating duty.

There are now some excellent ideas at work, but I am not permitted to go beyond the statement that, given perfect conditions, so far as the human element is concerned, an oil-fired steamer, locomotive, or stationary engine will give better results than its coal-burning competitor. Of course, the mere problem of using oil as fuel is easily solved; an apparatus that will simply burn oil can be made by almost any one, but a system that will give the highest results commercially—one that will compete with coal, give a satisfactory return upon the investment, and satisfy the critics and inspectors—must be designed by experts who have made a close study of the question of using this most subtle fuel under varying conditions.

To secure perfect results one must not neglect engineering details; oil on a battleship will make a larger demand on skilled labour than coal, but when it is employed under ideal conditions we are entitled to expect perfect economy of fuel and labour. We have made a great deal of the prominent part played by ignorant Caucasians and unskilled Chinese stokers, but while the work done by these men is all very well for show purposes in a high-powered battleship we must depend upon the higher expert intelligence of the engineers and stokers. The mechanism outside of the furnace is designed to deliver the oil in a finely divided, nebulised condition, with as little trouble as possible to the operator, and controlled by an experienced staff of artificers, a modern plant should guarantee ease and facility in manipulation. Those who have seen many experiments know that the flame may be increased or diminished at the will of the stoker by the opening or closing of a valve, but it is only by experience that the oil, the atomising agent, and the air or steam can be properly combined and perfect results obtained. When the oil is consumed as it ought to be the combustion will be faultless, and there will be economy of labour, a clear flame, which consumes less oil than a smoky flame, and greater efficiency all round. Different installations are suitable for different classes of boilers, and, of course, installations which are successful when attached to a Scotch marine boiler give

along a tube to the upper part of the cone, and was then distributed over the indentations. The unconsumed oil dropped on to the coal in the reservoir. There was no necessity for forced draught on account of the indented conical part of the apparatus gradually getting more heated as combustion proceeded. The top of the cone being in contact with the cold current of air was only slightly heated, while the lower part and base were made red hot. Therefore the oil was made to flow gradually from the colder to the hotter parts of the apparatus and finally into the reservoir of burning coal. The draught was increased by a spray of steam. Like Biddle, Shaw and Linton arranged the fuel tanks in the lower part, where the oil was pumped to the small tank, and entered the pipe, one end of which terminated in the upper part of the fire-box and flowed through a funnel-shaped nozzle to the upper base of the cone. A safety valve prevented the excessive accumulation of petroleum vapour.

Schmidt's method of burning liquid fuel differed slightly from those of Biddle and Shaw and Linton, but the only feature worthy of notice was an apparatus to prevent the fuel oil from spilling. Any overflow of water or oil returned to the reservoir along projections overlapping the apparatus.

In the apparatus of Adams the oil was forced out of an enclosed reservoir into the furnace under pressure. It entered the fire-box through the holes of a pipe encased in another pipe which supplied compressed air to the fire-box. Pulverisation on a small scale took place.

The Mackiney apparatus consisted of three parts—a lower division, in which petroleum or some other liquid fuel was contained, a central division with water for cooling the liquid fuel, and an upper division containing a special box (with a corrugated bottom and filled with sand) in which the combustion took place.

Verstrat's apparatus, based on the same principle, consisted of a semi-circular dish filled with lumps of pumice stone, serving the same purpose as the sand in Mackiney's and the limestone in Richardson's devices (see early history). The fuel entered the bottom of the dish. Hayes used crude petroleum directed straight on to the bottom of the fire-box, on which were piled lumps of crushed stone, coke or similar materials.

After three years' labour on his apparatus for gasifying petroleum and using it as a fuel, Colonel Henry Foote succeeded (in 1866) in installing his invention on a steamer. He conducted his tests, not with crude oil, but with kerosene, and the fuel consumption was, of course, much more expensive than in the case of crude. A detailed description of this apparatus was given by Dr. Zangerle in 1868. The apparatus consisted of a cast iron retort-like box with a wrought iron bottom. A pipe which served to admit the steam was packed with iron filings and coiled above the box. To the side walls of the box were fixed a number of bent pipes supporting cast iron plates which served for burners and also for enlarging the flame, and which, becoming highly heated, assisted combustion of the gases. Kerosene was introduced into the box through a pipe, and air entered through another pipe under a pressure of ½lb. to the sq. in. The gas generated in the retort was conducted through a pipe underneath the retort, where it was heated. A small wood fire was started under the retort, and as soon as the bottom was sufficiently heated to vaporise the kerosene it was introduced in small quantities. The gas was conducted to the burners by a pipe under the retort, where it was burned to intensify the generation of gas. While combustion took place with ordinary air draught, a yellow and smoky flame was produced, but as soon as the compressed air was forced into the retort the gas burned with an intense flame. The steam-conducting pipes and the iron filings were heated to redness, and when the steam passed through it was partly superheated, partly decomposed. The superheated steam and its products of decomposition mixed in the retort with the gasified kerosene and air, and the mixture streaming out of the burners had a pure bluish white flame and developed an intense heat. This apparatus had many defects. The principal one was the deposit of ash and coking in the retort. Kerosene and particularly crude petroleum when decomposed left in the retort a considerable quantity of ash and coke which could only be scraped out with difficulty; the retort had to be constantly cleaned, as otherwise the heat-conducting capacity of the bottom of the retort was greatly reduced. "As far as my knowledge goes," Dr. Zangerle said, "Foote's apparatus was a failure."

Karl Simen's regenerating apparatus for burning petroleum consisted of a cast iron retort fixed in the furnace. Preliminary firing was effected by means of wood, and, when sufficiently heated, some petroleum was introduced for conversion into gas. The gas streamed out of a special burner above the retort, and when it was sufficiently heated to generate more gas than was required the surplus was drawn off into a special chamber, where it mixed with air, heated by passing through pipes under the bottom of the retort and utilised in the working parts of the furnace. This apparatus was used in Tiflis. The generators invented by Simen's brother, Werner, met with a great amount of success on the Continent, where it was used in metallurgical works.

Hack's invention, a massive cast iron retort, was closed in front by means of hinged doors and was fixed to the furnace. It had many features in common with Foote's. The petroleum flowed into the retort from the front and spread over a slightly inclined plane extending the whole length of the retort. Reaching the bottom, the oil dropped on to another inclined plane, down which it flowed, and, when ignited, heated the retort. By the time the latter was sufficiently heated, the oil commenced to evaporate and stream out, partly as gas. In order to increase the heating surface, the bottom of the retort was corrugated. When work at the retort was stopped it was removed from the furnace and cleared of coked matter. The apparatus did not prove a success when used at Baku.

Saroni worked simultaneously with, and in the same country as, Foote, and his documents were issued in December, 1866. Like Foote, he aimed at burning petroleum or its products in a gasified condition. The kerosene tank was 8ft. above the boiler, from whence it flowed down by two vertical pipes to about half the level of the boiler, whence it was taken by another set of pipes in the form of a fire-grate in the fire-box. Brass burners were fixed to the pipes, each burner having three nozzles provided with capillary orifices for the gas flow. The petroleum-conducting pipes were about 1 in. in diameter, and were fitted with taps for regulating the flow of the kerosene. The draught came from below. The taps being slightly opened and some kerosene introduced, two or three burners were lighted; these gave a small yellow flame, but when the burners became heated the kerosene evaporated and streamed out of the nozzles in a gasified state.

While Foote and Saroni were working up their ideas in America, Dorsett conducted similar ones in England, not, however, with petroleum, but with creosote. In principle and design his device resembled those of Saroni and Adams. Creosote or some other liquid fuel was pumped into a special tank by a forcing pump at a pressure of 25lb. to the sq. in. From the tank it was conducted to the furnace by a wrought iron pipe, which, entering the furnace, became ring-shaped near the surface of the fire-grate and terminated on the outside with a tap. At the ring-shaped part of the pipe, four small orifices, one-sixteenth of an inch in diameter, the fuel was sprayed into the furnace under a pressure of 25lb. to the sq. in., and it was claimed that the fuel was completely and smokelessly consumed. When the pipe had been thoroughly heated the creosote which streamed out of the orifices reached a temperature of about 360° C.

The method of spraying liquids by means of compressed air was known in the earliest days of the Russian industry. Early inventors found that if steam or compressed air was made to pass across the orifice of a pipe having its other end immersed in a fluid the air became rarefied and the liquid was drawn upwards. The fluid rose to the orifice, where it was caught up by the stream or current of air and sprayed in all directions in microscopic particles. Idgin, Biddle, and Adams were the pioneers, and in their devices the current of compressed air struck the liquid fuel and hastened combustion, not only by the increased supply of oxygen, but also by the mechanical motion of the current. Adams, in 1863, sprayed oil by means of compressed air, and Mallet, in 1864, designed an apparatus for spraying liquid fuel vapours for carbonising timber and soldering.

In 1865, Spakovsky went further than Mallet, "because," according to the inventor, "his apparatus could be used for all kinds of furnaces."

Aydon patented (in 1865) a process for burning petroleum with the aid of a spraying apparatus. "Formerly," said Mr. Goulichambaroff, "I was inclined to believe that the idea of spraying had been copied from Spakovsky and Stonge, who patented their invention in London on June 27th, 1865, while Aydon only received his patent on October 16th of the same year. A closer investigation of Aydon's method and apparatus, however, soon convinced me how little his invention had in common with the one of the other two inventors. The latter was merely a weak attempt, or rather a repetition of previous attempts, whilst Aydon came forward with an elaborated scheme; he submitted plans and drawings of locomotive furnaces together with detailed descriptions of his apparatus and its utilisation and working, which proves that the method was entirely the result of his own unaided inventiveness. Besides, there was no need for him to imitate Spakovsky; there were before him many others, a study of whose experiments could not fail to lead him to the same conclusions. It would have been impossible for him to copy Spakovsky, considering that only three months passed between the granting of the patents. It is clear that Aydon arrived at his conclusions independently of Spakovsky. There is a greater similarity between Mallet and Spakovsky's inventions than there is between Spakovsky and Aydon's. The originality of the latter is demonstrated by the fact that he persevered in working upon improvements in connection with his apparatus and soon came forward with modifications, while Spakovsky made very slow progress."

The original apparatus consisted of a long pipe with a drawn-out end and a sharp rod, which, extending its entire length, protruded from the front part of the pipe, while the other end carried a screw arrangement for imparting a rotary movement. Pressing the rod slightly forward, the opening in the pipe for admitting the superheated steam was closed. Another pipe for the petroleum was screwed on perpendicularly to the first pipe. The fuel pipe terminated nearer the centre, so that the oil dropped on to the steam pipe and flowed down the drawn-out part as far as the end, where it was caught by the steam. The divided petroleum spray entered the narrow neck of a sleeve before it burst into the wide mouth.

This, in brief, describes the construction of the spraying apparatus patented by the Wise, Field and Aydon Company. It was subsequently modified and improved.

Aydon's apparatus was the first attempt to spray petroleum by means of steam. The chief defect of the apparatus was superheated steam, superheating invariably causing great inconvenience. The spraying was imperfect; a broom-shaped spray resulted, and the heat in the furnace was unequally distributed. Aydon, however, made many improvements in his apparatus. To meet the steam-raising difficulties means had to be employed to heat the water in the boiler and raise steam to a satisfactory spraying degree. Aydon provided the furnace with ordinary fire bars on which coal was burned, but as soon as steam was up the coal was dispensed with and heating was continued by means of the spraying apparatus, the coal assisting combustion. The oil, however, was not entirely consumed, and some dropped on to the burning coal, where combustion was effected without residue.

"That the apparatus failed to perfectly atomise the fuel is, in my opinion, an important defect," said Mr. Goulichambaroff; "a perfect spraying apparatus should not leave a single drop of petroleum unconsumed, and in this apparatus it is likely that perfect spraying could not be effected because of the cylindrical shape of the current of steam and oil and part of the oil remaining outside the atomising radius of the steam."

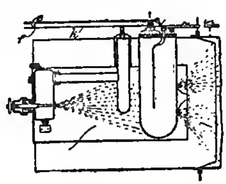
In 1869 Aydon made further improvements, but even then the spraying apparatus exhibited many serious defects. The boiler had to be first heated by coal burned on the fire bars, and the coal fire continued to smoulder so that petroleum was not really employed as an independent fuel, but merely as an aid to coal. Irregularities of consumption injuriously affected the work of the boiler.

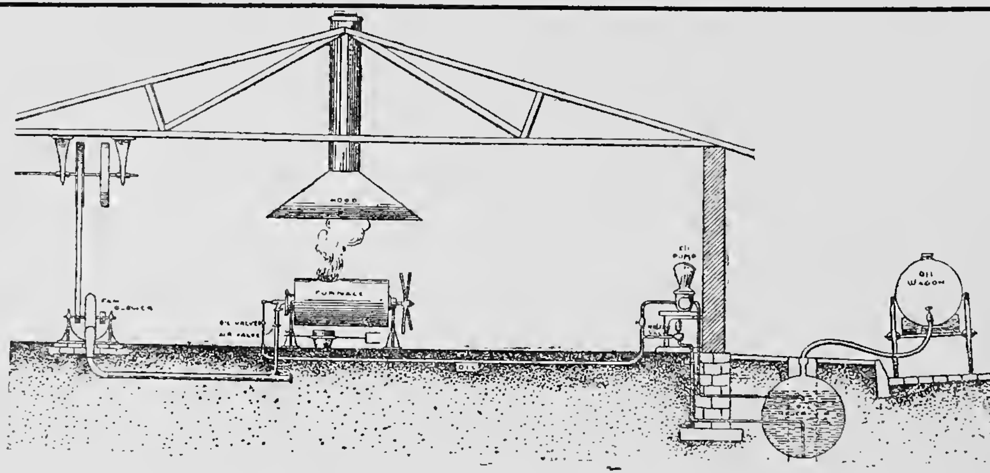
Continuing his experiments, Spakovsky tried to substitute ordinary steam for compressed air. This difference, trifling though it may appear, was of great importance, considering the many disadvantages connected with the superheating of steam. The Spakovsky tests with ordinary steam were completely successful, and he secured the Russian rights for twelve years. But even this apparatus, although superior to all its predecessors, had many defects. Only the lower part of the current of steam performed atomising action, while the side and upper parts expanded upwards and sideways on issuing from the pipe. The fuel was only atomised by the lower rush of the steam, and then imperfectly. The atomised spray carried drops of oil which fell and collected on the bottom of the furnace, where they were consumed in a liquid condition. However, a certain improvement was effected by the extension, the whole spray of steam being brought into operation, and drops of oil in the flames were of rarer occurrence and detected with greater difficulty. Still, even then, the combustion chamber was being continually covered with coke, which adhered to the surface and could only be scraped or chiselled off with the greatest difficulty. The flame was broom-shaped and long; it concentrated at the back of the furnace, while the other parts were only heated by radiating flames. The result was a most unequal heating of the boiler. In a large boiler one atomiser was inadequate and several had to be fixed so that the working of the furnace was complicated without any advantageous altering of the shape of the flame.

Several years afterwards (during the eighties) Walker, an English engineer, appeared with an apparatus like the Aydon and Spakovsky inventions. He fixed several, sometimes as many as twelve, atomisers in a single furnace, and oil from two pipes served all the atomisers. By this arrangement the inventor sought to simplify the handling of the furnace; but the idea, put into practice by Kamensky, in Baku, and Smith, in America, was unsatisfactory, and the results were so discouraging that no further tests were made.

Paul Auduin started his experiments in July, 1865, with the heating of a 20 h.p. boiler by liquid fuel at the Lavilet Works, near Paris. Unfortunately, he had to stop his experiments for over two years, and was only able to resume work in September, 1867. The apparatus was based on the simplest of principles; in it "petroleum, or indeed any other liquid fuel, was burned without the aid of any special arrangement whatever." The ordinary furnace of a boiler was fitted above and below the furnace doors with six pipes, through which the liquid fuel stored in a special tank above the boiler entered the furnace.

These devices (selected from many others) were the chief ones experimented with, and, in some cases, employed, by the pioneers of liquid fuel burning.



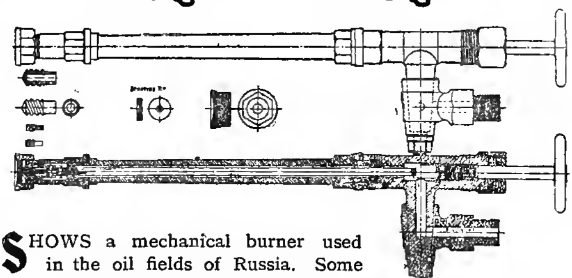



MR. H. J. J. Charlier (of Philadelphia), maker of the Charlier oil and gas fuel melting furnaces and the inventor of the Peat Tilting Furnace, produced in 1898 his first gas or oil furnace. In 1901 he invented an oil or gas fuel furnace, dispensing with crucibles. It melts brass, bronze, copper, grey and white iron, wrought iron, steel, aluminium, lead, tin, zinc or manganese. The oil, supplied to the burner by gravity, flows from an overhead tank (10 to 20 gallons), to which it is pumped by hand or power from a reservoir tank located conveniently for piping either inside or outside a building and generally underground. When the gravity tank is placed at a height of 12 ft. or more above the furnace a head pressure of 5lb. to the square inch is obtained, which is ample for the oil feed. Any ordinary grade of fuel oil may be used for fuel, or, where procurable, crude oil. The quantity consumed per 100lb. of metal varies from 1 to 2 gallons according to the quality of the oil. In winter results are better, and there is less consumption when the oil is heated to 100° F. This is often attainable by running an exhaust steam pipe through the gravity tank.

BURNERS

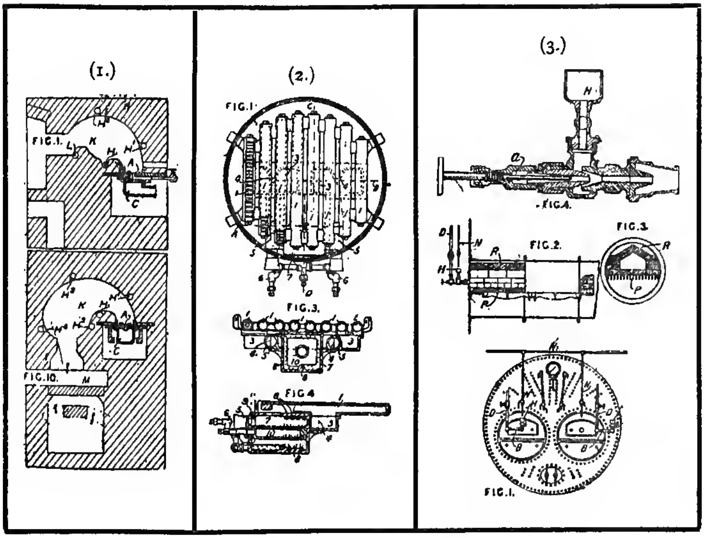
(CONTINUED).

1901–7.



SHOWS a mechanical burner used in the oil fields of Russia. Some consider that burners for work ashore need not be specially economical in the use of steam as a spraying medium; but as the use of a steam burner inevitably entails loss of water, and as the Baku oil fields are practically on the edge of a desert, where all water has to be hauled or pumped, it is necessary to economise the water. This burner does this. In it the spraying is effected by the action of two sets of spiral guide blades—one set within an inner tip and one within the outer tip. The outer spraying tip is removable, so that, as the tip edges wear, new tips can be inserted or special tips can be placed for use under certain conditions of pressure or fluidity of the oil.

# BURNERS OF THE PRESENT CENTURY



(1.) C. SPEIGEL. Jan. 29tn, 1901.

Petroleum residues are burned on a hearth A, which is formed with perforated protuberances for the supply of air. The hearth is supported on levers (not shown) by which it may be raised and lowered. The liquid fuel is supplied through a channel opening at the centre of the hearth, and air is supplied to a chamber C below it. The flame is projected into a chamber K with a vaulted roof, in which slit pipes $H, H^1$, &c., for the further supply of heated air are embedded, as shown. Air is also supplied behind the bridge at L. The flame then passes horizontally into the working chamber of the furnace, as shown in Fig. 1, or is further deflected downwards to and around the hearth M, as shown in Fig. 10.

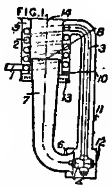
(2.) B. Rein. Feb. 5th, 1901.

Relates to vapour generators and burners, especially applicable for heating steam boilers. Fig. 1 shows the apparatus in plan; Figs. 3 and 4 are sections on the lines A-B and C-D respectively. The burner consists of a number of parallel tubes 1, with transverse slits for the escape of vapour and air. These tubes are connected together in two sets, and beneath each set is a mixing chamber 3, which is supplied with vapour and air through the injector tube 5, and provided with a deflector 4. The vapour is delivered through needle valves 6 from the generator 7, which is heated by the auxiliary burner 10. The walls of the vaporiser are formed with two sets of retorts or passages 8 and 9, which are fed with liquid for supplying the auxiliary burner and the main burner respectively. The auxiliary burner serves also to re-ignite the main burner.

(3.) E. Dyson. May 9th, 1901.

Steam-jet burners are mounted on branch steam-supply pipes B, Fig. 1, which can be turned round the vertical pipes D to bring the burners into working position, as shown on the left hand of Fig. 1, or to turn them aside, as shown on the right hand of the same Figure. They may also be set on any inclination. The liquid fuel is allowed to drip or run from pipes N into cups H on the burners when they are in their working position, so that the supply is under observation. Fig. 4 shows a burner in section to an enlarged scale; the steam pipe B is connected to the chamber *a*. The furnace is preferably provided with a floor of tiles P, Figs. 2 and 3, and an arch R at the front end.

(4.)

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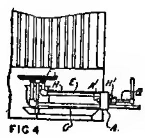


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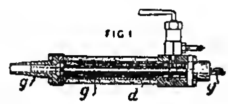



(4.) J. A. Rey and J. M. B. Rey. May 14th, 1901.

Liquid fuel under pressure enters at 1 into a worm 2, which is heated by the flame, the liquid being thereby vaporised. The vapour passes by a tube 3 to a chamber 4 having an outlet nozzle. Surrounding the coil is a closed annular pipe 9, having openings 10 through which air enters and becomes heated by contact with the casing surrounding the flame, and from which the heated air passes by a tube 11 surrounding the tube 3 to the chamber 12. The vapour and heated air then pass to a mixing and diffusing tube 7 having a narrowed port 6, and the mixture escapes through the opening 8, which may be covered with a grating or with wire gauze, and is ignited. The flame passes through the outlet 14 to the apparatus it is desired to heat. An annular collar 13 is provided for starting the vaporiser.

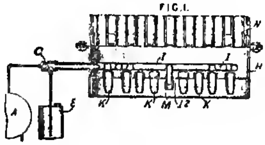
(5.) J. D. ROOTS and C. E. VENABLES. July 31st, 1901.

A vapour burner for heating a small tubular boiler is formed as follows: The tube C is connected to an oil reservoir, the oil being placed under pressure. The oil passes to a hollow plate F, and thence flows by the tube H to a casting A and escapes through a removable jet $A^1$. In its passage through the tubes C, H, and the plate F the oil is vaporised. The vapour is ignited at the jet. The size of the nozzle orifice is regulated, and the orifice kept clean, by a needle valve B. The tubes C, H are surrounded by a casing E, the inner end of which is turned upwards at right angles. In either or both the tubes C, H is a rod, removable by a screw $H^1$.

(6.) H. TAPP and W. H. AKESTER. Sept. 5th, 1901.

The supply of liquid hydrocarbons to a burner for heating purposes in general is mechanically divided into minute streams before being vaporised by a jet of steam. The division may be accomplished by a bundle of fine wires *d*, placed within the burner casing and surrounding the steam-supply pipe *g*.

(7.)

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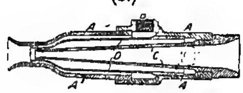


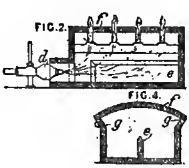
(7.) T. MILLER, E. MILLER, and E. KLAHN. Oct. 28th, 1901.

Relates to a method of burning a liquid hydrocarbon, namely, by spraying it with an excess of air, vaporising it, and finally burning it without admitting any fresh air. The invention is not limited to any apparatus. In the example shown, air under pressure passes from a tank A to a nozzle C, and oil is withdrawn thereby from the tank E, and is sprayed to a coil I in which it is vaporised. The vapour and the excess of air pass through a tube $I^2$ into a closed chamber M, from which they escape through burners K and are ignited in the closed combustion chamber H. Above the latter is a tubular boiler N for generating steam. Instead of the burners K, the chamber M may be entirely covered by a sheet of wire gauze, above which the vapour is ignited; or in another modification, the chamber M itself forms the combustion chamber.

### (8.) A. Renny. Nov. 9th, 1901.

Oil is supplied by gravity at B to the casing A, within which are the concentric nozzles D, C for the supply of steam and air respectively. The steam nozzle is contracted near its end, as shown, so that the steam is compressed before it mixes with the oil. The air becomes heated in passing through the central nozzle; it may be supplied under pressure, and used in place of the steam to induce the flow of oil.

(9.)

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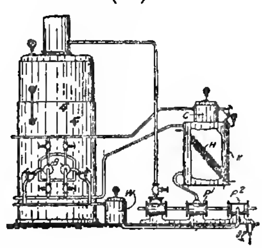


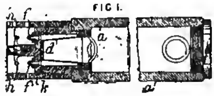
(9.) L. C. Boyle. March 5th, 1902.

A chamber of the form shown in longitudinal section and cross-section, respectively, in Figs. 2 and 4, and made of refractory material, is placed in the ashpit of an ordinary marine boiler or other furnace, the fire bars being removed. Into this chamber the flame from a burner *d* is delivered so as to impinge against the bevelled front edge of the division wall *e*. The flame escapes through openings in the arched roof *f*, and through openings *g* at each side.

(10.) A. Brunn. March 7th, 1902.

Mazoot or other liquid fuel is sprayed by compressed air instead of by steam, both the liquid fuel and the air being previously heated, preferably by exhaust steam. In the Figure, $P^1$ represents the air pump and $P^2$ the liquid-fuel pump. The air is conveyed through the receiver K, where it is heated by a steam coil or ribbed pipe H. The burners are shown at B. The liquid fuel is passed through an air vessel W. At starting, carburetted air is supplied to the burners from the carburetter C.

(11.)

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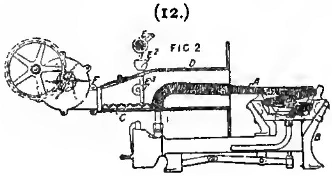


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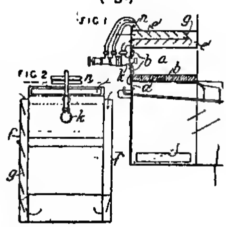


(11.) J. D. SWENSSON. March 24th, 1902.

For spraying liquid fuel, apparatus is provided consisting of a tubular vessel *a* charged with the liquid under pressure and fitted with a removable strainer *d*, through which the liquid passes to a series of nozzles *f*. In front of each nozzle is a pyramidal disperser *h* with its apex in line with the jet. Enclosing the nozzles is a perforated guard tube *k*.

(12.) T. CLARKSON. March 27th, 1902.

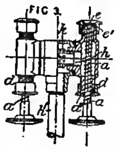
The vaporising tube is encased with non-oxidisable or incorrodible metal wire or ribbon, preferably nickel wire, which is coiled round the whole or a part of the tube, some portions being, if required, enclosed by a greater thickness of wire than others. For starting purposes, the tube is heated by the flame of a subsidiary burner consisting of an asbestos or like wick or pad fed with the same heavy oil, when such is used, as is supplied to the main burner. Fig. 2 shows the invention applied to a burner of the kind previously patented by the present inventor, but it may be applied to burners of other kinds. A is the vaporising tube, B the main burner, and C the wick or pad of the subsidiary burner. The subsidiary burner is enclosed in a casing D, and is fed with oil from the pipe E by means of the funnel $E^2$ and pipe $E^3$. A blast of air is delivered through the casing D by means of the hand-operated fan F.

(13.) E. L. ORDE (SIR W. G. ARMSTRONG, WHITWORTH & CO.). April 4th, 1902.

Boiler furnaces for the combustion of liquid fuel are provided with the primary combustion chamber or ante-furnace *a* formed as a prolongation of the main furnace. The ante-furnace *a* is fitted with the burner or burners *k*, and is lined, preferably at its bottom and front, with refractory material *b*. The front $a^1$ is hinged at *n*, the trunnion being formed by two burner pipes fixed together and turning upon a common centre. The primary combustion chamber *a* has an external casing *f* on its sides forming an air flue, and has also an air-heating flue $e^1$ at the top. Baffles *g* may be provided in the air flues. If necessary, air may be forced to the furnace under pressure. The main furnace may have ordinary fire bars covered with suitable refractory blocks, and the bars may be lengthened to form the bottom of the primary combustion chamber. Preferably, the air supply through the bars of the main furnace is controlled by hinged shutters.

(Sir W. G. Armstrong, Whitworth and Company, who have had a larger output of oil-carrying tonnage than the whole of the British shipbuilding concerns combined, have played a prominent part in the scientific development of oil fuel burning. They were amongst the first to recognise the manifold advantages of liquid fuel, and when their expert, Mr. Orde, made the early discovery that the installations of that day failed to do justice to oil fuel, the question of securing the highest possible heating efficiency received most careful and earnest attention. Some of the earliest tank steamers built in the Walker shipyard to run on the Caspian Sea were fitted with boilers arranged for the use of oil fuel. In 1890 a small tank steamer was built to trade in a place where fresh water was unattainable, and the company then saw the necessity for departing from the practice of spraying the oil fuel by steam. The vessel was fitted with a somewhat elaborate installation of compressed air burners, and, after a long course of trials, during which considerable modifications were made in the apparatus, satisfactory results were achieved. Some time later (in 1900) the company considered it desirable to investigate the subject a little further with a view to seeing whether it was possible to improve the efficiency of the steam burners which were ordinarily fitted, and experiments showed that, at rates of combustion such as obtain in the ordinary marine boiler in cargo and oil steamers, it was quite possible to obtain a very high efficiency from liquid fuel; an evaporation of 14 to 15lb. of water per lb. of oil from and at 212° F. was within the reach of an ordinary engine room staff, provided, of course, that the fuel was of first class quality and free from water. When the question of liquid fuel was taken up by the Admiralty, more experiments were initiated to prove that it was possible to develop the full power of an express water-tube boiler as fitted in torpedo boats and destroyers without producing any smoke and without extravagance in fuel. These results were satisfactorily obtained, and the company found that it was possible to evaporate water at the rate of about 10 to 11lb. per sq. foot of heating surface without producing any smoke or sacrificing fuel efficiency to a greater extent than obtained with coal burned under the same conditions. The company made a number of designs for the apparatus before they arrived at the one which was ultimately successful, and carried out a somewhat lengthy course of experiments on a large scale with an express water-tube boiler fitted up in a temporary stokehold arranged with a fan for forced draught so as to approximate as nearly as possible to the conditions which obtain with torpedo craft at sea. The Orde system has been remarkably successful in the Burmah Company's tank steamers. This is not the only sphere in which Mr. Orde has earned reputation as an expert in liquid fuel burning; no contributions made on this subject to the literature of the Institution of Mechanical Engineers have been more correct and useful than those which bear his name.)

(14.)



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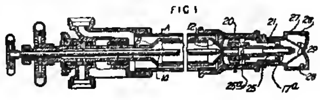

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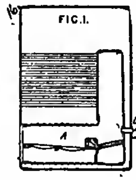

(14.) R. Wallwork, C. H. Wallwork, and A. C. Wells. April 29th, 1902.

Relates to a nozzle for spraying liquids, such as liquid fuel, &c., and consists in arranging the device so that the form of the spray can be varied and the nozzle fixed at any desired angle. Fig. 3 shows an arrangement in which two nozzles are employed. A coarsely-threaded spindle *a* passes through a stuffing-box and gland *d* arranged on each nozzle. The packing $d^1$ in the box serves to form a liquid-tight joint and also as a nut for the screw *a*. The screw is pointed at the end and acts as an adjustable valve to control the passage of the liquid through the spraying aperture *e*, which may be formed in a detachable piece $e^1$. A passage *h* leads from each nozzle to the supply pipe $h^1$, and within this passage is screwed a hollow plug *k* provided with perforations. This plug acts as a strainer for the liquid, and may be surrounded by a sleeve of wire gauze, &c. By turning the nozzle relatively to the plug, the angle of the nozzle may be adjusted relatively to the supply pipe. The pipe $h^1$ is provided with a spring-controlled valve to control the supply to the spraying device. This valve is operated by a hand lever pivoted to a projection on the hose guard.

### (15.) L. A. Pfeiffer and L. D. Staples. July 22nd, 1902.

Oil and steam or air are passed respectively through an inner tube B and an outer one A, and through specially arranged perforations to a mixing chamber 21, whence the mixture passes through other perforations and channels to a head 27 containing baffling-plates 29, finally escaping through openings 28. The various openings are not in a line with one another, so that the stream is broken up. The oil tube B contains a regulating spindle 14 with a pointed end fitting the coned end 12 of the tube B, which itself serves as a valve to regulate the supply of steam and oil. The oil enters the mixing chamber through radial perforations 25 or inclined ones $25^a$, the issuing streams being, in either case, broken up by opposing surfaces. The steam or air enters the mixing chamber through passages 20 parallel to the axis of the tubes. The channels through which the mixture escapes to the burner head may be formed as slots in an enlargement $17^a$ of the end of the oil tube. These channels, as also the other passages, may be spirally arranged.

### (16.) J. Weir. July 17th, 1902.

Liquid fuel is introduced into a steam-generator furnace, in an opposite direction to that in which the products of combustion leave the furnace, by a nozzle D. The liquid is thus vaporised in its passage to the grate A. A marine boiler is shown in Fig. 1. In applying the invention to a double-ended marine boiler, the oil is introduced at both ends, and projected beyond the firebridge openings. In applying the invention to a water-tube boiler of the combustion chamber type, the liquid fuel is introduced at the back of the combustion chamber.

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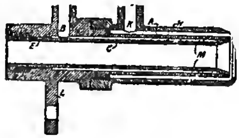

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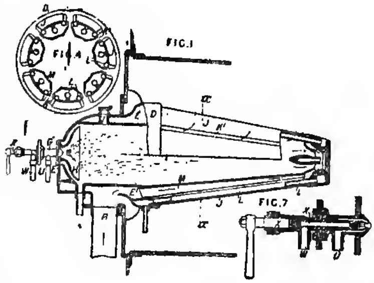


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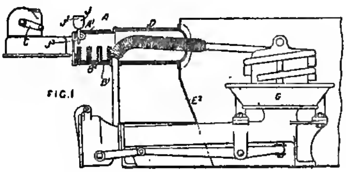



(17.) W. J. Osborn. July 16th, 1902.

In burners in which an annular jet of steam, compressed air, or the like impinges on an annular stream of liquid fuel, a central air-supply tube C is provided to ensure more perfect combustion and prevent the formation of smoke. The main tube A has a steam inlet B, and is slightly flared at the end. The inner tube C is flared externally, and preferably internally also, and has a screw-threaded part E to enable it to be operated by an external handle to regulate the size of the steam outlet. The liquid fuel is supplied to the outer tube H through an inlet K, the end of the tube being curved inwards as shown. A flange L is provided to be secured to the boiler or furnace, and the end of the inner tube C is supported by lugs M.

(18.) E. E. Glaskin. Aug. 6th, 1902.

Fig. 1 shows a petroleum or other oil burner as applied to a steam boiler; Fig. 4 a cross-section on the line *x–x*,

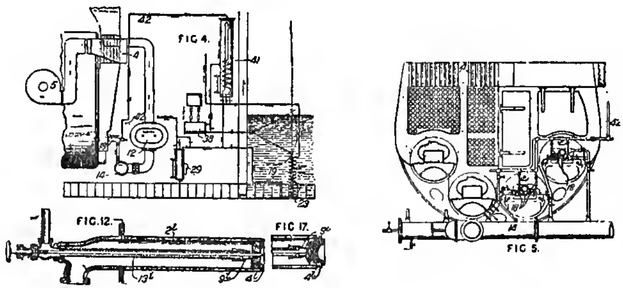
Fig. 1; and Fig. 7 the device for injecting the fuel. The burner consists of the cylindrical chamber D having annular or other air passages E, $E^1$ supplied by the pipe R. Liquid fuel is passed into this chamber by the vaporising device G, round the nozzle of which is placed the cone H. The vaporised fuel is ignited through the hole I by electricity or by other suitable means. Extending longitudinally of the burner are a series of air conduits M, J, which carry water-circulating pipes L. The openings $K^1$ between the conduits serve for the escape of the flames. As regards the device, Fig. 7, the steam which enters by the passage U acts as a carrier when the pressure of oil through the passage W has been reduced to a minimum, and is used for washing off deposits of carbon on the valve. The escape of the fuel and steam from the vaporiser is regulated by rotating the spindle X. The end of the burner may be provided with a deflector for breaking up the current, or may be closed by a conical plate.

(19.) T. Clarkson and Clarkson and Capel (Steam Car Syndicate). Aug. 22nd, 1902.

An oil-burning apparatus for starting the vaporisation in, and igniting, burners of the kind described in Specification No. 18,146, A.D. 1899, or for other heating purposes, has a straight or curved burner box A, on each side of which burner pins $B^1$ are arranged. These pins are preferably staggered, and are secured to a movable bottom covered with asbestos, wool, or the like, $B^4$, on to which a measured quantity of oil can be discharged from a funnel J with a bent stem $J^3$ and a measuring pin $J^1$. Each pin $B^1$ supports a cylindrical piece of asbestos with vertical fibres intermixed with or enclosed in nickel or other wire gauze, perforated metal, or refractory material. The lid $A^1$ may be removed to admit a lighted match, &c.

Air is supplied by a fan C operated by hand or clockwork, its speed being raised gradually. An asbestos-lined box D connects the chamber A with the casing $E^2$ of the vapour burner G. The part of the vaporising tube in the box D is wrapped with nickel or other wire, the tube preferably being of thin steel or other metal.

(20.)




(20.) V. F. Lässoe and L. D. Lovekin. Sept. 18th, 1902.

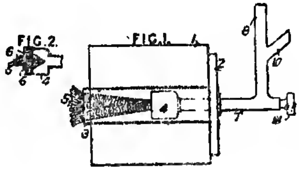
Relates, more particularly, to systems of supplying liquid fuel from the oil bunkers of steamships, and supplying heated air for atomising the liquid fuel in the burners and for supporting combustion. Constructions of burner are also described as part of the invention. Fig. 4 is a diagrammatic view of the apparatus. The oil is drawn from the bunker 19 by a pump 38, and delivered to a service reservoir 41, wherein it is heated by a steam coil, and whence it is taken by the pipe 42 to the burners 18. The suction pipe 23 within the oil bunker is adapted to be raised and lowered, so as to keep the nozzle or strainer out of the water which may accumulate in the bunker. It is also surrounded by a steam-heating coil.

The steam from the heating coil is passed through a trap 29, which retains, with the condensation water, any oil which may leak into the coil. Means are provided for withdrawing oil and water which may leak into the hollow bulkhead beside the bunker. The air for atomising the oil in the burners, as well as that for supporting combustion, is passed through a tubular heater 4 in the uptake of the boilers. The two supplies are distinct in the arrangement shown, being maintained by separate blowers 5, 12, but they may be maintained by a single blower, in which case they are both taken from the air main 14. The air for supporting combustion is, in the arrangement shown, supplied by the blower 5 direct from the heater 4 to the hollow furnace fronts shown in Fig. 5; it is at a lower pressure than the atomising air, and need not be heated. Steam may be used with, or instead of, the atomising air. Fig. 12 shows one form of burner, consisting of an air tube $2'$, extending into the furnace, and having its end closed by a head $4'$, which is provided with a series of converging and helically-arranged jet apertures arranged round the oil nozzle $9'$. The oil nozzle is fitted with a regulating spindle $13'$, the end of which is shaped to spread the issuing oil in a thin conical film. The spindle $13'$, in this and other forms of burner, may be hollow for the supply of steam. The spraying-head may be made in two parts with conical meeting surfaces, in one or both of which the air-delivery apertures may be made in the form of grooves. It may also be made in two parts, as shown in Fig. 17, with a conical space between them, through which the oil spreads to meet the air jets.

### (21.) T. LANE. Dec. 3rd, 1902.

In a smokeless boiler or other furnace burner for consuming heavy oils, a rectangular or cylindrical casing 1 is

(21.)

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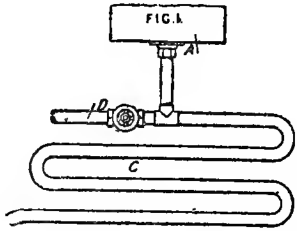


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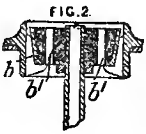


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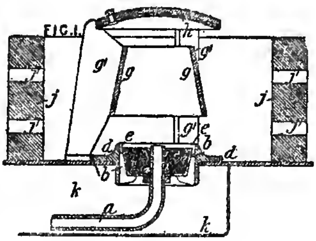


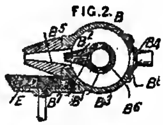


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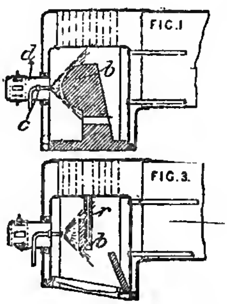


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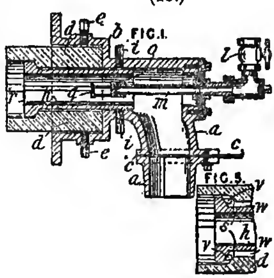


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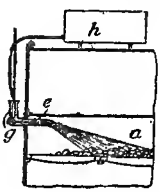

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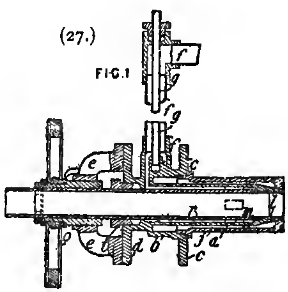


closed at the rear by a plate 2, which carries a cylindrical, funnel-shaped, or bell-shaped tube 3 and has an aperture to admit the fuel-supply tube 7. The steam and liquid fuel are distributed by a bunch of rods 5 and a nozzle 4 having an internal cone and peripheral apertures 6. Oil is supplied by a valved pipe 8, and the pressure fluid, which may be steam, air, or gas, by a valved branch pipe 10. A cleaning plug 18 is provided at the end of the pipe 7.

(22 and 22A.) T. W. Barber. Dec. 11th, 1902.

In a furnace for heating a steam generator or the like, liquid fuel is supplied from a reservoir A to a burner B through a vaporising serpent C, to which steam or air is supplied by a pipe D to drive the vapour forwards. The burner consists of an inner tube $B^1$ having nozzles $B^2$, and of an outer tube $B^3$ having air-holes $B^4$ and nozzles $B^5$. A tube $B^6$ within the inner tube has slots and holes $B^7$, so that, by shifting it, the number of nozzles allowed to be effective can be varied. The size of the air-holes $B^4$ can be regulated by a sliding hole plate $B^8$. Liquid fuel is supplied to asbestos in a tray E and lighted to start combustion at the burner: or gas may be used.

(23 and 23A.) W. Cross. Jan. 13th, 1903.

Oil from the pipe *a* flows on to loose or "fluffy" incombustible material, such as asbestos, contained in a cup-shaped vessel *b*, and is carried up through a cone *g*, in the form of spray, by air passing up through the annular space *e*, between the vessel *b* and a surrounding ring *d*. The air, under pressure, is led into a chamber *k*, enclosing the pipe *a* and the opening of the ring *d*. Projecting brackets $g^1$ support the cone *g* and a baffle *h*, which becomes heated and prevents the formation of smoke.

The cone *g* is surrounded by a wall *j* having openings $j^1$. In a modification, Fig. 2, the vessel *b* is traversed by air passages $b^1$, which are specially designed for furnaces.

(24.) E. KORTING. Feb. 22nd, 1903.

Relates to arrangements for burning oil in short furnaces. The oil is injected into the furnace through a spreading nozzle *c*, Fig. 1, in the middle of the air-supply pipe *d*, and is distributed by impinging against a fixed surface *b*. In a modification, Fig. 3, the surface *b* is carried by a water tube *r* depending from the roof of the fire-box. This modification permits the use of ordinary fire bars for coal-firing. Figs. 1 and 3 show the arrangements as applied to a locomotive fire-box.

(25.) C. A. E. FERMOR. April 30th, 1903.

The steam pipe *e* is led into a boiler or other furnace *a* through an elbow pipe *g*. The liquid fuel from a tank *h* is allowed to drip into the pipe *g* over an enlargement of the steam pipe. It is thus heated before being mixed with air.

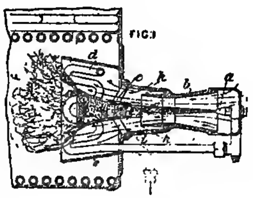
(26.) F. R. DAVIES. May 21st, 1903.

Relates to hydrocarbon burners, more particularly for use in furnaces, in which the oil, before entering the furnace, becomes atomised and vaporised. The oil is delivered through a jet hole *o*, against an inclined baffle *q*, within a tube *h*, which is held by set-screws *i* in a hollow firebrick block *d*. This block, which is interchangeable, projects into the furnace, and is held within the casing *b* by set-screws *e*. The hole through it is enlarged at the outer end to form a shoulder, against which bears the flange of the tube *h*, which is also interchangeable. The oil-supply pipe *m* is fitted with a regulating valve *l*. Air entering the inlet *a*, through a regulating slide *c*, is stated to be "throttled" as it enters the tube *h*, and thus brought into intimate contact with the atomised oil. The outer end of the tube *h* may be provided with a perforated disc *r*. In the modification shown in Fig. 5, the tube *h* is provided with holes *s*, and lugs *v* are provided behind the flange, so that an annular passage *w* is formed for the vaporisation of the oil.

### (27.) K. S. Murray. May 30th, 1903.

Relates to liquid fuel injectors in which the liquid fuel or carburetted air and the working fluid, such as steam, or heated or cold air, interchange their heat during their passage through the injector and are intimately mixed at the nozzle. The internal part is readily withdrawn. A hollow tubular sleeve *a*, screwed into the body *b*, forms an annular passage *j*, into which passes the working fluid from the inner tube *g* of a compound branch. A removable inner tube *m*, forming an air-supply passage, carries a hand-wheel *o* and is screwed into a bridge-piece *e* so as to form at its other end *l* a valve. Through this valve flows the liquid fuel or carburetted air which has been fed into the annular space *r* by the outer annular passage *f* of the compound branch. A gland ring *t* and packing are fixed at the outer extremity of the body *b*, which carries flanges *d*, *c* bearing against the bridge-piece *e* and furnace door respectively. A bonnet-shaped chamber and outer shell, interposed between the injector and furnace, form between them an annular air-supplying space, and set back the nozzle so as to enable the flame to traverse the whole length of the furnace.

(28.)



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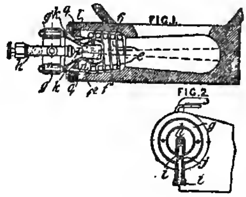



(28.) M. Freidmann and R. Knoller.
July 13th, 1903.

The vapour burner and injector is shown as applied to a boiler furnace. It consists of a vapour nozzle *a*, an injector casing *b*, through which air is drawn to complete combustion, a cone *i* with apertures, the nozzle *c*, the gasifiers *d*, and the shell *e*. By means of the baffle-piece *f* on the mouth of the nozzle the burning gas is deflected towards the air supply. Holes *k* and the annular space within the cone prevent the flame, on striking back, from reaching the nozzle *a*. The gasifier *d* round the nozzle *c* may be curved in S or U form in such a manner that the turns are approximately parallel to the direction of the jet. The gasifier is rendered independent of the reflection from the walls of the combustion chamber in which the burner is placed, owing to radiation from the heated shell *e*. Instead of one nozzle, several nozzles, concentrically or laterally disposed, may be employed.

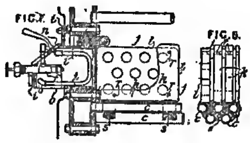
(29.) J. Badger. July 14th, 1903.

The steam for injecting the oil is generated or superheated in a coil *e* and led into an annular drum *g*, whence it passes to the burner *h*. The connection between the coil *e*, drum *g*, and burner *h* is made by means of a single down-tube *i*, Fig. 2, which passes through the drum. The part of the tube situated within the drum is provided with inlet and outlet holes separated by a partition *j*, which prevents a sudden rush of steam to the burner. On the outside of the coil *e* is wound another coil *f* for supplying vapour to the pilot burner *l*. This is mounted on a conical collector *k*, packed with unglazed earthenware, and connected by a pipe $f^2$ with the outlet of the vaporising coil *f*. In starting the burner oil is poured into the mouth of the combustion chamber *a* and ignited. To prevent premature firing and oscillation a perforated bulb *n*, containing a cone *p*, is fixed in front of the burner *h*, as shown. Air grids *q* may be fitted at the mouth of the chamber *a*.

(30.) P. DAVIES (Hydroleum Co.). Sept. 17th, 1903.

Consists in the employment of a combustion chamber *j* of sectional construction, comprising a laminated structure, into which fuel is supplied by a feeder *f* of the kind described in Specification No. 6703, A.D. 1898. The apparatus is shown as applied to a water-tube boiler. The feeder is arranged within a metal casing *i*, which may be lined with refractory material, air being supplied to the casing through an aperture *o*. The casing is also provided with a door *n* the amount of opening of which may be regulated. The casing *i* opens into the combustion chamber *j*, which is composed of a number of L-shaped bars *k*, which may be perforated, arranged as shown in Fig. 5 between flat, perforated, rectangular or polygonal members *l*, all of which members are made of refractory material, and are spaced apart by means of distance pieces *r*. The members are supported upon the water tubes *c* by means of pieces of clay *s*.

(30.)



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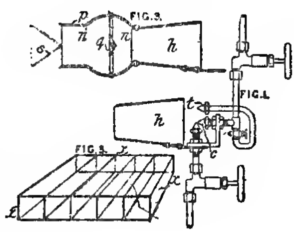

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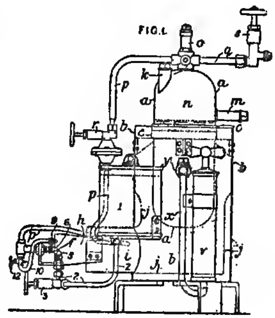
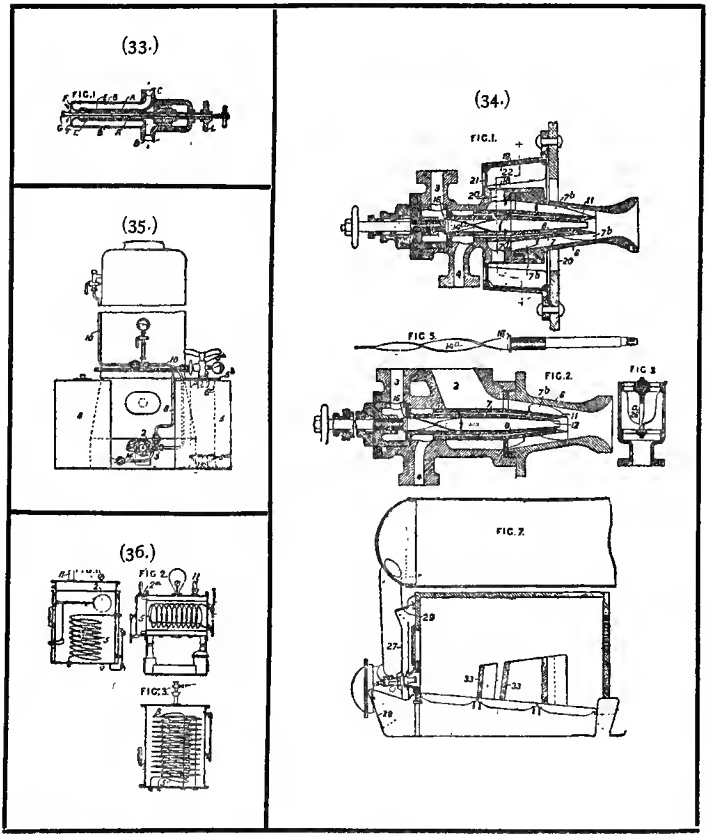


(31.) P. Davies and F. P. Davies. Dec. 14th, 1903.

A spray burner is combined with an open-ended chamber, in which the flame is produced. The hydrocarbon nozzle, and the steam, compressed air, or other spraying nozzle *c*, Fig. 1, are arranged, preferably at right angles, in front of a preferably conical tubular chamber *h*, the flame from which may be used for heating in boiler furnaces, &c., or for gas-making, &c. Additional nozzles *t* for injecting a gas or liquid, such as air or steam, may be provided. When a gentle flame is desired, as in crucible furnaces, an enlarged chamber *n*, *p*, Fig. 3, provided in some cases with a deflecting cone *q*, is attached to the outer end of the chamber *h*. A partitioned chamber *x*, Fig. 5, may be combined with several burners.

(32.) P. Davies and F. P. Davies. Dec. 14th, 1903.

Oil in a liquid fuel burner is sprayed by steam generated in a boiler heated by an auxiliary burner, the oil for which is sprayed, first by air under pressure, and afterwards by steam from the boiler. The casing *b* is provided with a refractory lining *j* and an outlet *g* for the products of combustion, and the steam generator *a* is supported by a ring *c*, which may be formed by making the boiler in two parts and screwing them together at the flanges. At the upper part or steam space *n*, the boiler is provided with a safety-valve *o*, an inlet *k*, and an outlet *m* for water, and is connected to the auxiliary feeder *f* and the main feeder by pipes *p*, *q*, which are fitted with valves *r*, *s*, respectively, and with filters or separators to prevent impurities from passing to the nozzles. Oil is supplied from a cistern 1 to the burner nozzle 5 by a pipe 2 having a valve 3. The boiler *a* is filled with water to the height of the pipe *m*, the valves *r*, *s* are opened, and the orifices *k*, *m* and the valve *s* closed. Air from a hand-pump *v* is forced through the water in the boiler and through the pipe *p* to the nozzle 6, and sprays the oil in an open-ended conical receptacle *h* projecting into a tubular extension *i* of the casing *b*. When sufficient steam is generated to spray the oil in the feeder *f*, the working of the air pump is stopped, the valve *s* is opened, and, after the main feeder is fully going, the starting apparatus is stopped by closing the valves *r*, 3. Any uniform supply of air may be used for initial spraying, but when the air pump *v* is used a non-return valve *y* is fitted in the delivery pipe *x*, the bucket is preferably packed with asbestos or other heat-resisting material, and a passage is formed through its body and fitted with a spring-controlled valve opening only at the suction stroke. Auxiliary nozzles may be provided for supplying a gas or liquid to the inlet end of the pipe *h*. When air, or a mixture of air and steam, is to be supplied, a nozzle 9 may receive, through a pipe 10 and a valve 12, the air or steam from the pipe *p* and direct it with a supply of air from the atmosphere into the pipe *h*.




(33.) J. N. Ryan. Feb. 22nd, 1904.

The casing of the burner is made with an annular chamber B, through which steam passes from the inlet C to the outlet perforations F. The oil passes by the inlet D to an inner annular chamber A formed between the casing and an inner tubular valve E, which is operated by a hand-wheel L. Passing down the centre of the valve E is a rod with an enlarged end G for regulating the flame.

### (34.) J. J. Kermode. July 8th, 1904.

Relates to burners in which the air for combustion, the oil, and the steam to induce a draught are supplied through inlets in the body of the burner. Fig. 1 shows one form of burner, in which the air, oil, and steam are supplied through inlets $2^a$, 3, 4 respectively. It consists of an adjustable nozzle 6 screwed into the body of the burner, and attached by means of ribs $7^a$, having spiral deflectors $7^b$, to the intermediate barrel 7. The latter is provided with a valve seating 11 for regulating the supply of steam admitted through the inlet 4 into the annular space enclosed by the intermediate and inner barrels 7, 8. The inner barrel 8 supplies liquid fuel, which is admitted through the inlet 3, the supply being regulated by the valve 16. This valve is provided, as shown separately in Fig. 5, with a helical deflector and scraper $14^a$. To regulate the supply of steam, the nozzle 6 is turned the desired amount in order to regulate the opening of the valve formed at the end of the intermediate barrel 7. Air is admitted to the annular chamber surrounding the intermediate barrel through a series of radial ports $2^a$, the amount of opening of which is regulated by an adjustable band ring 18 having corresponding ports. Air is guided to the holes $2^a$ by means of a conical hood 19 provided with helical deflecting vanes, which are carried by an inner casing 22, mounted in ball bearings, so that, in the event of a tube bursting in the boiler, and steam consequently blowing through, the inner casing is rotated by the current of steam and closes the openings 21 in the end of the hood. The deflecting vanes may be attached to the ring 18, so as to operate it, but it is usually operated independently. The hood also conducts air direct through openings 20 to the furnace. Fig. 2 shows a modification in which air passes to the burner by an inlet 2, the supply pipe to which is provided with a valve shown in Fig. 3, adapted to be closed by outrush of steam. The valve is in the form of a perforated disc mounted upon a spindle upon which are vanes $26^a$. Fig. 7 shows the burner as applied to a torpedo-boat boiler. The air for supplying the burner and furnace passes through a casing 27 provided with swing doors 28, 29, which open by an air draught and close by an outrush of steam. The flame is distributed evenly over the furnace by deflecting plates 33.

(35.) J. J. KERMODE. July 8th, 1904.

Relates to burners for boilers in which steam is required to be raised very quickly to the desired pressure, as in the case of torpedo-boat boilers and fire-engine boilers; the burners are adapted to be supplied with air, coal gas, or oxygen, under pressure, until the steam in the boiler reaches the required pressure, when the air or gas supply is shut off and steam is turned on. The Figure shows a fire-engine boiler and furnace with the liquid fuel fittings applied thereto. The steam inlet 3 of the burner 2 is connected by means of the pipe 10 with the boiler, and by means of pipe 8 with an air or gas reservoir, which is arranged within one of the oil tanks 5, and held in position by a stand $5^a$ and bracket $5^b$, the object of so arranging the reservoir being to prevent its temperature from rising. The supply of gas to the burner is regulated by a valve within the fitting $6^a$. The reservoir may be refilled through the inlet $6^c$. Oil is fed to the burners through the pipe 14.

(36.) J. J. KERMODE. July 8th, 1904.

Relates to apparatus for heating liquid fuel by steam, water being employed to prevent an undue rise of temperature. The steam (live or exhaust) is passed through a coiled pipe 5, which may be immersed in the oil, as shown in Fig. 1, or in the water, as shown in Figs. 2 and 3. With the arrangement shown in Fig. 1, a water jacket surrounds the oil vessel. In Fig. 2, the oil vessel is annular, surrounding the water vessel. In Fig. 3, the oil is passed through an outer coil 8, surrounding the steam coil and immersed in the heated water. Filtering apparatus 2, Fig. 1, or $2^a$, Fig. 2, may be fitted to the apparatus. The pressure of the oil may be regulated by a relief valve 11, and its level by a float valve, as shown in Fig. 1. Fig. 2 shows the apparatus mounted above the oil-supply pump.

(Mr. Kermode is one of the most active advocates of liquid fuel burning. He has studied the mechanics and science of the adaptation of liquid fuel for all possible purposes. When the Naval authorities first used oil in warships of the Surly type he took a practical interest in the tests, and his system is to-day extensively used in all parts of the world.)

(37.) EDWIN W. TUCKER and C. L. GRUNDELL (San Francisco). Sept. 19th, 1903.

The invention relates to improvements in apparatus for burning fuel oils, and relates particularly to the adaptation of such apparatus to steam generating plants. It consists of the combination with a steam generating boiler of an air compressor and receiving tank, with means for maintaining a normal pressure, an oil heater fed by an oil pump automatically maintaining a normal pressure in the heater, strainers interposed in the pipe-line from the

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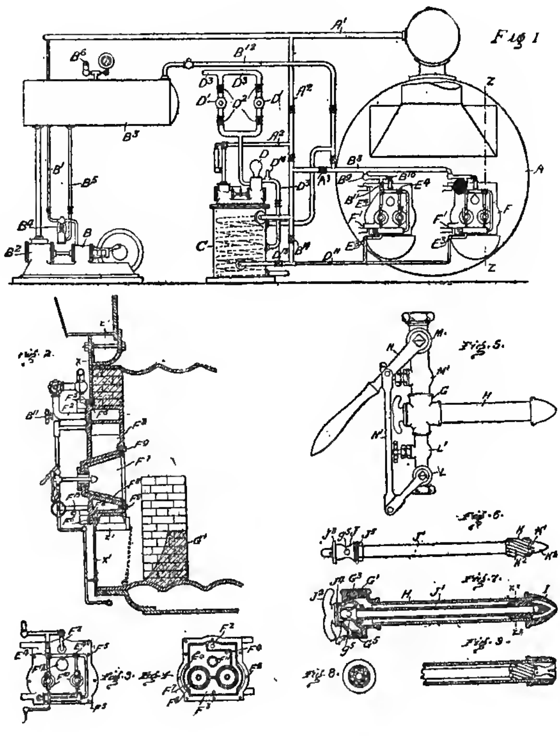

main storage tank to the heater, suitable piping from the heater to the furnaces of the boiler, special furnace fronts consisting of a box-like structure normally flush with the face of the boiler front, and having interior chambers extending into and subjected to the heat of the furnace, cone-shaped openings through the fronts, flaring inwardly to form flame inlets for the burners and internally insulated from the extreme heat thereof, the whole special furnace front being either hinged or bolted to the front of the boiler, so as to be readily swung free to facilitate access to the burners and to the furnaces, the air and oil supply to the burners fixed to the furnace front being swivel-jointed on the same axis and adapted to swing with the said front, the said air supply being led through and superheated in the internal chambers of the said furnace front before entering the burners; suitable valves, gauges, and secondary mechanisms in connection with above main groups to comprise a complete, co-operative, and equipoised system for burning fuel oils.

Fig. 1 is a diagrammatic side elevation of the various apparatus and mechanisms forming the subject of this invention.

Fig. 2 is a vertical cross-section through the furnace and boiler, taken on the line $z$—$z$, Fig. 1.

Fig. 3 is a front elevation of the special furnace front, showing form and mode of connecting air and fuel pipes to burners.

Fig. 4 is a vertical cross-section of the special furnace front, on the line $z^1$—$z^1$, Fig. 2, looking outward, showing the outlines of the internal chambers therein.

Fig. 5 is a side elevation of a burner and controlling mechanisms constructed in accordance with this invention.

Fig. 6 is a side elevation of the oil-tube complete, removed from the burner.

Fig. 7 is a longitudinal cross-section of the burner.

Fig. 8 is a cross-section of the same on the line $z^2$—$z^2$, Fig. 7.

Fig. 9 is a longitudinal cross-section of a portion of the burner, showing a form of tip adapted to project a long annular flame.

In the drawings similar letters of reference refer to similar parts throughout the several views. The invention is described with particular reference to its application to marine conditions.

The steam generated in the boiler A passes into the pipe $A^1$ for distribution. Steam is led into the actuating cylinder B of the air-compressor through the pipe $B^1$, which operates to compress the air in the cylinder $B^2$, from which it passes to the receiving tank $B^3$. The pressure of air is regulated by the automatic pressure governor $B^4$, on the pipe $B^1$, set to the desired pressure and balanced by the opposing pressure of the steam and air through the pipe $B^5$ and the compensating spring to the governor.

The pop-valve $B^6$ acts as a safety against excess of pressure. From the tank $B^3$ the air passes through the pipe $B^{12}$ and thence to the oil heater C, causing oil to flow through the distributing pipe $D^{11}$ to the burner. Steam is led from the pipe $A^1$ through a coil to the oil heater C.

The oil heater C is supplied from the main oil storage reservoir or settling tank by the duplex pump D, through the pipe $D^3$ and spring check valve $D^{14}$. The pump is actuated by steam from the pipe $A^2$. The oil is pumped through the strainers $D^1$, arranged between the valves $D^2$, on the oil conduit $D^3$. The strainers are arranged in two separate sets between valves so that the oil may be diverted while one set is inoperative, without interrupting its flow to the heater.

The burner consists of a fitting having an internal dividing wall, an air pipe forming the shell of the burner screwed into the fitting, and terminating in a tip, an oil tube centrally located in said shell and screwed into the dividing wall of the fitting from behind in such a manner as to be readily withdrawn and replaced, a mixing head screwed on to the end of the oil tube near the burner tip adapted to entirely fill the bore of the burner shell and having an extension into the bore of the tip, spiral grooves cut in the periphery of the mixing head to give the escaping vapour a cyclonic whirl as it picks up the globules of oil squirting from the holes in the mixing head, means for controlling and regulating the supply and proportion of oil and vapour, consisting of regulating valves located on the respective supply pipes adjacent the burner, and stop-valves adjacent the regulating valves, operated simultaneously by a throttle lever.

In construction the burner consists of the cross-fitting G, having the dividing wall $G^1$ therein, across the line of entrance and separating the air and oil within the fitting. The tubing H, screwed into the fitting, extending forward, and carrying the tip I at the extreme end, forms the shell of the burner. The oil-conduit consists of a plug J, having the tube $J^1$ screwed therein, extending forward and carrying the mixer head K. This construction divides the burner into two elements. The air-conduit, forming the shell of the burner, is the fixed element. The oil-conduit, carrying the operative parts, is the removable element. The two elements are assembled by inserting the oil-conduit into the air-conduit, the outer threaded portion of the plug J engaging the division wall $G^1$ in the fitting G. When the plug is set up tight by means of the wings $J^2$ thereon, the shoulder $J^3$ on the plug jams the fibre gasket $J^4$ against the faced boss $G^2$ on the fitting. This sets the threads on the plug in the engaging threads of the wall $G^1$, preventing leakage through the wall into the air-conduit and preventing escape of oil around the plug at the rear. Thus assembled the body of the mixing head K fills the bore of the shell $J^1$ adjacent the tip I. The oil enters the fitting through the inlet $G^5$, passes through the perforations $g^5$ in the plug J, enters the tube $J^1$, is carried forward into the mixing head K, squirting through the radiating holes $K^1$, either in the passage of the spirals or at the exit thereof as conditions demand. The compressed air enters the fitting through the inlet $G^3$, rushes forward and enters the spiral grooves $K^2$ cut in the periphery of the mixing head K, escapes with an accelerated cyclonic twist picking up the spattered globules of oil, the mixture escaping from the tip as a highly atomised combustible gas. The length and power of the flame emitted may be regulated by the pitch given the spiral grooves $K^2$ in connection with the form of tip used. For an attenuated flame of great length a conical tip with a quick pitch groove is used. For a quick-diffusion flame of large volume the alternative tip shown in Fig. 9 in connection with the slow pitch groove and reverse spirals is recommended. The nose $K^3$ on the mixing head K, extending into the tip, preserves the annularity of the flame, preventing eddies and back suction within the tip.

The air-conduit being a straight passage, free from asperities and obstructions, could not under the most unfavourable conditions become clogged. By the construction and arrangement of the parts as shown all the mechanisms subject to clogging are carried upon the oil-conduit, which is interchangeable and capable of being removed and a new one substituted in a few seconds. The oil-conduit may become clogged by the oil "freezing" in the holes $K^1$ during inactivity. This is readily removed by withdrawing the oil-conduit and immersing in kerosene, which dissolves the obstruction.

To get effective results from crude oil burners it is essential that the proportion of oil and vapour be determined and maintained. By the arrangement of regulating valves and throttle, forming a part of this invention, the volume of combustion may be increased or diminished without affecting the proportion of its ingredients. The oil in passing to the burner passes through the throttle valve L and regulating valve $L^1$. The air passes through the throttle valve M and the regulating valve $M^1$. After the proportion of oil and air has been determined by regulating the valves $L^1$ and $M^1$, the throttle valves

L and M, through the throttle lever N, and connecting rod $N^1$, may be opened or closed without affecting the proportions of the ingredients of the flame. The advantages of this arrangement are obvious. The locknut $J^5$, on the tube $J^1$, jamming against the plug J, provides a means for adjustment of the mixing head K, with relation to the tip I.

From the distributing pipe $D^{11}$ the oil passes to the oil-conduits of the burners. The swivel joint $E^3$, located on the axis of the hinge $F^1$ of the furnace front F, permits the latter to swing upon its axis without oil leakage. The joint also acts as a valve to shut off the oil flow when the furnace front is swung outward.

From the distributing pipe $B^8$, the air is led through the swivel joint $B^9$ (similar in every respect of operation to $E^3$) to the inlet $F^2$ on the internal circulation chambers $F^3$ of the furnace front F, around and through which it passes, absorbing the radiated heat from the furnace before passing through the outlets $F^4$ to the burners. From the outlets $F^4$ the air passes through the valves $E^4$ and M to the air-conduit of the burners, combining with the oil and escaping in combustion in the furnaces. The valves $M^1$ and $L^1$ act as regulating valves to control the proportions of oil and steam admitted to the burner: the valves L and M, operated by the throttle N, control the volume of combustion independent of the proportions thereof.

The special furnace fronts F combine four radical improvements in this art, to wit, superheating the air or steam used in combustion, keeping the furnace fronts cool by using the radiated heat formerly lost in firebrick fronts, and rendering the burners and furnace space easily accessible, and, further, rendering the change from oil fuel to solid fuel quickly and easily made by unhinging the front and substituting one especially adapted to the form of fuel.

Under ordinary circumstances the furnace front may be cast in one integral piece, the internal chambers being suitably cored. It may be of any desired shape or contour, as conditions may demand, and is hung upon the hinges $F^1$, set out from the face thereof, to allow a free swing and room for the swivel in the pipe connections. It is held snugly to the face of the boiler front X by the bolts $F^5$, compressing the non-combustible gasket $F^6$ between. The flared burner openings F subjected to the extreme heat of the burners are therefore lined with the graphite or cast iron lining $F^8$, held in place by bolts $F^9$. The bushing $F^{10}$, through which the burner extends, is slightly larger than the burner to give a draught of air around same. The opening $F^{11}$, covered by the swing plate $F^{12}$, gives a peep-hole view of the interior of the furnace. Should the air supply for any reason fail, steam may be instantly substituted by opening the valve $A^3$, permitting steam to enter and follow all the paths the air would follow excepting through the heater. To draw off any water which may collect within the special furnace fronts from condensation, the petcocks $F^{13}$ are provided.

The temperature of the air entering the burners can be regulated to any degree by opening the valve $B^{11}$, leading from the distributing pipe, mixing the air direct from the compressor with the superheated air issuing from the furnace fronts. Should it be desired to cut out the superheating chambers in the furnace front, close the valves $B^{10}$, and open $E^4$ and $B^{11}$; this gives a direct flow from distributing pipe to burners. To blow out the oil distributing pipe $D^{11}$ and burners with steam or air close valve $D^{13}$ and open $B^{14}$. This is advisable when shutting down the plant to prevent any oil from remaining in pipes or from running into the furnaces when the boiler is not under steam. Air is admitted through the damper door $X^1$ in the usual manner, except that the bridge wall $G^1$, which has an upwardly curved face, gives it an upward trend into the path of the flame to prevent any cold air from passing into the furnace which would otherwise form a strata of cold air between the combustion and the bottom of the furnace. The burners are arranged in sets so that under a "slow-bell" alternate burners may be shut down and the remainder regulated: in this manner the heat is more evenly distributed than it would be where all the burden was placed upon a single burner. This arrangement of the burners in sets amounts to more than a double use, inasmuch as a new result is accomplished. By this arrangement it is possible to cut down combustion to one-half and keep all ignited burners operating at full capacity, insuring perfect combustion and an equal distribution of heat under the boilers. This is a very important item in stormy or foggy weather where it may be necessary to run for days under half-speed.

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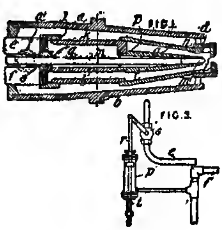

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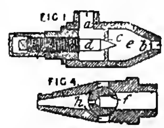

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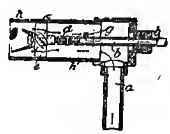

(38.) C. Leistner. Nov. 10th, 1904.

In liquid fuel burners for steam generator, glass, and metal furnaces, and for other purposes, the ejected mixture of spray and air is surrounded by an air jacket to ensure complete combustion, and the oil supply is automatically regulated to the pressure of the air used for spraying the oil. The oil is admitted to the body *k* of the burner through a pipe *e*, and passes out at the conical valve $m^1$ of the nozzle *p*. Compressed air from the pipe *f* is separated from the oil in the body *k* by a partition *l*, curved to clear the regulating spindle *m* of the oil valve $m^1$, and, after passing through the annular chamber *t*, issues through the orifice *i* in the adjustable impingement plate *h* with the oil, which is thus finely sprayed. Air at a moderate pressure is admitted to the casing *a* by a pipe $a^1$, and issues around a ring *d* screwed on the nozzle *g*. Bosses *b* serve to carry the burner on pinions or trunnions. The supply pipes *e*, *f* screw into a ring *j*, fitted with a gland *s* and a packing ring *q*. To regulate the oil supply, the air pipe *f* is connected to a cylinder *p*, Fig. 3, the piston rod *r* of which is linked to a cock *s* in the oil-supply pipe *e*. Should the air pressure fall, the cock is closed by an adjustable spring *t* on the rod *r*. The liquid fuel and compressed air may be contained in the same reservoir so as to issue under the same pressure.

(39.) KORTING. Dec. 29th, 1904.

Consists in means for increasing the subdivision of, and for uniformly dispersing, the liquid fuel to be sprayed. The liquid fuel is mixed with vapour in a chamber behind the issue orifice of the nozzle by allowing it to flow through a restricted orifice to this chamber for the purpose of forming vapour before passing to the nozzle orifice. Fig. 1 shows one form of the apparatus. The liquid fuel enters through the passage *a* and passes through the restricted orifice *c* to the chamber *e* behind the issue orifice *b*. The orifice *c* can be regulated by the plug *d*. Fig. 4 shows another form in which a nozzle has a small issue orifice and a still smaller internal orifice. The internal orifice is formed in a rotatable plug *f* which may be turned so that the orifice is in line with the apertures *h* and may be cleared. In the rotation of the plug, the size of the restricted orifice may be regulated by the plug being kept in such a position that its orifice does not clear its seat.

(Korting employs two methods of spraying the oil, centrifugal sprayers or steam-jet sprayers—the first for marine purposes and stationary plants of large size, and the second for small plant, in which the cost of installation has to be kept low, or where the liquid fuel employed is of a thick nature. It was the Korting burner which was used on some of the steamers of the Hamburg-American Line. Two of these, the C. Ferd. Lacisz and the Segovia (already referred to), having boilers of about 750 sq. ft. heating surface in twelve furnaces, worked with natural draught and consumed about 32 tons of oil per 24 hours, as compared with 45 tons of good German coal, while the other steamers, the Sithonia and Silvia, of about 7,000 sq. ft. heating surface and nine furnaces, with the air heated on the Howden system, used only about 27 tons of oil in 24 hours as compared with 42 tons of coal. The tank steamer Buyo Maru, one of the latest vessels equipped with the Korting burner, steams absolutely without smoke.)

(40.) F. A. Murphy. Dec. 31st, 1904.

In a hydrocarbon burner for furnaces and for other purposes, a fan *e*, which is attached to an oil-distributing cone *f*, is loosely mounted on a spindle *d* secured to the end of the oil tube *b* or in the mixing chamber *h*. The fan and cone are rotated by air supplied under pressure from the tube *a*, and oil from the tube *b* is directed towards the blades of the fan by a nipple *g*. The surface of the cone may be plain or longitudinally corrugated, or divided into a number of arms.

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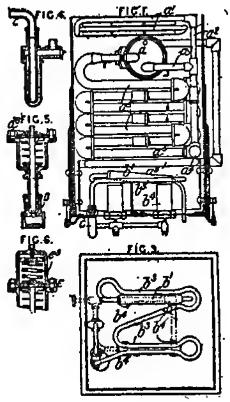

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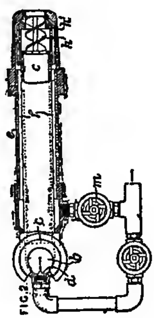

(41.) J. S. V. Bickford. Sept. 5th, 1904.

The boiler shown in section in Fig. 1 is heated by a series of burners $b^4$, Figs. 1 and 3, which are supplied with oil under pressure through the inclined vaporiser $b^1$, bent pipe $b^3$, and purifier C. This purifier is shown separately in Fig. 4. The oil supply is controlled by a valve D, Fig. 5, operated automatically by the boiler pressure acting on the upper face of a spring-loaded diaphragm $d^8$. A valve E, Fig. 6, similar to that shown in Fig. 5, except that the upper face of the diaphragm is pressed against a comparatively strong spring $e^9$, is employed for regulating the oil pressure.

(42.) G. Wilton and T. Wilton. Oct. 21st, 1904.

Oil fuel is fed from above into an open cup-shaped vessel *b*, shown in plan, and by means of a steam jet *d* is mixed with air and steam and forced through a tube *c*, the end of which is surrounded by an annular opening for steam. A spiral device *h* is preferably fitted at the end of the tube *c*. Steam is admitted by a valve *m* into the space *f* between the tubes *c*, *e*, and, passing round the fluted piece $h^1$ attached to the tube *c*, meets the jet of oil and steam from the spiral, thus producing a rotating spray of oil, air, and steam, which is ignited and delivered into a furnace.

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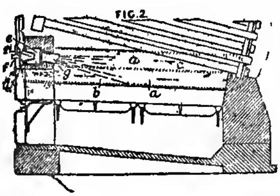


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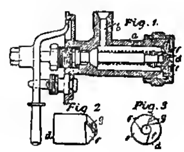


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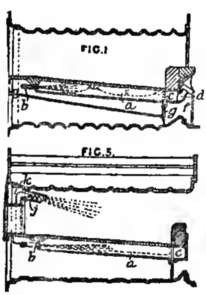


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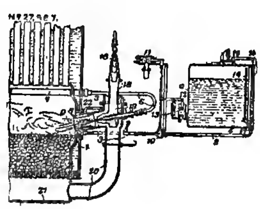


(43.) G. R. GREGORY. May 28th, 1906.

Liquid fuel, after being gasified in retorts in the walls of steam generator furnaces, is exhausted from the retorts and delivered, mixed with air, above the ordinary fire. Fig. 2 shows part of a Babcock and Wilcox boiler with a retort *a*. The retort is built in the furnace walls and consists of two compartments *b*, *c* in which liquid fuel fed to it by an injector *d* is gasified; the gas passes into a chamber *c* on the boiler front, and is injected into the furnace by a steam jet from the injector *f*, which also induces a flow of air through the nozzles $f^1$, *g*.

(44.) G. R. GREGORY. Nov. 28th, 1906.

Liquid fuel is forced through a retort or generator in or near the fire-grate of a steam generator &c. furnace, and the gases thus produced are discharged into the furnace, inducing an inflow of air, and consuming the smoke. Fig. 1 shows a retort *a* set in the middle of the fire-grate, receiving the liquid fuel by means of an injector *b*, and discharging the gases by means of nozzles *d* on a transverse chamber *c* in the fire-bridge *f*, which is made hollow so as to allow the passage through it of a quantity of air regulated by a damper *g*. In a modification, the rear part of the chamber *c* is closed, and pipes at the sides of the grate lead the gases through an arched chamber *k*, Fig. 5, above the doorway, and discharge them through the nozzles *j*, inducing a flow of air through the chamber *k*.

(45.) J. I. THORNYCROFT. Nov. 8th, 1906.

This apparatus for spraying liquid fuel comprises two relatively movable members having adjacent parts thereof shaped to engage with each other in such a manner that upon moving such members relatively to each other there will be formed at the point or points where the members engage one or more discharge passages, which, or each of which, may be arranged at an angle to the axis of the discharge nozzle, and more or less tangentially thereto, and which can be varied in cross-sectional area to vary the quantity of liquid passing therethrough. *a* is the casing from which the oil fuel, introduced through an inlet pipe *b*, is to be discharged through the nozzle. *d* is the adjustable plug of the nozzle, having its front end portion of truncated conical shape, and its rear end portion of cylindrical shape, as shown. The conical end of the plug is formed with three helical surfaces *f*, each terminating in a step *g* that is inclined to an imaginary line *h* connecting corresponding diameters at the base and apex end of the truncated cone, and lying in an imaginary plane containing the axis of the plug. The inner surface of the nozzle is similarly formed with corresponding helical surfaces and steps, so that the surfaces and steps on the one part closely fit those on the other. The arrangement is such that, as the plug *d* is partially rotated in the nozzle *c*, the stepped portions of the plug and of the nozzle, which are normally in contact when the oil supply is arrested, will recede one from the other, and form longitudinally extending exit passages, through which the oil will flow in an inclined or tangential direction from the casing *a* of the apparatus to the exit aperture, where it will impinge at an angle against the wall of such aperture, so that a rotary motion will be imparted to it, and will thence escape over the outer edge of the aperture in the form of a thin hollow body, and finely break up into a finely-divided state or spray. By reason of the helical formation of the plug and nozzle, the plug *d*, whilst being partly rotated, is simultaneously retracted, and the size of the exit passages will vary with the extent of such rotation.

flaming at the funnels are invaluable advantages over coal-fired boats of the torpedo boat and destroyer class, where it is with only the most careful stoking that the smoke may be kept to reasonable proportions, and the efforts involved in so doing are very great.

Mention has been made in Mr. Thornycroft's paper of the much greater steadiness of steam secured by the British oil fuel torpedo craft. This is a point which has been found somewhat unsatisfactory in many of the devices adopted abroad.

(46.) G. H. Mann, Joseph Clayton, and J. R. Pickering. Dec. 4th, 1906.

Relates to apparatus for feeding liquid fuel to steam generator furnaces, and particularly to liquid fuel apparatus for use in connection with furnaces of motor road vehicles subject to considerable variation of load. The drawing is a sectional elevation. The boiler furnace 1 is provided with a burner of the steam injector type adapted to spray oil on to the solid fuel or pieces of refractory material provided in the interior of the furnace, which burner consists of an injector tube 2 coupled up by a pipe 3 to an oil supply tank 4 and an injector tube 5 coupled up by a pipe 6 to a steam superheater 7; but instead of the oil being sprayed in liquid form, as is now usual, the oil is converted into gas before discharging it into the furnace 1. This is accomplished by passing the oil through a jacket 8 round the orifice 9 through which the mixture is discharged into the furnace 1 so as to heat the oil, but not sufficiently to vaporise it, and the heated oil is then sprayed by the steam jet 5 into the furnace 1, the steam being highly superheated so as to gasify the oil by mixing with it, whereby any solid residue from the oil is carried into the furnace. The supply of oil to the jacket 8 of the burner is automatically regulated by means of a valve 10, in the supply pipe 3 between the oil tank 4 and the burner, through the movement of the throttle valve 11 of the engine, so that as the steam supply to the engine is diminished a corresponding movement is given to the oil supply valve 10; but this only applies to a diminishing movement of the valve 10 and not to opening the same, as, supposing the throttle valve 11 was suddenly opened to a considerable extent, after being closed or nearly closed, if the oil supply was opened at the same time and to a corresponding extent, there would not be a sufficient draught of air to effect perfect combustion, and consequently smoke would be produced owing to the condenser being comparatively cool and condensing a large proportion of the exhaust steam instead of allowing it to act as a blast in the chimney; therefore in connection with the oil supply valve 10 a timing valve is provided in the form of a spring-operated plunger 12 working in an oil cylinder 13 in connection with the oil tank 4, which valve only allows the oil supply valve 10 to open very gradually; and this movement of the oil supply valve 10 is also controlled by the position of the throttle valve 11, so that the oil admission is in direct proportion to the steam required. The oil supply from the tank 4 is also controlled, so that the head or pressure of oil in the pipe 3 leading to the burner is always the same independent of the quantity of oil in the tank 4, by making the said tank 4 air-tight and providing a pipe 14 for admitting air to displace the oil consumed, pipe 14 having its lower extremity connected to a pipe 15 through which the oil flows, so that when the oil is too high it closes the mouth of the pipe 14 and cuts off the air to the tank 4, and thus prevents any further flow of oil from the tank 4 until the mouth of the air pipe 14 is again open; while in conjunction with this oil regulating pipe is employed a steam-operated piston 16 working against a spring and provided with a valve 17 adapted to cut off the supply of oil to the tube 3 when the steam in the generator exceeds the working pressure. In order to regulate the supply of air to the furnace 1 so as to produce perfect combustion, a steam-jet blower 18 is fitted of just sufficient capacity to force air into the furnace when the generator is working light, that is when the air condenser can just condense all the steam produced, and there is no effective blast in the chimney to cause suction draught, the blower 18 delivers air into a chamber 19 connected by a pipe 20 leading to a closed ashpit 21 under the furnace grate, which chamber 19 is also formed with a branch 22 leading to the furnace 1.

(47.) R. A. MEYER (Marine Superintendent of the Asiatic Petroleum Company). Jan. 24th, 1907.

This invention relates to means for effecting the more perfect combustion of liquid fuel in furnaces and consists of improvements in and additions to the invention described in the specification of patent No. 1962 of 1899. These improvements and additions comprise arrangements for effecting the more perfect intermixture of the liquid fuel spray and the vapours or gases evolved therefrom with the air for their combustion, means for facilitating the regulation of the quantity of air supplied and for entirely closing the air passages when desired, and constructional improvements in the means for supplying the liquid fuel and effecting the connection of the contrivance to the mouth of the furnace.

The nature of the improvements and additions and the constructional forms in which they are embodied will be explained with reference to the accompanying drawings, in which

Fig. 1 is a vertical longitudinal section through the axis of a corrugated furnace of a boiler of the marine type.

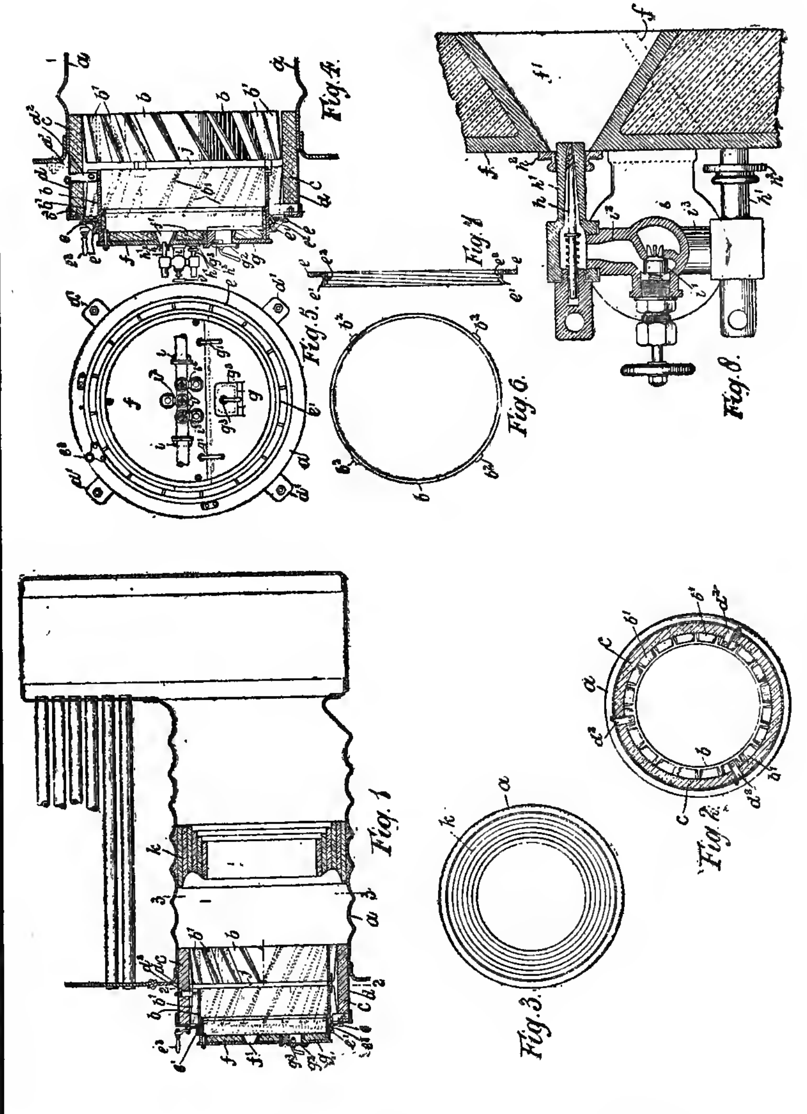


Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 8

Figs. 2 & 3 are sections along the lines 2—2 and 3—3 respectively of Fig. 1.

Fig. 4 is a vertical section on an enlarged scale showing more clearly some of the details of the construction.

Fig. 5 is a front elevation on a corresponding scale.

Figs. 6 & 7 are sections showing details, and

Fig. 8 is a vertical section on an enlarged scale of the injecting apparatus.

In some of these figures it will be observed that to the mouth of the furnace *a* there is secured a contrivance for supplying liquid fuel and air, the general character of which is much like that employed in a previous patent, an important feature of which was and still is an arrangement for the admission of air for combustion consisting of an annular passage, divided into a number of channels by fins $b^1$ which are formed on the exterior surface of a short length of tube *b*. Two or more lengths of fin-bearing tubes may be employed, two being shown in the drawing, separated a little from one another by an interval which provides an opening leading to the interior.

In the present construction the exterior edges of the fins fit into a lining of heat insulating and refractory material *c* fitted, for a portion of its length, within a tubular case *d*, which latter, by means of lugs $d^1$ . . $d^1$, is secured to the front of the boiler around the mouth of the furnace. Also by means of short brackets $d^2$ the case *d* is secured to some of the fins $b^1$.

In this manner the liquid fuel burning contrivance is adapted to be secured to boilers of ordinary construction without any alteration whatever, the lugs $d^1$ . . $d^1$ being fastened to the same stud-bolts as are used for the attachment of the ordinary furnace door fittings used when solid fuel is intended to be burnt.

The manner of mounting the contrivance constitutes one of the improvements according to this invention, the edges of the fins making contact with the refractory material *c* and the latter forming a portion of the air channel surface.

The outward ends of the air channels are adapted to be opened to a regulated amount or alternatively, when desired, to be entirely closed by means of a flanged ring *e* of which, in the interior surface of the flange $e^1$, helical grooves $e^2$ are formed.

This ring rides on the outward end of the exterior fin-bearing tube *b*, which latter has secured thereto small projections $b^2$ helically situated in such a manner as to fit within the above-mentioned helically shaped grooves $e^2$. Thus by turning the ring *e* by means of a handle $e^3$ the area of opening for the admission of air can be adjusted in a controlled and measured manner to suit the quantity of fuel which is at the time being supplied, and, when it is required to cease the generation of steam, the air passages can be tightly closed, the admission of air being thus entirely precluded, the boiler will cool down at a very slow rate, thereby greatly promoting the maintenance of its fluid-tightness and its durability.

The mouth of the exterior fin-bearing tube *b* is closed in its upper portion by a plate *f* which carries the liquid fuel injectors. The lower portion *g* of the closing plate is made easily removable to permit of entrance to the furnace for repair and is secured by means of the fastenings $g^1$ $g^1$. The plates *f* and *g* are lined with a refractory heat insulating material. In the plate *g* an inspection orifice is formed which is adapted to be opened with facility and closed by a door $g^2$ and secured by a fastening $g^3$ similar to those denoted $g^1$.

In the plate *f* apertures $f^1$ are formed for the insertion of the injecting nozzles. These apertures diverge inwards to permit the spray to spread laterally under the influence of the centrifugal force due to a whirl effected in a known manner by causing the liquid fuel to traverse helical passages provided between the threads of a screw *h* (Fig. 8) and the interior surface of the nozzle $h^1$.

The nozzles $h^1$ fit loosely in the apertures $f^1$, leaving an annular passage for the admission of a relatively small quantity of air. The area of opening through these passages can be regulated or closed entirely by means of discs $h^2$ fitted to slide relatively to the nozzles.

The rate of supply of the liquid fuel is controlled by means of a screw-down valve $i^1$ carried in a mounting *i* which is adapted to be secured to the plate *f* and to have secured thereto the liquid fuel supply pipes. By directing the central branch $i^2$ leading to the nozzle in the upward direction and the other branches $i^3$ and $i^4$ downwards, three nozzles equally distantly situated from the centre line of the furnace and from one another can be fitted and be supplied with liquid fuel from one line of pipes. More or less than three jets may be fitted according to circumstances. The division of the supply, in the manner thus described, will tend to a more intimate mixture of the fluid fuel with the air, and provide means for a larger variation in the rate of supply. In order to produce the divergence derived from the whirl before mentioned in an efficient manner a considerable velocity of exit will be requisite. Accordingly, when getting up steam from a cold condition of boiler, or when running at reduced power, one or more of the valves $i^1$ should be entirely closed and the fuel fed through the other one or more as the case may be.

The fins $b^1$ are made helical with one advantage, that, by the consequent extension of their length, their capacity for heating the inflowing air will be augmented also, on account of the helical shape, the air is caused to enter the furnace with a whirl. By giving a left-handed twist, in this manner, to the air, and a right-handed twist to the spray of fluid fuel in the manner previously described, the two fluids, by having opposite circumferential directions of motion, whilst progressing in the same direction longitudinally, will have prolonged opportunity for intimately mixing.

The air in passing along the fins of the first tube *b* will be somewhat heated and expanded, causing a portion to escape through the opening *j* between the two tubes *b* into the interior space containing the fluid fuel. The partial combustion which will result will serve to still further heat the second tube *b* and render it still more effective in further heating the remaining major portion of the air which will continue its flow and pass between the fins carried thereon.

In Fig. 1 the outside tube *b* is shown completely in section, the inside tube *b* being, in its upper half, not in section.

In Fig. 6 the outside tube *b* is entirely in section, whereas the inside tube *b* is shown entirely in outside elevation. By these figures it will be seen that the fins of the two tubes are so relatively situated that the helical surfaces would be continuous but for the gap between the two tubes, and thus the velocity of the air will be impeded as little as possible.

A further important feature of this invention is comprised in the ring *k*, made of firebrick or other refractory material, which is so situated and its front surface so shaped as to receive the whirling ring of air and deflect it in a direction towards the centre and also backwards to meet the whirling jets of fluid fuel. This ring *k* will be adapted not only to promote the intimate mixing of the two fluids, but, by virtue of the high temperature it will attain from the radiant heat of the burning fuel, it will complete the heating of the air.

By the co-operation of the whirl-producing nozzles, the oppositely directed surrounding whirl of heated air for combustion and the highly heated ring of refractory material which is arranged to deflect the whirling envelope of air towards the interior space containing the whirling jets of atomised fuel, the conditions requisite for perfect combustion will be satisfied with a close approximation to perfection.

The mixing of oppositely whirling air for combustion with the whirling jets of atomised fuel, according to this invention, is to be distinguished from the known means of atomising liquid fuel in which a modicum of the total air is supplied under pressure in streams which whirl in one direction and break up streams of liquid fuel which are whirling the opposite way, the mixing of the streams in the latter case taking place before ignition.

(The sole right of manufacturing the Meyer's liquid fuel burner in this country was recently acquired by Smith's Dock Company, of North and South Shields and Middlesbrough. We are, therefore, likely to hear more of this system in the future. Quite recently important tests have been conducted in Smith's docks at North Shields, and the results are said to have been highly satisfactory. The system is being employed on numerous steamers, and the announcement has been made that it will be adopted in the case of the new tank steamer which the Anglo-Saxon Petroleum Company is having built on the Tyne. Other steamers now under construction are being fitted with the arrangement.)

The feature of the Meyer system is the distribution of the oil as a spray in the furnace in a heated condition and under pressure from an oil-pumping plant. The pumps are in duplicate, one being for use while one is in reserve, and a suction heater having two filters, one of which can be used while the other can be cleaned. There are also two delivery heaters, of which one is always in reserve. The general construction of these heaters consists of a chamber within which heating pipes are arranged, the suction heater having its duplicate filters arranged one on each side. Steam is supplied and passes through three stop valves and pipes to the coils of the delivery and suction heaters, and leaves them by pipes connected to the main exhaust pipe, which also takes the exhaust pipe of the pumps.

The pipes from the various fuel tanks in the vessel are led to a distributing box having a stop valve for each tank, and this box is connected to the pipe communicating with the suction heater. The pump sucks the oil through the pipe from the filter out of the suction heater and delivers it through to one of the delivery heaters in use, and thence through a pipe to the furnaces. Each furnace is provided with a distributing box having four valves and four jets, viz., one valve for each jet. Each jet consists of a nozzle having a needle spring pressed into place by a spring and end cap, and is also provided at its end with a screwed portion by which the oil under pressure is sprayed into the furnace. The fuel delivered is regulated by the stop valve of each jet, and any excess delivered by the pump is discharged through the spring-pressed by-pass valve back to the suction heater, so that the stokehold regulation can be carried out without reference to the speed of the pumps, although naturally this latter is regulated under conditions just above the maximum demand for the sake of economy.

The furnace front is fitted into the furnace tube so as to leave an annular space between the front and the furnace tube, while the periphery of the front has angularly disposed ribs by which the air is heated in its passage through the annular space. Upon the furnace front and covering the annular space is a ring damper having a screw arranged on its inner surface, which co-acts with studs on the furnace front, having the function of a male screw. On the ring being rotated by the handle, the face of the ring can be brought up to and be receded from the furnace front, so that the area of the air passage can be regulated at will.

In order to obtain a further supply of heated air in the vicinity of the fire bridge, some of the screwed stays in the back of the combustion chamber are in the form of tubes through which air enters and, passing along a firebrick channel, is heated, and, finally passing through holes in the bridge, it comes in contact with the furnace gases. When it is desired to use coal instead of liquid fuel the burner fitting is removed from the fire door, the cast iron damper is replaced by an ordinary plate damper, and the furnace is furnished with the usual dead plate, fire bars and bridges, an operation taking a relatively short time.

The actual results obtained on the Romany—an oil-carrying vessel of 1,500 i.h.p. with a speed of 10 knots, fitted with the Meyer apparatus—show that the consumption of fuel per i.h.p. per hour is 1·21 lb., and this gives an average daily consumption of about 20 tons.

Messrs. Smith have had fitted up in their yard at North Shields a donkey boiler for experimental purposes. On Thursday, April 2nd, a number of experts and others interested in the system were present and witnessed a series of trials and tests extending over the whole day, and expressed their satisfaction with both the system and the results. The details of these tests were as follows:—

Dimensions of boiler, 8 ft. 9 in. × 8 ft. 6 in. with two plain furnaces, 31 in. external diameter, 6 ft. 1 in. long. Total heating surface, 470 sq. ft.

Grate surface for coal, 22 sq. ft.

Time raising steam from cold water to 80 lb. pressure, 2½ hours.

Temperature of air, 54° F.

Temperature in passages round air conveyor through which the air passes to furnaces, 870° F.

Temperature of furnace, 2375° F.

Temperature of combustion chambers, 1,280° F.

Temperature of smoke-box, 580° F.

Temperature feed water, 120° F.

Temperature oil in heaters, 210° F.

Pressure of oil to burners, 35 lb.

Pressure of steam on boilers, 80 lb.

Consumption of oil per hour, 164·36 lb.

Total water evaporated per hour, 2592·51 lb.

Water evaporated from and at 212° per lb. of oil used, 15·7 lb.

Evaporative efficiency, 90·2 per cent.

Brand of oil mixed with 2 parts Texas, 1 part Borneo.

Specific gravity, ·944.

Flash point by Abel's close test, 246° F.

Calorific value, 17·4 lb. of water per lb. of oil at 212° F.

Water, ·4 per cent. Sulphur, ·32 per cent.

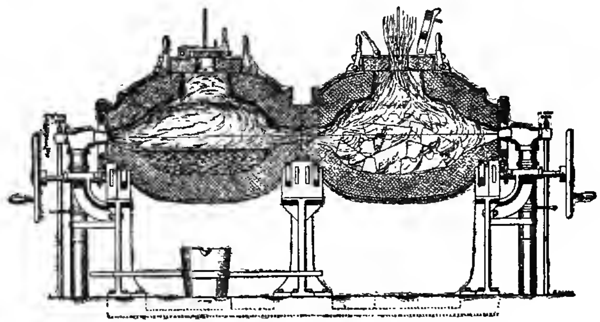
Smoke light brown colour, variable in quantity and not more than might be expected with small donkey boiler.

| | | |
|---|---|---|
| Area of opening to air of passages round conveyor . . . | 324 sq. in. | 2·4 sq. ft. |
| Area of two sight holes in furnace front . . . . . | 24 ,, | |

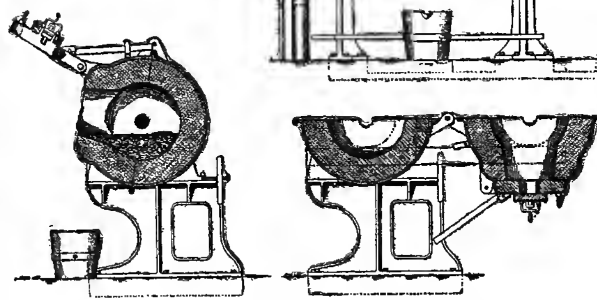
"PRIOR to the Russo-Japanese War a number of ships were fitted in the Russian Navy with the Svensen, Gordejeff, and other burners spraying the fuel without the employment of steam or compressed air. The Dutch Navy also have fitted a number of their torpedo boats for use in the Colonies with Korting sprayers working on this system, while in Austria several battleships have been fitted with a very successful system in which a single fluid burner is used as an auxiliary to coal firing."

WHEN the cruiser Gladiator was struck and sunk by the St. Paul, in the Solent, on April 25th, this year, the coal poured in an avalanche out of the bunkers. The legs and arms of stokers could be seen protruding, and, one report stated, "it was impossible to extricate the poor fellows." Here we have the terrible truth made clear that coal, instead of being a protection in a time of collision or war, is a source of danger. It would not be difficult to prove that if the oil fuel bunkers of a warship were cut into there would be no such shocking spectacle as the one described in the case of the Gladiator.

THE Rockwell rotary oil-fired metal-melting furnace uses the heat from the spent gases of combustion by means of two independent chambers located end to end, and communicating through the necks. One chamber is always in the act of melting, the other receiving the spent gases which give up their heat into the fresh charge of metal. As soon as one melting is poured and the chamber is recharged, the fire is reversed, and in this manner the melting is practically continuous. It saves fuel and time and protects the metal. While the operation is rapid the metal is heated gradually and the fuel never enters a cold chamber. Another feature is the absence of crucibles, nor are there any tiles or firebrick used in the lining. The lining is an inexpensive material rammed into the furnace shell in bulk and burned hard and refractory. The furnace will melt two different metals at the same time. While the normal operation is that of melt and reverse, it is practicable to operate both burners and melt in both chambers at the same time. The one kind of metal can be melted at the same time in both chambers, if an unusually large casting is wanted. Oil or gas is used as fuel, and the air for combustion is supplied from an ordinary fan.



SHOWING THE ROCKWELL OIL-FIRED FURNACE IN ACTION.



ON THE LEFT IS A SECTIONAL VIEW OF THE FURNACE IN POURING POSITION.

THE LAST SECTION SHOWS THE FURNACE OPEN FOR RE-LINING.

THE use of crude petroleum is absolutely safe, more so than coal.

No spontaneous combustion is possible.

Crude petroleum takes one-third less space than coal.

More crude petroleum can be carried per mile than coal.

A ship can load oil from a tank steamer while at sea.

The cost is about one-half (in California).

It is easier to maintain depôts of petroleum than coal.

For fuel purposes oil does not deteriorate, but improves with age.

Oil tanks are cheaper than receptacles for coal.

The supply of crude in California, as far as we can judge at the present time, is sufficient to last for a great many years.

Because a ship burns oil does not mean that she cannot burn coal also, as an oil-burning ship can be changed in less than an hour to burn coal. In other words, if a ship is fitted as an oil-burner you have your choice of fuel.

*List of advantages presented by the California Petroleum Miners' Association to President Roosevelt, in 1906.*

# APPENDIX.

(BEING EXCERPTS FROM SPECIAL ARTICLES IN *THE TIMES* AND OTHER PAPERS, TOGETHER WITH STATISTICS AND SOME FRAGMENTARY INFORMATION.)

1908.

THE earliest petroleum engines gained attention because those who used them recognised the advantage of a direct delivery of the motive power in its original condition. An oil engine of the internal explosive type is independent of any external adjunct. The earliest attempts to use oil in the production of mechanical energy were made soon after the introduction of gas engines. The latest idea is the use of petrol and heavy oils in the same engine, the cheaper power coming automatically into service after the car or tractor has been started by the petrol.

# APPENDIX

(J. D. HENRY, in an article on "Oil Fields of the Empire," in *The Times Engineering Supplement*, January 15th, 1908.)

It would not be easy to over-estimate the importance of the position secured by liquid fuel in naval engineering science. Practically every problem arising out of its safe storage, complete atomisation, and smokeless consumption has been solved, and 1908 finds it permanently established in the British Navy as an emergency fuel in battleships and the steam-raising power which gives the greatest speed in 36 of the "coastal" torpedo destroyers and at least five of the "ocean-going" type.

We have this further evidence of the Admiralty's confidence in fuel oil—that many oil-fired warships are being built; that the Fleet auxiliary tank steamer Petroleum is due in this country with a cargo of Texas oil; and that the new tank steamer Oberon is, on Government charter, bound for Rangoon to load the first full cargo of Indian oil for the Admiralty.

Used in conjunction with turbines, it has revolutionised the power and speed ideas of those who are responsible for the steam-raising equipment of the mosquito and scout types. The British triumphs of 1907 were secretly secured while foreign naval authorities neglected the subject; in the future, however, as the result of these successes, oil fuel will be an important naval and engineering subject in every country which has a navy.

But every problem has not been satisfactorily solved. Experts who believe in the future of oil confess that before it can become a standard fuel in our industrial organisation the questions of a guaranteed supply, the establishment of an ordinary commercial market, and a reasonable Imperial control, which will prevent an artificial manipulation of the price by any company or combination of companies, will have to be seriously considered by different opposing interests.

Five years ago, when the Texas oil fields were being developed, the oil fuel movement in this country was damaged by the fluctuations in the cost of crude and a failure to guarantee supply. Instances are on record where British firms, having gone to the expense of installing the necessary plant, based their estimates on their first oil contracts, only to find, when these expired, that the price had risen; but, no doubt, when a proper market has been organised and the transport facilities have been extended and improved, reasonable business guarantees will be forthcoming, and users of oil fuel will receive more advantageous terms from the oil companies.

Then there is the question of the price to-day. On a rough calculation, liquid fuel, U.K. delivery, will cost the customer a *minimum* of £3 per ton if it is a real market transaction and not an advertisement speculation on the part of the seller. Transport from America, Russia, or India will be responsible for £1 10*s*. or £2 (present freights), or, at a time of depression, 15*s*., below which freight tank steamers cannot be worked at a profit. The f.o.b. rate (really the cost of the oil abroad) will not be less than 15*s*., more likely £1, even more, and in this country it will, of course, be necessary to face the inevitable storage and transport charges, which, on a low estimate, will be 5*s*. or 6*s*. These are all low figures, and the total price arrived at is the one and only reason why oil fuel cannot, under present conditions, be recommended for wide adoption in our industrial system. Of course, in many parts of the world it is cheaper than coal.

The question of transport is at the very root of the great trouble of the high price of liquid fuel. An absolutely modern system of marine transport—sufficient steamers to meet any possible demand for tonnage during the next three or four years—is one of the best guarantees we can have for the reduction of the present abnormally high freights to a point where it will be possible to contend that there are commercial reasons why shipowners and manufacturers should seriously consider the subject. This year the output of new vessels will be a record in tank steamer building.

It should not be difficult to properly organise the commerce of liquid fuel; there is nothing in the unsettled questions of supply which need cause any one to anticipate failure in the end; but, if the organisation of this new branch of the petroleum industry is not found easy of accomplishment, the Government will find a guarantee against serious trouble in the undoubted possession of extensive and, petroleum experts and geologists say, most promising petroleum-bearing territories in almost every part of the Empire. Sources of supply are multiplying, and every year the engineering and geological problems of production are becoming fewer in number and less formidable in character—in fact, we have reached a time when there is justification for much of the optimism of those who contend that every producing country in the world ought to be more diligently searched for new oil regions.

The oil fields of the Empire ought to be developed on a scale which will do justice to British naval enterprise. The oil is in the Empire, and the machinery of an absolutely permanent market, based upon a perfect system of pipe line, tank car, and tank steamer transport, and a greatly increased storage accommodation, will be put in operation directly the producing and distributing companies see that liquid fuel—one of the most useful and popular products of the oil fields—is going to be a real permanent need of the Navy and likely to grow in popularity with shipowners and others interested in our industrial organisation.

* * * * *

Oil was used as a fuel in ancient times, and its early history is most interesting. A quarter of a century ago the engineering problems of its use at sea were solved on the Caspian. The secrets of the use of oil for steam-raising purposes in the great tank steamer fleet and ordinary cargo vessels were for a generation a valuable asset in the business of the exceedingly alert and clever shipowners of Baku and Astrakhan. Those who have made a study of the methods of the men who run the industries of Baku find nothing to wonder at in the fact that it was the birthplace of the idea of liquid fuel burning, for (let it never be forgotten by foreign competitors) there are a multitude of brilliant engineers and keen men of business in the metropolis of the oil world.

Liquid fuel is burned in hundreds of vessels running between Baku, Petrovsk, and Astrakhan, at the mouth of the Volga, while on the great river itself there are large fleets of oil-fired cargo carriers. The Caspian tank steamers (oil-fired) completed the following voyages between Baku and Astrakhan—in 1905, 4,550; in 1906, 3,631; and in 1907, 4,212. During years of large exports the monthly voyages equalled 900, or 7,200 voyages by liquid fuel-burning carriers of petroleum and its products for a single navigation.

Other countries, notably Roumania and Galicia, followed Russia, and this is but natural in the case of the two I have mentioned, because they produce oil. Liquid fuel and natural gas are employed in practically every oil field of the world. Although liquid fuel has been burned beneath the boilers of refineries in the shale-mining districts of Scotland for a quarter of a century, England only took up the idea for marine purposes some ten years ago, when the vessels of the Shell Transport and Trading Company (now the Anglo-Saxon Petroleum Company) provided Sir Marcus Samuel with those practical results which make him the foremost shipowning advocate of oil fuel in this country. Most of the missionary work in the marine branch of the business was done by Shell steamers, which have many well-known records to their credit. The steamers of other oil-carrying companies have done excellent work with oil fuel, and the tank steamers Romany and Pinna (converted from a coal burner to run with California oil for the Japanese) are amongst those which have given splendid results, while it is known that some of the Standard Oil Company's tank steamers, trading between the Gulf of Mexico and Philadelphia, have increased their speed by two knots by the use of liquid fuel. There are fleets of oil-fired vessels trading on the Pacific coast.

Great Britain is not a probable source of supply, although it is never safe altogether to overlook the petroleum possibilities of the natural gas district of Heathfield. Serious attempts are being made to secure permission to drill a well in a supposed petroliferous spot in Ireland. We have, however, this inducement to use oil fuel denied to other countries which have no oil fields: we admit it without tax or duty, and it is the cheapest fuel we can import.

The needs of the Admiralty demand that this new power creator shall be produced in greater quantities in the Crown Colonies and Dominions, and, as the Earl of Elgin has stated, the Colonial Department, alive to the importance of an Imperial oil supply, is conducting expert geological investigations of the oil-bearing parts in the Island of Trinidad.

India and our Colonies have about the same production as Germany, which counts for little in the oil world, and there is a strong feeling that a programme of inter-colonial oil-field development work should be prepared and officially encouraged so that the output of the Empire may be brought up to Russian, if not American, level.

India and Canada give the largest production. The inland possessions which constitute the oil-bearing part of the Empire include Newfoundland, Trinidad, Barbados, Australia, New Zealand, and several other small islands in the Antipodes, while it is believed that important discoveries of oil will shortly be made in West and South Africa.

Many of the foreign fields, particularly those of Russia and Galicia, and even Roumania, are not attempting to supply liquid fuel for the British Navy. The Russian oil fields, for well-known reasons, are incapable of contributing to British needs; other producing countries, owing to large home demands, cannot guarantee us supplies even in times of peace; in fact, if we omit Texas and Borneo, foreign sources of supply, so far as they can contribute to the growing needs of this country, are too insignificant to deserve notice.

Borneo, California, Texas, and Indian Territory contribute the largest quantities of liquid fuel to the ocean needs of the world. Steamers which, before the massacres in the Caucasus, ran regularly in the Russian oil trade are now bringing Indian Territory products from the Gulf of Mexico to this country, and oil is being shipped in greater quantities from Port Arthur (Texas), where the British Government has placed important contracts for fuel oil.

Respecting a possible increase of the world's supply, oil men are confidently pointing to the rapid manner in which new fields are being discovered and the vast improvement in the mechanical means employed to reach the lower deposits of oil in the oil fields. This is correct; in the famous Baku fields, the Boryslaw and Tustanowice fields of Galicia, the old and well-drilled fields of Petrolia (Canada), and in America, both in the old fields in the north and in the new ones of Texas, Kansas, and California, the drillers are finding more prolific sources of supply in the deeper strata, which are now being more easily reached by the employment of modern drilling tools.

The world's production will undoubtedly go on increasing, and there is no reason why, in time, we should not make the Empire contribute a fourth of the total output of crude oil.

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(J. D. Henry, in *The Times*, March 11th, 1908.)

The increase of rapid and powerful street and railway motor vehicles and motor cars, the building of racing and pleasure motor launches, the adoption of petrol-driven submarines by the Admiralty, and the almost marvellous expansion in the use of internal explosion oil engines of various types make the problems of the supply and distribution of power-creating fuels of vast importance, not only in this country, but in all parts of the civilised world.

Motor fuels still have their unsolved problems. Some of these are connected with the difficulties of transporting supplies, while others arise out of the mechanical development of existing appliances and new inventions which are intended to give us economical and effective power, with a *minimum* consumption of the motive products.

In the early examples of internal explosion engines the use of highly volatile oils was necessary, but it is now possible, by improvements in the design of the engines and the application of the power, to use much heavier products, and some of the latest appliances even work with the heaviest of crude petroleum. This broadening of the base on which the industry rests (for, of course, the success of the industry depends on an ample and efficient supply of cheap fuel) should ensure for it a permanent and prosperous future, and this fact is particularly gratifying in this country, where so many of the various appliances are the result of the genius and ability of British inventors and manufacturers.

The most remarkable development of the world's petroleum business has been the recognition by the large producers and exporters of America and those who control the petroleum fields of the Dutch East Indies of the value and magnitude of the British, Continental, and other foreign markets for the sale and distribution of spirits used for motor purposes.

American refiners have developed the motor fuel business on this side of the Atlantic at a time when they have been maintaining and fostering a large and increasing home demand. The East Indian producers, on the other hand, have very few markets for the consumption of their products outside the Continent and the United Kingdom. They are also hampered by the fact that in producing their spirit they are left with large quantities of residuals for which there is no ready market in the immediate vicinity of the refineries, owing to lack of population and large manufacturing centres. In this respect the American refiners have a decided advantage; their products are all saleable at the doors of their refineries, and it is known that the home demand is at prices which are just as good as those obtained for export. Then, again, the American-United Kingdom ocean freight is much less than from the East, the proportion being about 15*s*. per ton to 35*s*. per ton in normal times, the present freight rates being abnormally inflated.

The estimates of crude production in the several great oil fields of the United States during 1907 have just been received in London, and put the total at 157,300,000 barrels, against 126,493,936 barrels in 1906. . . . To produce crude oil for the sole purpose of making spirit of a quality suitable for motor cars is not a profitable undertaking, even if the crude is as rich in the lighter hydrocarbons as that of the East Indies. Markets must be found for the balance of production, and it is this problem which is troubling the Far Eastern refiners and limiting their output.

It will be seen, therefore, that, although the trade in petroleum spirit for explosive motors only came into existence with the present century, the British and Continental demands are enormous (the United Kingdom alone importing some 120,000 tons annually), but, nevertheless, the requirements have not increased at the same rate as the crude oil production of America, to say nothing of the other important fields of the world. As a matter of fact, the supply of spirit is well in excess of the demand, and it is no secret that huge stocks of spirit of all grades are held at American exporting centres—a fact which not only indicates that there will be no immediate advance in the price, but, rather, an early reduction, which is the point of greatest interest to the general public in this country.

The imports of spirit of all grades into the United Kingdom for 1907 and 1906 were as follows:—

| — | 1906. | 1907. |
|---|---|---|
| | Gallons. | Gallons. |
| U.S.A. | 8,105,220 | 7,216,642 |
| Dutch East Indies | 15,174,650 | *23,866,310 |
| Belgium and Holland (reshipments) | 1,557,763 | 631,290 |
| Roumania | 1,892,460 | 1,459,000 |
| Russia | 7,410 | 321,690 |
| Germany | 2,380 | 80 |
| Other Countries | 4,130 | 2,500 |
| | 26,744,013 | 33,497,512 |

The imports of motor spirit for last year would have been even larger than those recorded if there had not been a scarcity of suitable tank steamers. This disadvantage has been largely overcome, and will not exist when many of the large tank steamers which are now nearing completion in our shipyards have been placed in the trade. We have, therefore, not only a growing demand and an increasing supply of motor spirit and petroleum oils, but we will soon be in possession of what, in the opinion of the writer, will be adequate means for their transport and the maintenance of more normal markets.

So far as prices are concerned it may be of interest to know that the wholesale London price to dealers to-day for best grades of motor spirit is 10½*d.* per gallon in cans and cases, which compares very favourably with the 1*s.* 1*d.* of last year and the 9½*d.* of 1906.

Petroleum spirit or petrol is found in almost all crude petroleum, but the quantities vary greatly according to the localities of crude production, and, also, sometimes, in different samples from the same oil fields. The most

* The Americans import large quantities of petroleum spirit from the Dutch East Indies.

valuable constituents of crude petroleum, the benzine (from which motor spirit is made), kerosene (burning oil), and light and heavy lubricating oils are all separated from the less valuable and heavy portions by a process of distillation. The stills usually consist of horizontal wrought iron cylinders about 12ft. in diameter by 30ft. long, of a capacity somewhat more than the "charge" of oil, which varies from 600 to 1,000 barrels at a time. On the application of heat to the crude, the lighter portions, or "fractions," in which are contained the petroleum ether, benzines and naphthas, being of a low boiling point, are evaporated first, and these are afterwards recovered or condensed by cooling the vapour as it passes through pipes surrounded by cold water. The first distillation is usually carried sufficiently far at most refineries to vaporise the kerosene, which is separated from the benzine products as the condensed liquid runs off from the still. The lubricating oils and other heavy products left after the first distillation are further separated by redistillation, usually at a different part of the refinery.

The most common method of separating the different products of distillation is to run them all from the condenser through a receiving house, in which there is an iron box divided into compartments of a number equal to the products to be recovered. In an ordinary still-house there would be separate compartments for light and heavy benzine, two or more grades of kerosene, and possibly a heavy product known as gas oil. The distillate is run into each box or compartment until the desired specific gravity for that special product is reached, and is then turned into the second, and so on until the final and heaviest product is run off. The specific gravity of the products differs according to the nature of the oil to be produced, the stillman following the directions given by the works' chemist regarding the distillation. For motor spirit the benzine is redistilled, the second distillation being effected with the aid of superheated steam as the heating agent. The reason for the necessity for this second distillation is that in the first distillation the comparatively great heat causes some of the heavier fractions to be mechanically carried over with the lighter fractions, whilst a second distillation with regulated heating allows the lighter fractions to pass over, leaving the heavier products in the still.

The steam still used for benzine redistillation is smaller than the crude still and usually of the horizontal type. It consists of a steam-jacketed cylinder containing a steam coil, and after being charged with a certain quantity of crude benzine steam is passed through the coil at a low temperature, which is gradually raised until it reaches 140° C. or more. The refined benzine products, such as motor spirit, are again divided in a receiving house, as in the first distillation, and may further be purified by treatment with sulphuric acid and soda, but this is not an invariable rule, and its adoption is controlled by the nature of the crude from which the benzine is produced. Motor spirit is that portion of the benzine having a specific gravity of ·690 to ·720, and in some cases even as high as ·760, and as a rule requires no further refining for ordinary motor car use. As this portion is only a very small part of the whole volume of crude treated, it will readily be seen that its production commercially depends somewhat on the markets for the other products.

The American and East Indian crudes, as a rule, yield the largest percentage of the lighter hydrocarbons (naphthas and benzines). Petrol (motor spirit) forms half or less of the total benzines produced, and consists mostly of the liquid hydrocarbons known as heptane and octane. One kilogramme of a mixture of these hydrocarbons requires 11·8 cubic metres of air to produce a mixture suitable for complete combustion. Wood spirit or methyl alcohol requires 5·04 cubic metres of air, and grain alcohol 7·01 cubic metres of air under the same conditions. It will be seen from these figures that in the case of petrol or motor spirit a perfect explosive mixture absorbs a much larger quantity of air, weight for weight, than any of the other fuels.

Those who are familiar with the production of refined oil and know anything about the methods of transporting and distributing the lighter products pay little or no attention to the criticism of the special qualities of the principal brands of petrol. In this country, for practical purposes, all of the leading brands are perfectly satisfactory, any advantage which exists arising chiefly out of the more perfect methods of packing and distribution adopted by the older companies. In this respect the Americans, through long experience, have obtained a considerable lead, but the other importers follow closely behind.

Considerable emphasis is now being laid on the importance of the adoption by motorists of the heavier grades of spirit wherever possible, the practical advantage in the wider use of the heavier spirits being easily seen. If we are to have an ample supply of light spirit we must find markets for the heavier grades, or else submit to a much higher cost in the case of the special products. It has been successfully demonstrated that those brands of heavier spirit commonly known as ·760 specific gravity give perfectly satisfactory results with most cars except during exceptionally cold weather or a period of fog and dampness. It, therefore, cannot be an unwise policy to foster the use of heavier spirits.

While great strides have been made in the production, refining, and handling of petroleum products, as well as in the methods and means of ocean transport, the inland facilities are not equal to the demands of the motor spirit trade. Even the Thames has its vexed question of bulk petrol transport and storage; the difficulty is to settle where the line is to be drawn at which ocean-going tank steamers may be unloaded and the stocks of motor spirit carried for distribution. At present there is only one port in the United Kingdom—that of Barrow—where ocean steamers are allowed to lie in dock and discharge direct into the shore tanks, and both the leading importers have erected important storage installations at this point.

The storage arrangements on the Thames are certainly peculiar. . . . Even the Admiralty, depending as they do on motor spirit as the power for their submarines and launches, are compelled to handle and receive their supplies in the present inadequate and out-of-date manner.

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(At a recent meeting of the Society of Engineers, an important paper on the subject of Liquid Fuel for Internal Combustion Engines was read by Mr. R. W. A. Brewer, A.M.I.C.E., A.M.I.M.E., and from this communication the following extracts will possibly prove interesting. It will be noticed that Mr. Brewer's remarks agree in many respects with those expressed by myself in a special article appearing in *The Times*, March 11th, 1908. Extracts follow.)

Since the introduction of the gas engine as a commercial machine, the advantages of liquid fuel over gas, as the motive agent, became apparent, and these advantages have been steadily increasing to the present day. Manufacturers are designing and building liquid fuel combustion engines in constantly increasing sizes, and it is, perhaps, still a debatable point whether or no large marine engines of this type can be successfully used. In a discussion at the Institution of Civil Engineers, the author advocated the adoption of liquid fuel of high flash point for marine work, in place of produced gas, as proposed. The most important point in the problem being the production of the explosive mixture, he suggested the adoption of a heavy oil, that is, the residuals from the distillation of the lighter fractions, this having a minimum flash point of 350° F., and therefore being safe for marine use. About ten years ago the lighter fractions of petroleum were first utilised commercially as fuel for motor cars. At that time it was necessary for the fuel to be of the simplest nature, as far as its carburating properties and manipulation were concerned. The specific gravity of this spirit was ·680 and the type of carburetter then employed depended upon the volatility of the spirit for efficiency. The ·680 spirit may be considered as hexane, being a mixture of this with higher and lower members of the saturated hydrocarbons, and being represented by the formula $C_6 H_{14}$.

The carburetters in general use at the present day are of the jet-spray type, and allow the use of far heavier spirit. The specific gravity of the spirit alone is no true measure of its suitability for motor cars or similar use, the range of boiling points as observed in a distillation test being of far greater value. The proportion of hydrocarbon vapour which the air takes up varies with the volatility of the petrol and the humidity, pressure, and temperature of the atmosphere. For instance, dry air will take up the following quantities of vapour from petrol having a specific gravity—0·650.

17·5 per cent. by volume at 50° F.
27 ,, ,, 68° F.

before the air is saturated. These percentages are equivalent to

1 vol. vapour to 5·7 of air at 50° F.
1 ,, ,, 3·7 ,, 68° F.

showing that a small increase in the temperature largely increases the percentage of petrol vapour which can be retained by the air. Petrol of a specific gravity 0·700 containing 83·72 per cent. C. and 16·28 per cent. H. has a vapour density of 0·24 lb. per cubic foot at atmospheric pressure when at a temperature of 32° F., or nearly three times the density of air. With regard to the open evaporation of petrol of various densities and chemical compositions, the author has made a number of experiments in order to determine the effect of temperature and air currents upon the time taken to effect complete evaporation. The apparatus consisted of an electrically-driven fan with speed controller, anemometer, a portable furnace, and a thermometer. Air currents of different velocities were passed over thin strips of paper saturated with the different fuels, and the time noted when the liquids had completely disappeared. The experiments were made before the tables of distillation had been studied in order that no possible bias could be introduced during the experiments. The results clearly show that although at ordinary temperatures there is a marked difference in the time taken by the petrols of the highest and lowest specific gravity, the application of heat makes the behaviour more nearly alike than does the effect of air currents alone. It also shows that although the chemical compositions of the Borneo spirit of 0·760 sp. grav. and the spirit of 0·720 sp. grav. are dissimilar, yet, owing to the similarity of the distillation tests of the two, the time taken for evaporation in this way is practically the same. The deductions made from such tests lead one to expect that when comparing the Shell spirit of 0·720 sp. grav. and the Borneo spirit of 0·760 sp. grav. no perceptible difference will be experienced when starting an engine cold, and that the behaviour of the engine in traffic, as far as flexibility is concerned, will be the same with either fuel. But when comparing the spirit of 0·780 sp. grav. (which contains fractions having a higher boiling point) and the other two spirits, we find that the former requires assistance in the form of heat to accelerate the action of vaporisation. This heat can be added in the following ways. Either the carburetter itself or the incoming air can be heated by the exhaust when the ordinary types of carburetter are employed, or the spray of petrol can be mechanically broken up in order that such fractions as do not readily vaporise may be carried in suspension into the engine cylinder itself.

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(C. DE THIERRY, in an article on "Petroleum and Strategy," in the March, 1908, number of *The United Service Magazine.*)

Petroleum was "struck" sixty years ago, during which time it has assumed an importance unparalleled in industrial history. Its original impulse was, however, the discovery of an Englishman that it could be successfully utilised for commercial purposes, since when English skill, capital, and enterprise have been vital factors in its evolution. But as it was with our raw materials and food supplies, so it was with the power creator of the future. We developed it anywhere and everywhere but under the Union Jack. When the first well was drilled in Baku it was known that England was in possession of the largest oil areas in the world. Since then Russia has broken down the monopoly of the United States, and Holland, which started in the race later than either, is a good third. But England does not even hold the fourth place, and only for the energy of a Scots firm in Burmah she would make no show at all.

Apparently Cobdenism, and the fact that our supremacy rests on coal, blinded us to the commercial possibilities of petroleum under the Union Jack. Hence, while a few fortunes have been made in England by means of the carrying and shipbuilding trades, the great cities and ports, the hives of industry and sources of new business, created by the production and refining of petroleum, are in foreign countries. . . . Ever since the potentialities of petroleum as a power creator were first demonstrated by the Nobels, the Admiralty has laboured tirelessly to adapt it to the British Navy. In this respect they showed a foresight and enterprise which have left our rivals far behind. Whatever may be said of them in connection with wireless telegraphy, the torpedo, smokeless powder, and other epoch-making inventions, they have earned the gratitude of their country in connection with liquid fuel. Had they been as apathetic as the City, it is just possible that we might have awakened to the value of a great Imperial asset when it was too late.

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Even in Burmah, where we have shown enterprise in adding to the world's supplies of petroleum, we have done no great things. . . . It is obvious that we are not making any record. When one thinks of the difficulty Indian statesmen find in adjusting the Budget one can only regret that British apathy is a contributing cause, since in the development of petroleum there is a profitable source of revenue. The Government is, however, alive to the situation.

It is, indeed, the Navy which has most cause to complain. Up to 1902 experiments were made with increasing success to demonstrate the value of liquid fuel as a power creator superior to coal, but always with a certain reserve of doubt. Since then, however, its position has become assured. Every problem in connection with its safe storage, complete atomisation, and smokeless combustion has been solved, and naval engineers are unanimous in believing that, with time, it will entirely supersede coal in warships. A sign of the coming revolution is the fact that the Admiralty is providing its own tank steamers for the transport of oil direct from the wells so as to escape the middleman in this country. Moreover, it is constructing great storage works at Plymouth, Portsmouth, and Chatham, capable of holding millions of gallons, and is utilising old battleships as oil depôts for the use of the Navy on the coast. The scheme is to be further enlarged by forming a chain of stations all along the frontier, a beginning having already been made in the Falkland Islands. It will thus be seen that the Admiralty is not asleep whatever may be the case elsewhere.

Speed is not the only advantage gained by firing war vessels with oil. It can be transferred from ship to ship in rough weather, whereas coaling is dangerous except in a calm. Moreover, the fire can be fed automatically, which means a saving in labour and, as there is absolutely no waste, a saving in weight. That is why the use of liquid fuel enables a fleet to remain longer at sea than is possible in present circumstances, and why in battle its range of action is extended, considerations which tell both in strategy and tactics. True, when a ship's bunkers are full of coal it protects her vitals, whereas oil cannot, but it is the only point where the driving power which has had its day scores over the driving power whose day is come. Now, it is very evident that the Power which can depend on the latter with such certainty as to dispense with the former will have an enormous advantage over competitors not so happily circumstanced. For this reason the Admiralty is straining every nerve to secure control of future sources of supply under the flag. In short, the only problem that remains to be solved in connection with liquid fuel should have been solved by the commercial community long ago.

For if England herself is not endowed with oil as she is endowed with coal, at every strategic point on her frontier she is in possession of rich deposits only waiting for exploitation. With the exception of the fields at the base of the Rocky Mountains, they are, moreover, in close proximity to the sea. But those are so vast, and their possibilities so great, that the question of transport on their development will be easily settled. Up to the present the difficulty has always been to get capitalists sufficiently interested in them to set the oil flowing, though Texas and Borneo, on which the Admiralty depends for its supplies to-day, were discovered much later. It is to be hoped that British apathy towards petroleum is at an end. As a matter of fact, since 1902 the City has waked up as it did twenty years ago in South Africa. After ridiculing the idea that there was gold in the Rand, and supporting the Gladstone policy of surrender, it suddenly perceived the mistake it had made, and went mad with the fever of speculation. Something similar will happen with regard to oil. But it is costly to deride the advice of experts until terrible strategical blunders have been made, and then have to retrieve the situation which our own lack of foresight has created. There is no question that, only for the uncertainty of supply within the Empire, the motive producer in the Navy would now be liquid fuel. But as long as we are dependent for it on the foreigner we cannot afford to supersede steam coal, which is one of our main sources of strength. And until we take the initiative no other Power will, unless, indeed, new sources of supply are tapped. Neither Germany nor Japan can, and the United States has fallen behind in naval enterprise, at any rate so far as the use of oil is concerned. Admiral Melville, Engineer-in-Chief of the

American Navy, admitted in 1902 that the change must come, but saw difficulties in connection with adopting liquid fuel to battleships and cruisers, as well as in connection with transport. The first is being rapidly overcome, and surely the second is inseparable from supply. The moment it is placed beyond doubt that oil is a permanent need of the Navy, and enterprise develops our neglected resources, the creation of a perfect system of organisation is merely a question of time. When it is remembered that Baku is linked up with Batoum, its outlet, by a pipe line nearly six hundred miles long, and that the pipe lines in the United States would girdle the world, some idea may be formed of the magnificent way in which the transport necessities of the industry have been met for commercial purposes. Can any one doubt that the navies of the world would be served less well when their policy is definite?

That the substitution of liquid fuel for coal in the Navy will forge another link in the Imperial chain can hardly be denied. Hitherto England herself has produced steam coal, and of unrivalled quality, an advantage of which the coming change will deprive her, as her shale oil deposits can never secure her strategical position. This can only be done by the aid of her dependencies and the Dominions. Without it, however, England to-day would be in a worse position than any other of the great Powers, even Germany. She would be absolutely dependent on the foreigner for the motive power of her fleet in peace time, and in war time there would always be the danger that her supplies would be cut off. Can one imagine a more helpless position, or one more paralysing to strategy.

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(MR. HUGH PEARSON, M.I.M.M., M.Inst.Min.E., in an article on "Argentine and Its Oil Resources," in the March number of *The Petroleum World*. There is no country which is more urgently in need of oil fuel than the Argentine and there is certainly no part of the world about whose petroliferous possessions so little authoritative information has been published. Hence the following extracts.—Author's note.)

The Argentine is making rapid strides to the front, and must be considered one of the world's most valuable commercial assets. . . . A small but influential section of the community want Argentine to become a manufacturing country capable of supplying its own wants. In short, they want it to become another United States of North America, but, unlike the United States, it has no coal and little timber, and the level nature of the country for long distances from the present coast populated centres makes water power to generate electricity out of the question. The problem of a convenient and abundant source of fuel supply has not been solved. These facts make the discovery of petroleum in commercial quantities of immense importance—an importance which cannot be overstated, and any one who does not know the country and the actual state of affairs may be excused for blaming the Executive for not having practically recognised the existence of this possible source of wealth. In the question of fuel and light all are interested, and the time has undoubtedly arrived when the Government must act and encourage every legitimate private enterprise which honestly attempts to find a paying oil field. The railways have extended to within measurable distance of the recognised petroleum-bearing zone, for it should be pointed out that the presence of petroleum springs has been common knowledge for many years, and, indeed, efforts were made at one time to open up the oil fields of the country. One of these did meet with a fair amount of success. For a time some of the locomotives on the Great Western Railway were fired with liquid fuel from the Mendoza well. The quantity was diminishing when a torpedo was exploded and put an end to the enterprise by stopping the supply altogether. This was unfortunate, because there are those who firmly believe that if additional capital had been forthcoming this area would have proved productive. In any case, this is a question which should be thoroughly investigated by a capable engineer.

Some years ago, several attempts were made to find oil in the province of Jujuy, but these were less successful than the Mendoza enterprise, although the engineers who had charge of the works abandoned their posts with the strongly expressed conviction that if their financial backing had been sufficiently strong to enable them to put into practice their increasing knowledge of the district success would have crowned their labours.

Nothing more was done until quite recently, when a number of enterprising people took the matter up and are now busy carrying on operations at various points. Recent discoveries tend to prove that the deposits are even more extensive than even interested parties suppose, and I will be very much astonished if we do not hear of important developments in the near future.

If the British Government has found it advantageous to assist the exploratory work of finding petroleum in Nigeria, it is surely of greater importance to the Argentine to assist in proving its own immediate possibilities, the more especially as it has no fuel of any kind and is dependent upon outside sources for all its supply of fuel, petroleum, kerosene, petrol, &c. In 1906 the country imported 2,339,655 tons of coal. It was stated in the *Daily Telegraph* ·hat two cargoes of coal from Natal had been sold to the

Western Railway at 30*s*. per ton. Taking this figure as the price of coal in 1906, the sum paid for coal alone was £3,409,482. To this another million can be added for the cost to the nation of mineral oils and other products from petroleum. These are large figures for such a small population; they certainly speak for themselves, and will go on speaking louder and louder as the nation advances and the population increases—indeed, they constitute a direct appeal to the Government to act, not only to save this £4,500,000, but to establish new industries and manufacture their own ploughs, reapers, and the hundred and one things that are now imported at high figures. We are well aware that more than fuel is required in this connection. The raw material is wanted—iron, copper, and other minerals. These are to be had in the Andes for all the necessities of the country; but at present they are worthless because of the absence of fuel to smelt and the prohibitive cost of transporting the ore.

Find petroleum as fuel to smelt on the spot, or in the vicinity, and new and important industries will arise and spread themselves all over the Andes and carry prosperity and activity into every corner of the country.

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(Quotation from a Los Angeles source. By favour of H. B. Guthrey. April 16th, 1908.)

John Bull, staid old model of conservatism that he is, has advanced beyond Uncle Sam in the choice of fuel for his navy. Britain's ships are being changed to burn liquid fuel. Meanwhile we are building one vessel along this line as an experiment, although we have in California the finest supply of fuel oil in the world, while Great Britain does not produce one drop at home, and her colonies, India and Canada, do not rank high as producers of oil suitable for fuel. Moreover, in making the change Britain is going directly against the immense coal interests of England and Wales.

Admiral Evans's fleet is burning coal. Coming around the Horn the coal question was one of the serious problems to be faced. It has been demonstrated by merchant ships that enough oil can be carried to make a long voyage, and the statement was published, and never denied, that the Nebraskan actually did go from San Francisco to New York with enough oil fuel on board to last the entire trip. Quite recently Senator Hale created a sensation in the Senate by declaring that the navy was handicapped by lack of colliers. It will be readily seen that the enlargement of the steaming radius of ships without replenishing fuel supply would in itself be a great advantage. The objection that coal, on account of its world-wide use, is obtainable anywhere, while oil is not, is bound to lose its effectiveness very quickly when once it is used on British and American warships, as storage stations will have to be placed in every port just as coal depôts are now located. Oil could be kept just as well as coal at Magdalena Bay.

Besides greater storage capacity and larger steaming radius, there is the greater ease of loading. Coal in a warship is one of the things most dreaded by naval men; it means much work and dirt, while oil may be taken through a pipe without hard labour or dirt.

The reduction in the number of stokers, the substitution of cooler fire rooms for the present stokeholds, where men go often to sickness, and sometimes to death, in hot weather trips, such as the one just completed, or the Oregon's memorable voyage—these points are in oil's favour. There is in the popular mind a halo of romance connected with this work of the heroes of the stokehold, and there may be some sentimental regret at their passing, but there is not the least doubt that their elimination will be a benefit to all concerned.

Modern conditions have entirely done away with the "old salt," who cannot hold his own in this age of science and brains aboard ship, and, undoubtedly, the use of oil will do away with the services of the fireman, whose chief and only qualification is his endurance.

Fears of explosions and fires in oil tanks have been shown to be groundless. There were those who predicted all kinds of disasters when the Espee and Santa Fe decided to use petroleum in locomotives. Oil fires were to destroy all the cities of California (although oil, and high gravity oil, too, had been safely used for years in Russia), and horror after horror was to follow its use on the water. None of these predictions have proved true. Neither will any such disasters happen in the warships if the new fuel is properly stored and handled by experts.

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Sir Boverton Redwood has informed the author that in his Presidential Address, to be delivered at the Annual Meeting of the Society of Chemical Industry in Newcastle in July, he intends to refer to the progress which has been made in the employment of liquid fuel in the British Navy since he gave evidence before the Royal Commission on Coal Supplies, and especially to deal with the question of the substitution of internal combustion engines for steam engines in the propulsion of battleships.

Sir Boverton alludes to the remarkable results obtained by the use of oil fuel in the smaller vessels of the Navy, the torpedo boats and destroyers, the Thornycroft destroyer Tartar, with water-tube boilers and turbine engines of the Parsons type, having developed a mean speed on her trials of no less than 35·672 knots, whilst the difficulties at first experienced in obtaining smokeless combustion have been completely overcome. He also points out that the larger vessels of the Navy, the battleships and armoured cruisers, are now all fitted to burn liquid fuel as an adjunct to coal, giving increased radius of action without replenishing bunkers, and providing the means of very rapidly raising steam in an emergency.

He emphasises the fact that one great advantage of liquid fuel is that it can be kept in tanks for an indefinite period without deterioration, whereas coal, on prolonged storage under ordinary conditions, may lose 40 or 50 per cent. of its thermal efficiency, and he states that if he had the control of the public purse he should not hesitate to expend a large sum during times of peace in the accumulation at convenient ship-fuelling centres of large stocks of oil fuel.

Sir Boverton points out the difficulties attending the construction of internal combustion engines of the high power needed for the propulsion of battleships, quoting eminent authorities in support of his statements, and expresses the opinion that just as the incandescent mantle has enabled coal gas to withstand the competition of electricity as a source of light, and has given it a new lease of life as an illuminating agent, so the substitution of the Parsons turbine for the reciprocating steam engine, coupled with the use of liquid fuel, will delay for a long time the introduction of the internal combustion engine as the source of power in the larger ships, and meanwhile the importance of liquid fuel will not decrease.

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Some few months ago, when a scheme of storage for oil fuel for the Navy was embarked upon, and when many of the smaller craft were fitted to burn oil only, it was decided to provide armoured vessels with oil fuel burners as auxiliary to coal. No doubt the Admiralty are reluctant to make the great vessels of the fleet dependent on a foreign fuel, so the bunkers of battleships and cruisers will continue to be filled with the products of the Welsh coal field, while in the double bottoms and tanks oil will be stored as a reserve. It is proposed to spray the oil on the coal when an extra spurt of speed is needed. Used in this way, oil fuel has the same effect as champagne has on a sprinter, and really remarkable results are obtained from it.

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The real problem of the moment is to find a reliable method of mechanical stoking at sea, so that the terrible work in the stokehold of an Atlantic mail steamer may be lessened. In an article in the *New York Times*, Mr. Lewis Nixon, an American authority on marine subjects, says that, while the gas engine will soon be the prime mover most in use on the sea, the next great departure will be the doing away with the man-fired coal-burning boiler on Atlantic liners. This will result in a great saving in men, fuel, weight, and space, besides avoiding constant cleaning of fires, with incident violent changes of temperature conditions. While no longer experimental, the use of oil fuel for boilers means that methods of burning, handling the oil, and placing of tanks must be devised, offering a fruitful field for the inventor. The development of oil fuel for ocean liners is hampered by the uncertainty of supply. The whole available oil supply is in the hands of a few companies, who could play great havoc with customers if they were to combine.

# LLOYD'S RULES FOR THE BURNING AND CARRYING OF LIQUID FUEL.

(The Secretary of Lloyd's Register of British and Foreign Shipping has courteously supplied the author with a copy of the Society's latest rules for the burning and carrying of liquid fuel.)

Section 48. 1. In vessels fitted for burning liquid fuel, the record "Fitted for liquid fuel" will be made in the Register Book.

2. The compartments for carrying oil fuel must be strengthened to efficiently withstand the pressure of the oil when only partly filled and in a seaway. They must be tested by a head of water extending to the highest point of the filling pipes, or 12 feet above the load line, or 12 feet above the highest point of the compartment, whichever of these is the greater.

3. If peak tanks or other deep tanks are used for carrying liquid fuel the riveting of these should be as required in the case of vessels carrying petroleum in bulk. The strengthening of these compartments must be to the Committee's satisfaction.

4. Each compartment must be fitted with an air pipe to be always open discharging above the upper deck.

5. Efficient means must be provided by wells and sparring or lining to prevent any leakage from any of the oil compartments from coming into contact with cargo or into the ordinary engine room bilges.

6. If double bottoms under holds are used for carrying liquid fuel, the ceiling must be laid on transverse battens, leaving at least two inches air space between the ceiling and tank top and permitting free drainage from the tank top into the limbers.

7. The pumping arrangements of the oil fuel compartments and their wells must be absolutely distinct from those of other parts of the vessel and must be submitted for approval.

If it is intended to sometimes carry oil and sometimes water ballast in the various compartments of the double bottom, the valves controlling the connections between these compartments and the ballast donkey pump, and also those controlling the suctions of the special oil pump, must be so arranged that the suctions for each separate compartment cannot be connected at the same time to both pumps.

8. No wood fittings or bearers are to be fitted in the stokehold spaces.

9. Where oil fuel compartments are at the sides of, or above, or below the boilers, special insulation is to be fitted where necessary to protect them from the heat from the boilers, their smoke boxes, casings, &c.

10. If the fuel is sprayed by steam, means are to be provided to make up for the fresh water used for this purpose.

11. If the oil fuel is heated by a steam coil the condensed water should not be taken directly to the condenser, but should be led into a tank or an open funnel mouth, and thence led to the hotwell or feed tank.

12. The above arrangements are applicable only to the case of oil fuel the flash point of which as determined by Abel's close test does not fall below 150° Fahrenheit.

"I do not think you can possibly secure safety by any flash point, if there is leakage, for instance, of oil over the foot-plate in a stokehold, where they would be sure to get it on fire whatever the flash point is. If there is no leakage (and there ought not to be any), then 150° is high enough, because I do not think that tanks in which this oil is kept on board ship would ever acquire such a temperature as 150° F."

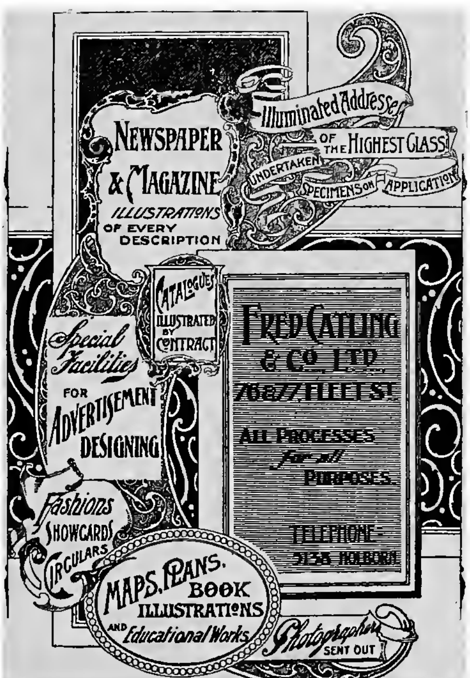
SIR BOVERTON REDWOOD.

"IT is evident that with a well-designed apparatus, it is possible by good management to realise in actual practice the full difference in calorific value between liquid and solid fuel, at rates of evaporation such as are usually obtained in the boilers of vessels of the mercantile marine. At the higher rates of evaporation required in war vessels the problem becomes more complex, but now it is receiving the serious attention of the Admiralty, no doubt a satisfactory solution of this most important question will be arrived at."

E. L. ORDE, in 1902.

THE results secured by the employment of British capital and brains in the oil fields of Burmah, California, and Mexico can be repeated and even surpassed in scores of territories in the Empire. There is no reason why these places should witness a repetition of British blunders in Baku; with the undertakings properly financed and the territories skilfully exploited, they should win for us a new record in this great and difficult branch of mining. Believing this, new men are being called upon to engineer the British petroleum enterprises of the future.

THE world-famous Austrian Company, the Galizische Karpathen-Petroleum-Actien-Gesellschaft, started to burn liquid fuel exclusively two years ago. On the subject of the advantages of oil fuel burning, Mr. F. J. MacGarvey has said—"The question as to whether liquid fuel or coal should be burned must always depend, in these regions, at any rate, on the price of the crude oil. As to the calorific value of crude, I should say that it is, in round figures, 10,000, whereas good Silesian coal is about 6,500. It is easy to understand that with the price of crude at 1.50 kronen per 100 kg. f.o.b. Boryslaw, and Silesian coal at 2.50 kronen f.o.b., refinery Maryampole, there cannot be much question as to which fuel is the most economical."



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