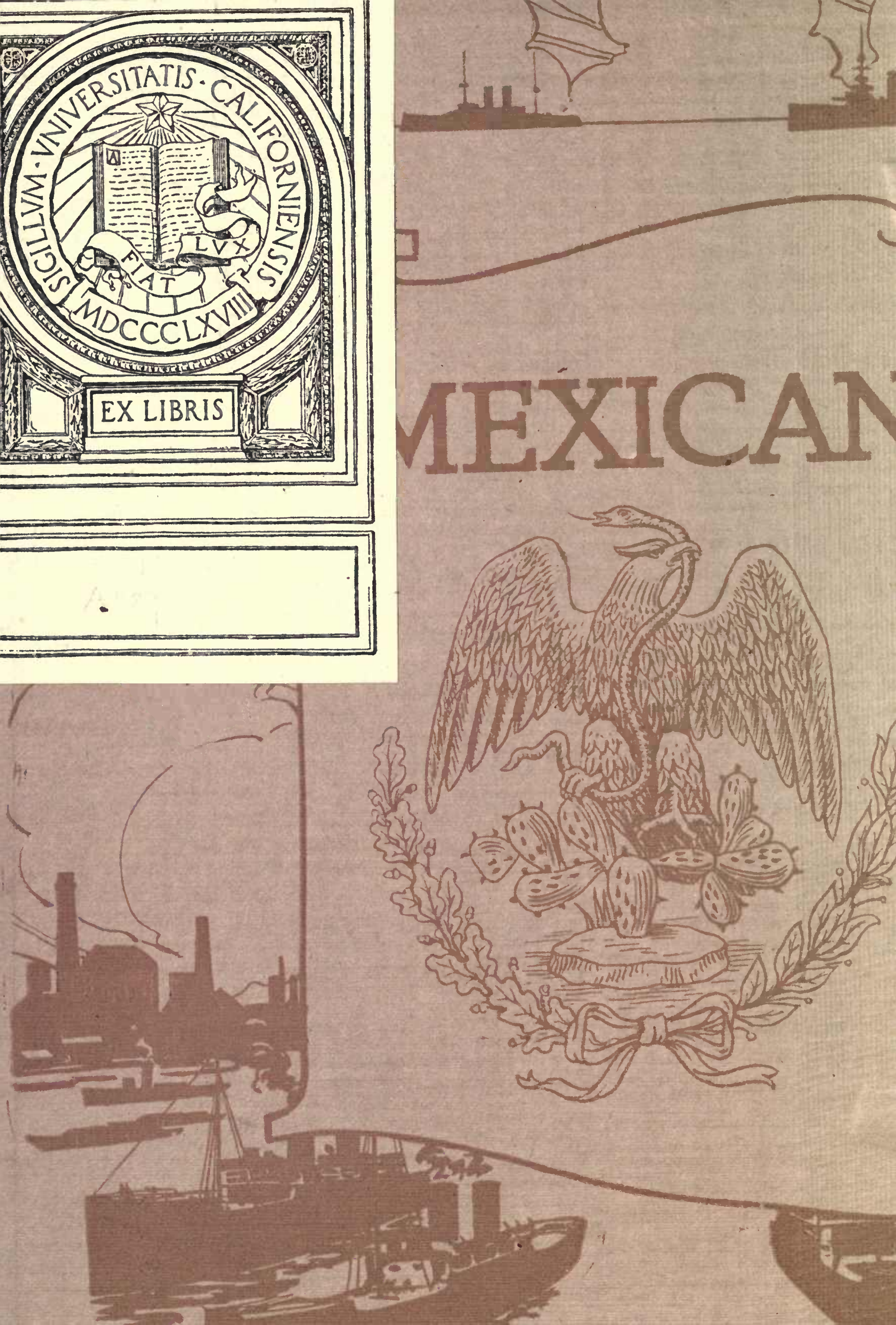
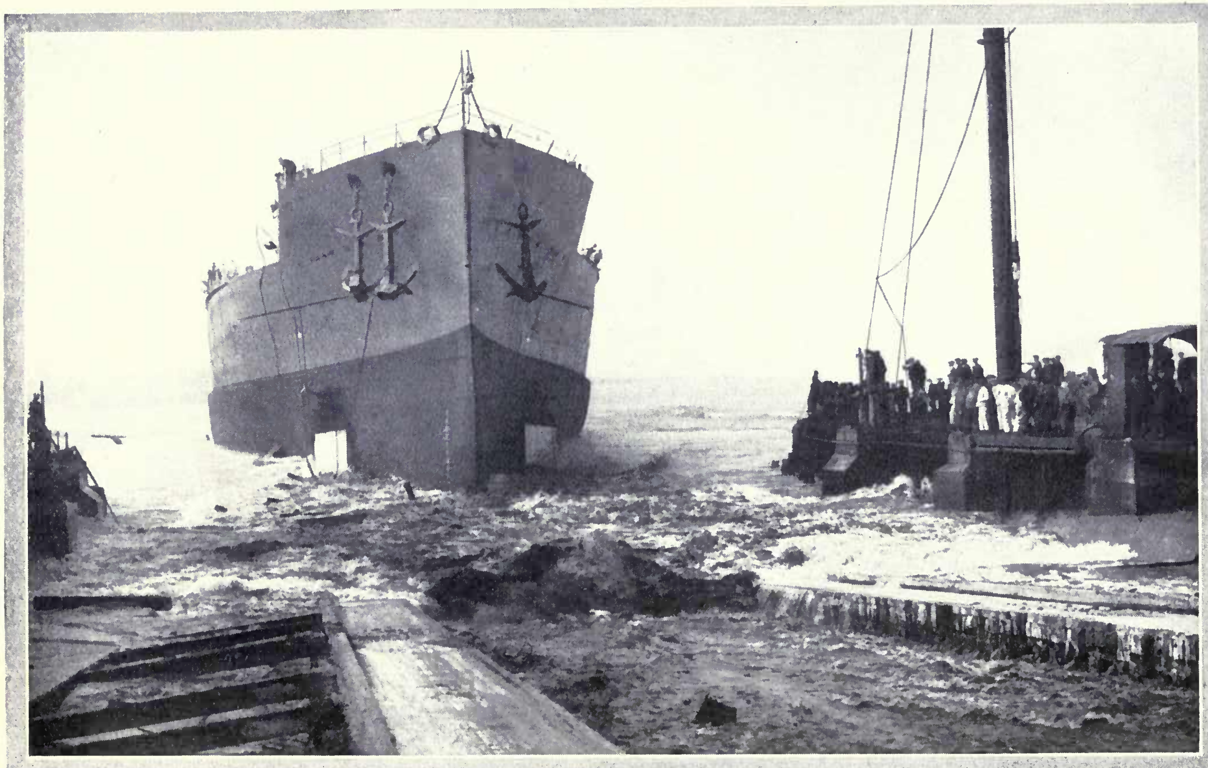
MEXICAN FUEL OIL


MEXICAN

FUEL OIL
for
STEAMSHIPS
LOCOMOTIVES
LAND BOILERS
INDUSTRIAL FURNACES
& OTHER USES

MEXICAN
FUEL OIL



Photo] LAUNCH OF H.M.S. "QUEEN ELIZABETH." [*Cribb. Southsea.*

The first large battleship built to burn oil fuel only.

MEXICAN FUEL OIL

Price 3/6 nett.

ANGLO-MEXICAN
Petroleum Products Co., Ltd.,

FINSBURY COURT, FINSBURY PAVEMENT,
LONDON, E.C.

New York: 32, Broadway.

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CHAPTER I.

MEXICAN FUEL OIL.

The Progress of Petroleum

THE growth of petroleum production from its early beginnings to its present world-wide development is one of the romances of commerce. From the drilling of the first well in 1859 to the present day has been a story of continuous expansion. In 1860 the production totalled 500,000 barrels; to-day the world's total output has reached the remarkable figure of over 351 million barrels. The production of petroleum during the last decade is shown in graphic form in the chart below.

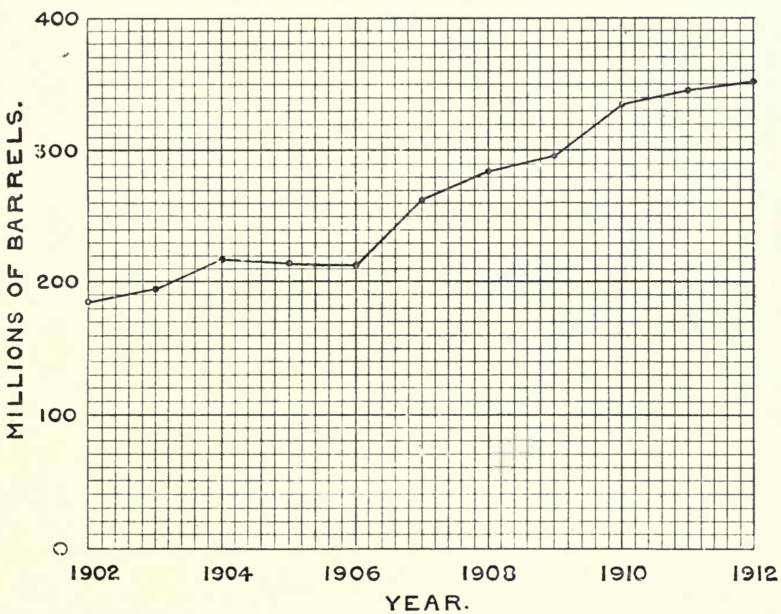


FIG. 1.—THE WORLD'S PRODUCTION OF PETROLEUM.

Oil for Power Production

This vast growth in output is beyond question due to the use of petroleum, especially within the last few years, in the production of power and heat.

It is only within the last few years that the extensive geological distribution of oil has been proved, and there can be no doubt that, although the progress of the industry has been rapid during the last decade, it will be altogether eclipsed by the expansion and development of petroleum for power purposes in the near future.

Oil and Coal

It is interesting to compare the latest available figures of the annual production of crude petroleum with that of coal. The former in 1912 amounted to 42 million tons, while the world's production of coal in 1911 amounted to 1,050 million tons. Less than one-third, however, of the coal annually consumed is used for power production, whereas three-fourths of the petroleum produced is so employed. In fact, the comparison, weight for weight, between the quantity of oil used for power purposes and that of coal is as 32 million tons to 350 million tons, i.e. 9 per cent.

When the respective heating values of the two fuels are considered the proportion is increased to 48 million as to 350 million tons, that is to say, the total power now produced by means of petroleum already reaches the significant proportion of over 13 per cent. of the total power produced from coal.

Petroleum provides a source of power in three of its principal products, namely :—

Motor Spirit or petrol as used for motor cars.

Refined Oil, generally known as paraffin or kerosene and used largely for internal combustion engines, and as a source of heat in certain types of steam motors.

Fuel Oil, which has its principal use in steam raising and heating for various industrial purposes. It is this branch of the industry to which this book is confined.

"Oil fuel," "liquid fuel," and "fuel oil" are interchangeable terms for the same product. The term "crude oil" in this connection is a misnomer, as crude oil contains certain fractions, such as petrol and kerosene, which are removed by distillation from the crude oil before it becomes fuel oil. Oil fuel is a heavy, dark-coloured product, and is usually more viscous than the crude oil from which it is produced. **Fuel Oil**

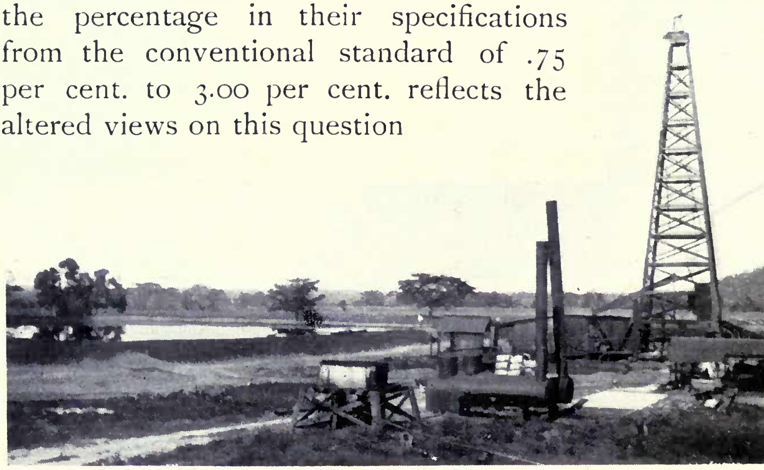
The analysis and specification of Mexican Fuel Oil is approximately as follows :—

Carbon	83·52%
Hydrogen	11·68%
Sulphur	3·27%
Ash	0·16%
Undetermined (presumably Oxygen and Nitrogen)...	1·37%
	100 00

Specific Gravity at 60° Fah.	about ·950
Flash Point	above 150° F.
Viscosity at 100° Fah. (Redwood No. 1) ...	1,500 seconds
Calorific value—	
Per pound	18,900 B.T.U.'s
Per kilogram ...	10,500 calories

In the past some prejudice has existed against an oil containing more than .75 per cent. of sulphur, although no scientific reason can be given for fixing this or any other arbitrary figure. No objection, however, is made to the presence of sulphur in coal, nor any record of deterioration of boilers on this account. It is significant that the amount of coal of average quality required to give an equivalent heating value to a pound of oil would contain more sulphur than is contained in one pound of Mexican fuel oil. The extensive experience with oil burning which is now available shows that boiler corrosion does not take place. The only point that need be mentioned in this connection is that it is advisable, when steel chimneys are used, that the temperature of the flue gases should not fall below 400° F., a contingency which rarely arises in actual practice.

The only drawback attaching to the presence of sulphur in fuel oil is that its heat value is somewhat low, *i.e.*, 4,500 B.T.U. per pound, and consequently the total B.T.U.'s per pound of oil are slightly lower on account of its presence. The fact that the British Admiralty have, after careful investigation, raised the percentage in their specifications from the conventional standard of .75 per cent. to 3.00 per cent. reflects the altered views on this question



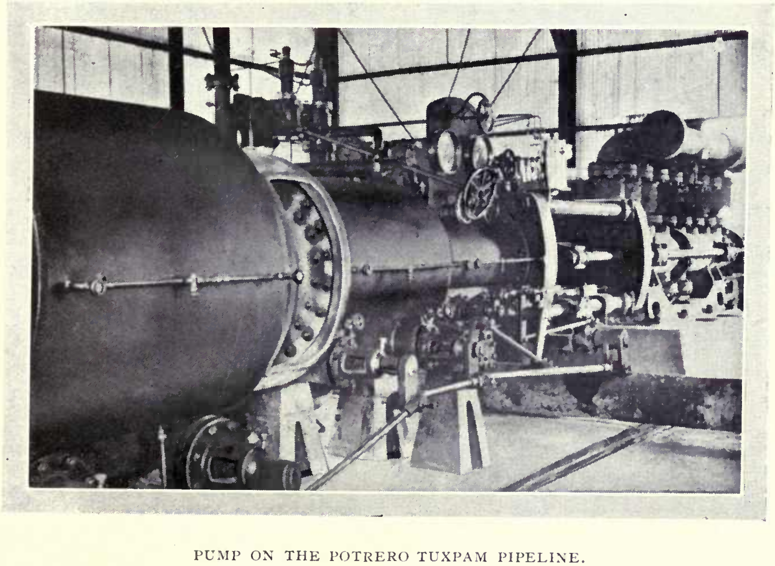
DRILLING A WELL ON MEXICAN OILFIELDS.

The Increasing Demand

Within recent years a widespread and constantly increasing demand has arisen for fuel oil, and there is no doubt that but for the uncertainty respecting supplies which has existed in the past, the progress made would have been even greater. It is self-evident that however satisfactory any form of power production may be theoretically, its commercial success inevitably depends on a fuel supply being available in large quantities, with uniform supplies and at reasonable prices. Hitherto there has been uncertainty about supplies, coupled with fluctuations in prices, with the consequence that many engineers have looked upon oil fuel burning, however desirable in other respects, as an expensive luxury.

Mexican Oil

Within the last year or two, however, a new factor has appeared in the oil fuel question, namely, the development of Mexican oil supplies. A few years ago Mexico was scarcely entitled to a place in the list of the world's



PUMP ON THE POTRERO TUXPAM PIPELINE.

petroleum production. To-day she holds third place in the list of oil-producing countries in the world, ranking next to the output of the United States and Russia. At the present rate of progress Mexico will in a few years become the second largest producing country.

Fig. 2 gives graphically the annual Mexican production from the year 1907, and it may be mentioned, in passing, that while the production of crude oil in Russia

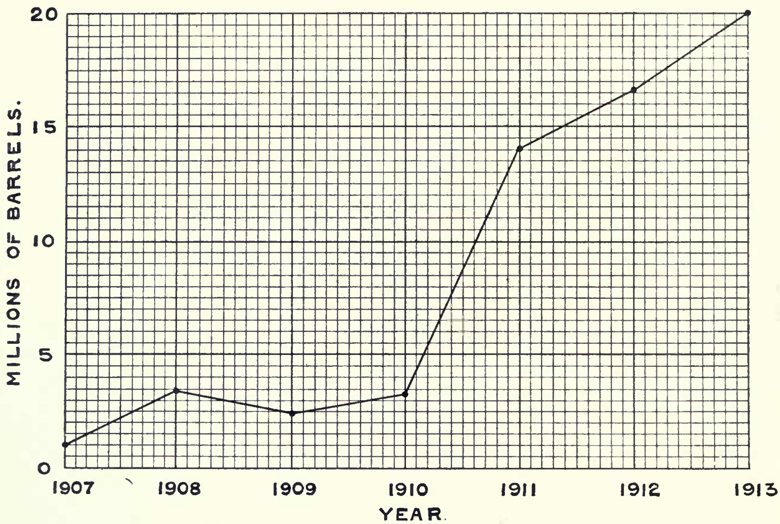
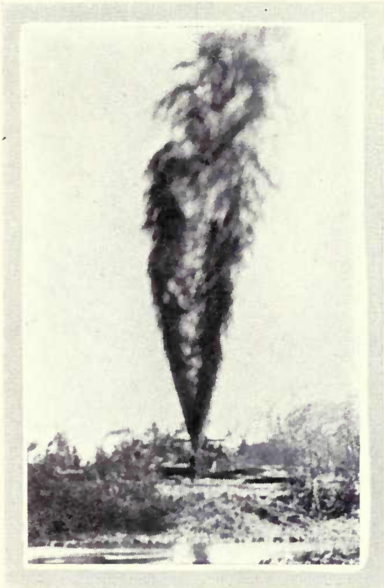


FIG. 2.—MEXICO'S PRODUCTION OF PETROLEUM (1913 *is estimated*).

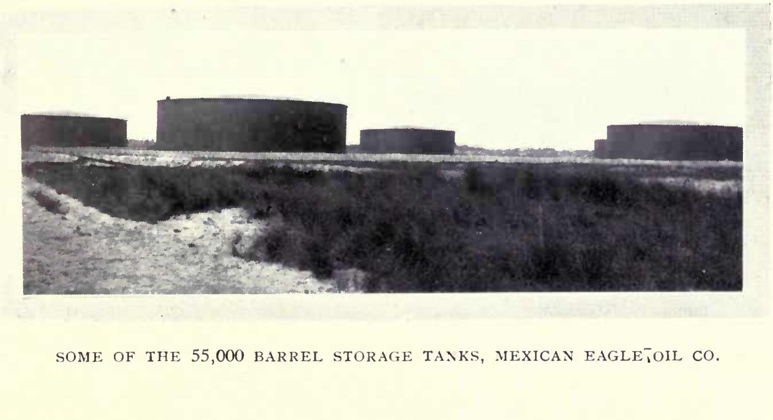
and the United States during the last three years has shown little expansion, that of Mexico has shown rapid increase. So vigorous has been the growth of its petroleum industry that in three or four years it has shot ahead of the old-established oilfields of Burmah, the Dutch East Indies, Roumania and Galicia. This remarkable progress is due almost entirely to the advent of the Mexican Eagle Oil Co., Ltd., the history of whose growth and operations could worthily form a book in itself.

Production

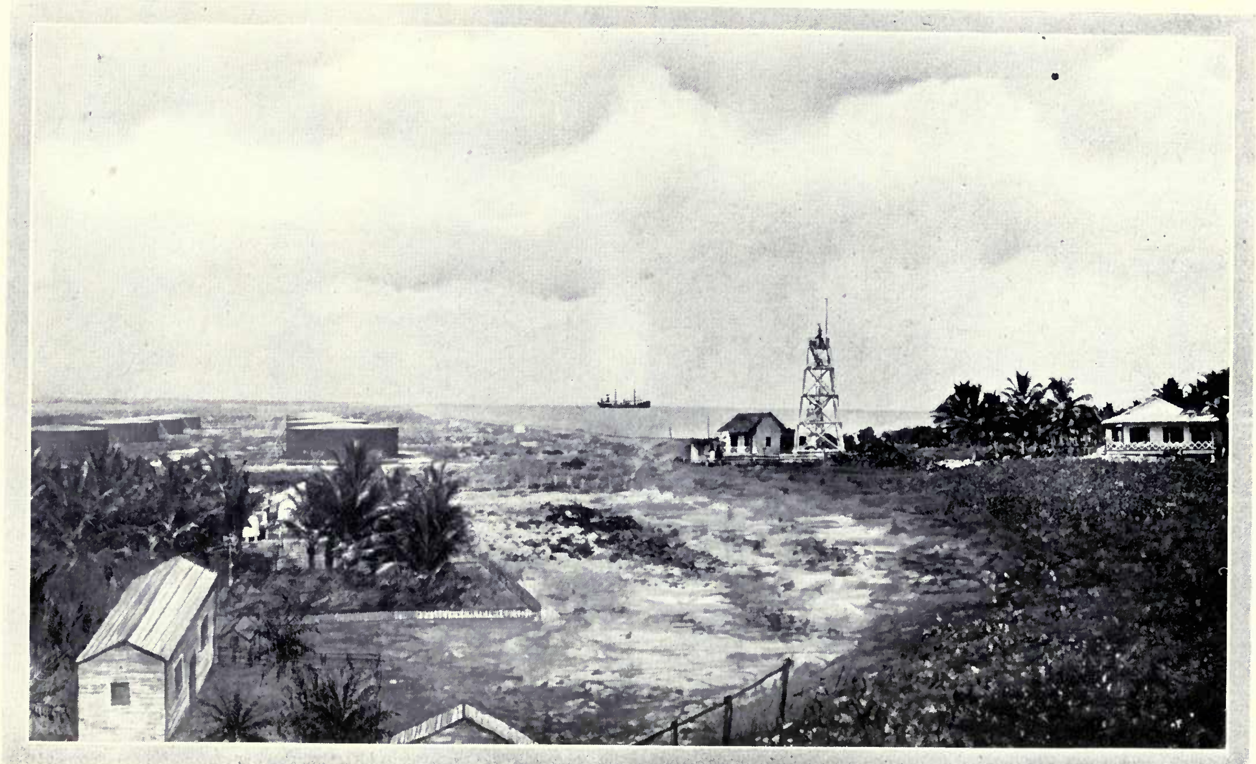


THE GUSHER POTRERO 4, BEFORE BEING CAPPED.

As is generally known, the Mexican Eagle Oil Co., Ltd., and its allied organisations have been created through the commercial activities of S. Pearson & Son, Ltd., and the position held by the Mexican Republic in the petroleum world to-day is mainly due to their initiative organisation and control. During the last decade the petroleum potentialities of Mexico were recognised by this engineering firm while they were engaged in the construction of railways and harbours in the Republic. Great areas of petroliferous territory, aggregating hundreds of square miles, were acquired. Numerous wells were sunk and several distinct oilfields



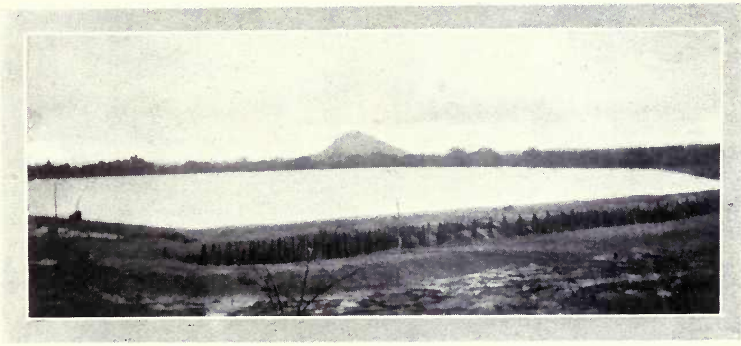
SOME OF THE 55,000 BARREL STORAGE TANKS, MEXICAN EAGLE OIL CO.



VIEW OF TUXPAM, SHOWING STORAGE TANKS AND STEAMER LOADING CARGO OF MEXICAN OIL FROM DEEP SEA LOADING LINES.

were rapidly developed. Reservoirs, tank farms, pipelines, pumping stations, refineries and tank-steamer loading terminals were established.

The territories developed have proved exceedingly prolific, and in 1911 the world's record gusher, Potrero well No. 4, was brought in with a natural capacity of

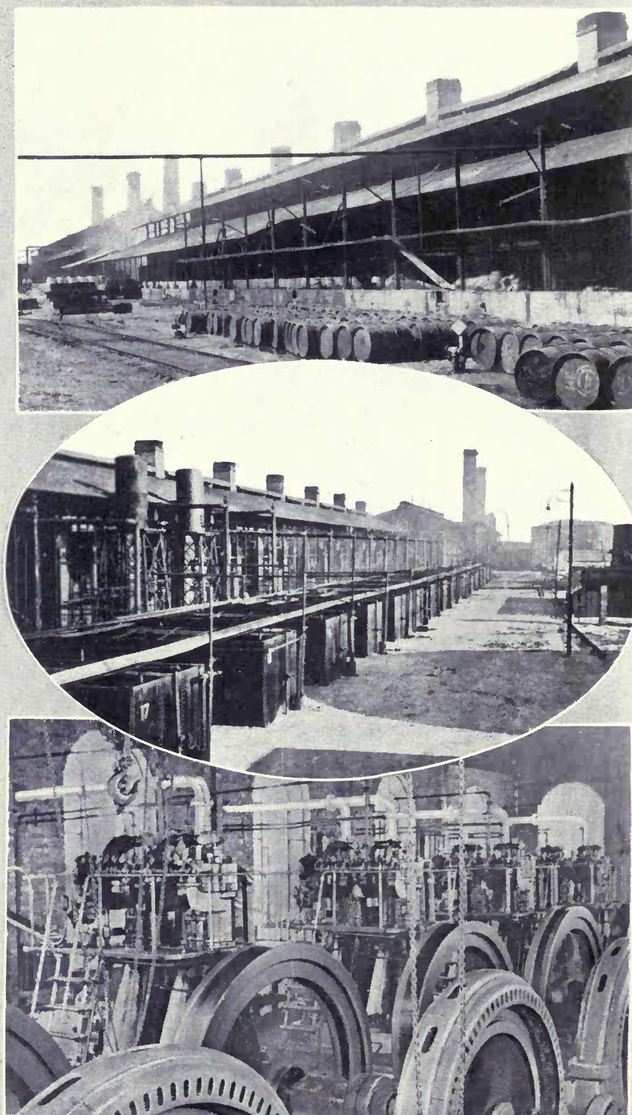


STORAGE RESERVOIR AT POTRERO—2,500,000 BARRELS.

over 100,000 barrels of oil per day, and the illustration of a vast lake of oil enclosed in an earthen reservoir represents a portion of its prodigious output.

By means of pipelines, aggregating over 200 miles in length, the oil is transported to the sea-board tank and refinery depots. On the Gulf coast, just north of the Tuxpam River, the Mexican Eagle Oil Co. have built a deep sea loading terminal where vessels of the deepest draught, lying at ocean moorings at a distance of about a mile from the shore, are rapidly loaded by means of pipelines laid on the bed of the sea. At the shore end these pipelines connect to a pump station and a large storage depot, with a capacity in steel tankage of over 150,000 tons.* Similar sea-board storage depots

* For ratio of tons to barrels see Appendix, page 138.



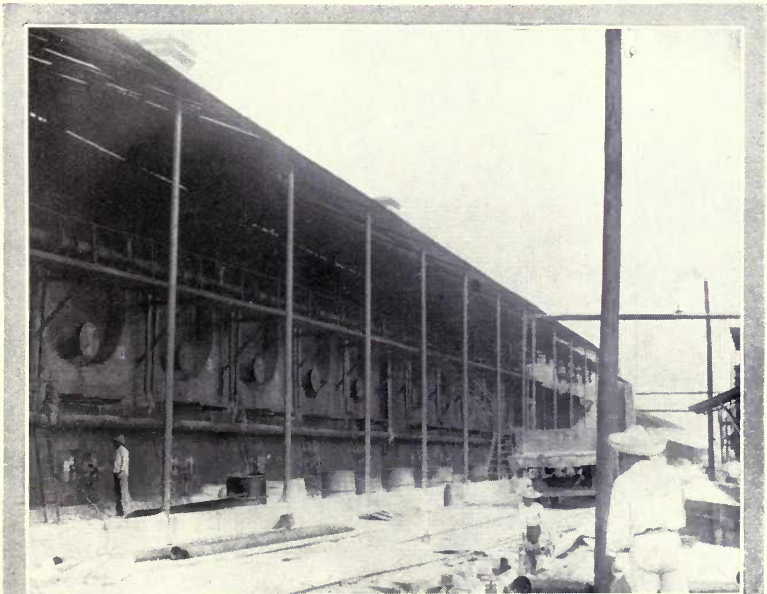
1. STILLS AT MINATITLAN REFINERY.
2. CONDENSER TANKS AT REFINERY.
3. POWER PLANT, MINATITLAN.

are located at Tampico, Vera Cruz and at Puerto Mexico on the Coatzacoalcos River. The total storage capacity of the steel tankage is over two million barrels.

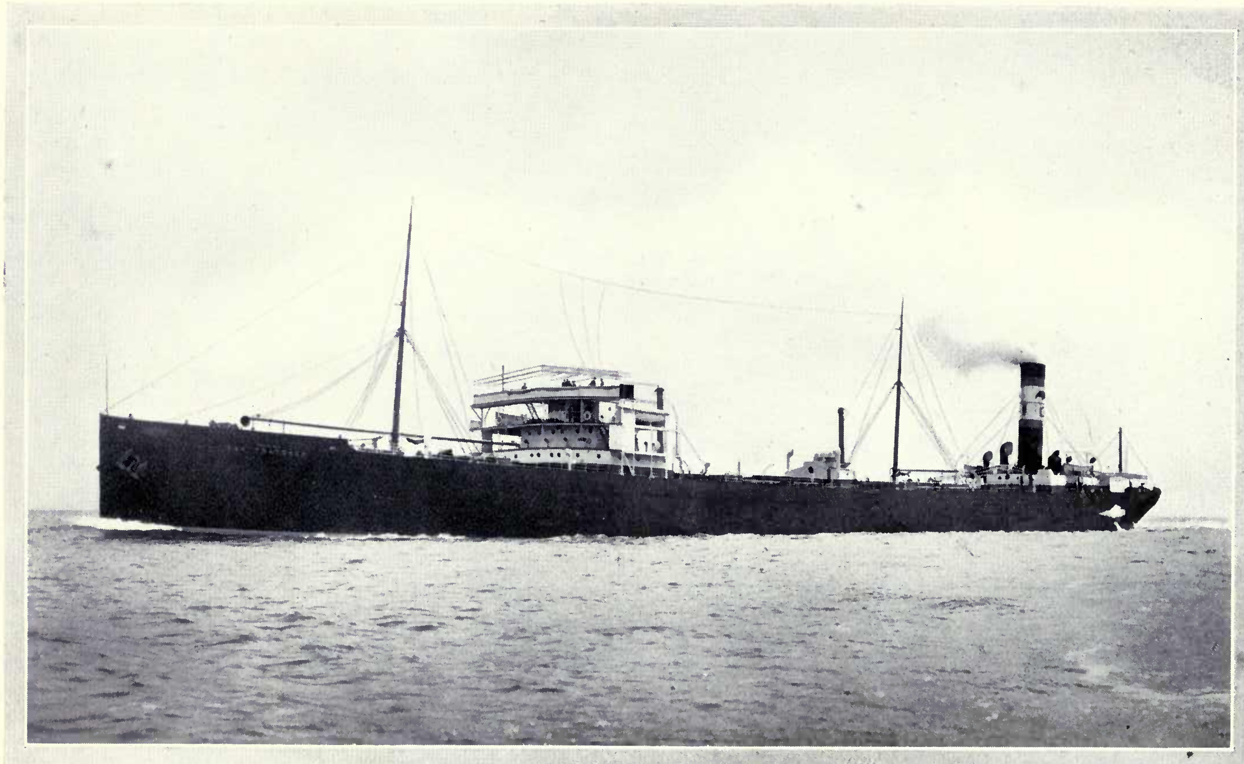
Refining

At Minatitlan the Mexican Eagle Oil Company have a refinery with a daily input capacity of 1,400 tons of crude petroleum, which is manufactured into a complete range of high-grade products, while another still larger refinery is now under construction at the port of Tampico, and when completed will treat some 4,000 tons of crude oil daily.

The Mexican Eagle Oil Co. possesses a complete and efficient marketing organisation for the supply of its home market in Mexico, where it has established over 160 depots throughout the Republic, and supplies the railways and other industries of Mexico with fuel oil and lubricants.



FRONTS OF CONTINUOUS STILLS, MINATITLAN.



THE WORLD'S LARGEST TANK STEAMER, "SAN FRATERNO."

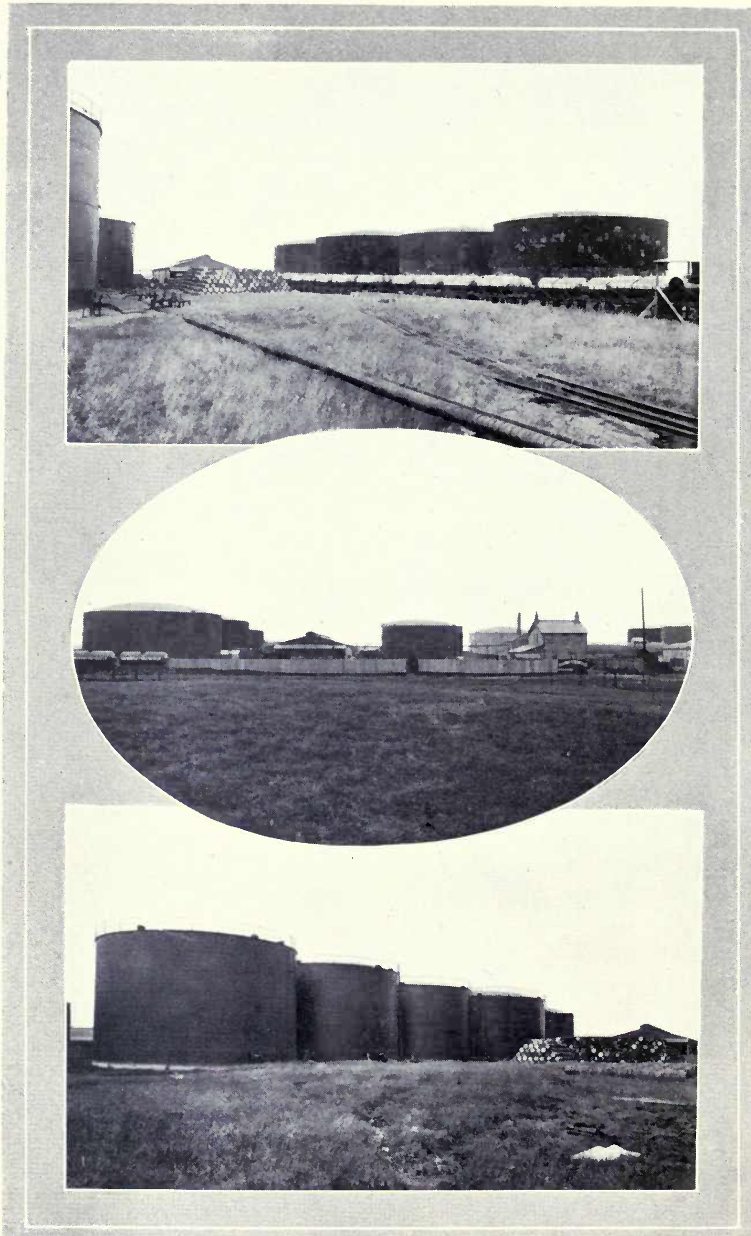
Transport

In order to deal effectually with the transport side of the business, the associated organization, the Eagle Oil Transport Co., is building a fleet of twenty large tank steamers. Ten of this number are giant vessels of over 15,500 tons dead weight capacity, larger than any other tank steamers in the world, the remainder of the fleet being of 9,000 tons capacity. Ten of these tank steamers are already in commission, and the sister ships are rapidly approaching completion in the yards of some of the premier shipbuilding companies of Great Britain. The whole of the fleet should be in active service by the end of 1914. It will give some idea of the capacity of this fleet to mention that placed end to end it would measure over 1¾ miles, the total carrying capacity being 250,000 tons per voyage.

The *San Fraterno*, the first of the larger vessels to be launched, has attracted widespread attention, and a few details of this mammoth vessel will be of interest. Built of steel on the Isherwood system, her length over all is 548 feet, and her total dead weight capacity is 15,700 tons. The oil cargo is carried in 12 holds, divided into 24 compartments by a longitudinal bulkhead. She is fitted with quadruple expansion engines, and the boilers are oil-fired on the Wallsend-Howden system. The cargo tanks are fitted with steam heating coils to facilitate the discharge of her cargo, and specially powerful pumps are installed, capable of handling 1,200 tons of oil per hour.

Distribution

From the seaboard refineries of Mexico the oil fuel is brought by these steamers to ocean storage installations in the United Kingdom and abroad. During the first nine months of 1913 more oil fuel was imported into this country from Mexican Eagle sources than from all



STORAGE TANKS AT BARTON, MANCHESTER.

other oil-producing countries combined, as is shown by the following figures, and during the same period the total United Kingdom imports of fuel oil exceeded those for the whole of the year 1912 by seven million gallons. These figures clearly indicate the progress fuel oil is making in this country.

IMPORTS OF FUEL OIL INTO UNITED KINGDOM.*

(Exclusive of Admiralty Imports.)

January 1st to October 13th, 1913.

Country of Origin.	Gallons.
Mexico	12 830,670
Roumania...	9,027,540
U.S.A.	2,836,330
Dutch Indies	299,497
Germany	400
Belgium	120
Other Countries	3,620
Total	24,998,177

It is significant that large quantities of Mexican fuel oil are now being exported to the United States of America, to the South American railways, and the State railways of Russia.

Fuel Oil Bunkers

For bunkering purposes oil can be taken ex storage installations at the principal ports in the United Kingdom.

The storage at Manchester, which has a capacity of over 31,000 tons, is typical of these facilities, and is the largest fuel oil installation on the west coast of England.

In order to meet the requirements of steamship lines engaged on transatlantic routes a number of oil bunkering stations at the usual ports of call in North and South Atlantic waters are in the course of active equipment.

* *Petroleum Review*, October 18th, 1913.

Inland Deliveries

Deliveries for inland requirements in the United Kingdom are made either by rail tank cars and road wagons, or by tank barges to consumers' works. The rail tank cars illustrated below have been built specially for the Anglo-Mexican Petroleum Products Co. for carrying Mexican fuel oil, and are provided with four-inch outlets on both sides, while a steam coil is fitted

FUEL OIL RAILWAY TANK CAR, FIFTEEN TONS CAPACITY.

inside, for permitting the fuel to be heated in frosty weather to facilitate discharge. Where the consumer has works adjacent to railway sidings, this method of delivery is usually employed Failing that, the oil is transferred to road wagons, and so delivered to consumers' storage tanks. Where works are situated on the water side, delivery is effected in tank barges with a carrying capacity of from 30 to 100 tons, and in this way a saving in the cost of transit is effected.

Forward Contracts

The organisation represented by the foregoing companies for the production, refining, transport and distribution of Mexican oil fuel is of the most complete and comprehensive character, and the extent of its properties and its transport facilities are in themselves a guarantee of continuity of supplies, which has hitherto been lacking. Forward contracts have been entered into with big consumers both in this country and abroad, and quotations for any quantities will be furnished on application.

Crude Oil

It is not generally known that large quantities of crude oil with a comparatively low flash-point are being used as a substitute for high-flash fuel oil. The difference between crude and fuel oil, as mentioned on page 3, is that with crude oil the preliminary distillation or topping process is omitted and the oil is used substantially as it comes from the wells. The saving in distillation enables crude oil to be offered at a price which is lower than that of fuel oil. In Mexico large quantities of crude oil are used in sugar mills, electric light and power stations, breweries, steel works, cement works, brick factories, and railways. This oil, which has a flash point of 80° F., can be used with entire safety and appreciable reduction in cost in all land plants where oil is the motive power.

While not specifically recommended for marine purposes, crude oil can be safely used for vessels, provided certain structural alterations are made. The Board of Trade now recognises that there is a future for the use of crude oil, and has passed regulations subject to which it may be used. These regulations stipulate that the oil pumps shall be isolated from the boiler room, and it may be mentioned that the *San Fraterno* is built on this principle, and runs on crude Mexican oil. There is no disadvantage in the use of crude oil as compared with fuel oil. The viscosity is lower, and it is therefore easier to handle, while the margin in price certainly makes it attractive from a commercial standpoint. It may be mentioned that no special structural precautions or increase in premiums are required by insurance companies in the United Kingdom when crude oil is burned in connection with land plants.

Quotations for supplies of fuel oil or crude oil will be furnished on application to Anglo-Mexican Petroleum Products Company, Ld., Finsbury Court, Finsbury Pavement, London, E.C.

ONE OF THE MEXICAN EAGLE OIL COMPANY'S RAIL TANK CARS.

CHAPTER II.

GENERAL ADVANTAGES OF FUEL OIL.

THE great advantages which fuel oil possesses over coal lie chiefly in its physical properties. These advantages, which are dealt with in detail in succeeding chapters, are briefly summarised below:—

Calorific Value.—The calorific value of Mexican fuel oil is about 18,900 B.T.U. per lb. as compared with coal, which usually varies between 11,500 and 14,500 B.T.U. per lb., according to the nature and quality of the coal. There is, therefore, an increase of from 30 to 64 per cent. in the heating value of oil as compared with coal, weight for weight.

Higher Efficiency.—The thermal efficiency of an oil-fired furnace is much higher than that obtained with coal firing, as there is perfect smokeless combustion of the fuel. The efficiency of the great majority of coal-fired furnaces in this country, under average working conditions, does not exceed 65 per cent., whereas experience with oil firing shows that 80 per cent., and sometimes more, of the theoretical heat value of the fuel is recovered under normal conditions.

The ratio of the heat units utilised per pound of oil fuel when compared with coal, taking into account the higher calorific value and better thermal efficiency, is as follows:—

		COAL.		OIL.
With coal of 14,500 B.T.U.'s	... ...	1	...	1½
,, ,, 11,500 ,,	... ...	1	...	2

The particulars of a number of oil fuel results are given in the subsequent chapters, and are summarised in tabular form on page 136 of the Appendix.

Uniformity.—The heating value of coal varies over a wide range, and is further often depreciated by the absorption of moisture. On the other hand, oil possesses a constant heating value which seldom varies from specification. In oil contracts a clause is often inserted basing price on actual calorific value, a form of contract which is rarely obtainable with coal supplies.

Storage.—It will be seen from the above that the quantity of fuel required to do the same work is much less with oil than with coal, consequently there is great saving of space in storage of fuel. There is a further advantage that, while oil maintains its calorific value indefinitely, coal steadily depreciates in thermal value in the course of time.

Saving in Labour.—With fuel oil furnaces the labour required for stoking, cleaning fires, and handling ashes is eliminated, effecting a great reduction in the cost of labour, which is one of the important factors to be noted in comparing the respective fuels.

Flexibility.—An oil-fired furnace rapidly attains its maximum heat from cold. and is easily maintained at full capacity for prolonged periods. It can be instantly shut off when not required, and stand-by losses are accordingly avoided.

Absence of Smoke and Ashes.—The perfect combustion readily obtained with oil fuel means absence of smoke, soot, and clinker.

Facility in Handling.—Oil can be pumped into storage with great rapidity and an absence of the dirt, trouble, and labour associated with handling coal.

The above advantages have, of course, a different significance for each class of work in which oil fuel is used, as is shown briefly by the following summary:—

For Naval Purposes.—

1. Increased radius of action.
2. Increased evaporation.
3. Increased speed.
4. Absence of smoke.
5. Improved steaming facilities.
6. Great reduction in stokehold staff.
7. Constructional advantages.
8. Facility in bunkering.

For Mercantile Marine.—

1. Increased cargo or passenger capacity.
2. Increased speed.
3. Reduction in running costs.
4. Saving in stokehold staff and improved conditions for men required.
5. Quick and easy bunkering.

For Railways.—

1. Reduction in the cost and weight of fuel.
2. Saving in cost of handling fuel.
3. Increased mileage on one load of fuel.
4. Greater power.
5. Rapid adjustment of fuel to suit varying load.
6. Rapidity in getting up steam.
7. Elimination of fires caused by coal-fired locomotives.
8. Absence of smoke.

For Land Steam Plants.—

1. Higher boiler and furnace efficiency.
2. Increased capacity of boiler plant.
3. Rapidity in adjustment to varying loads.
4. Absence of smoke, ashes and dust.
5. Saving in labour.
6. Minimum variation in furnace temperature.
7. General cleanliness and efficiency.

For Industrial Furnaces.—

1. Increased output.
2. Decreased cost of fuel.
3. Saving in time and labour.
4. Less wastage, owing to more uniform results.
5. High temperatures obtainable.
6. Greater control of temperatures.
7. Less floor space and cleaner conditions.

DISTILLATE RECEIVING TANKS, MINATITLAN.

CHAPTER III.

BURNERS AND SYSTEMS.

Methods of Using Fuel Oil for Power

THERE are two methods of using fuel oil as a source of power :—

1. By introducing the oil into a furnace in the form of a spray. This is accomplished by atomising the oil by means of a burner, of which there are many forms.

2. By introducing the oil fuel direct into the cylinder of internal combustion engines of the Diesel type. The oil is sprayed into the cylinder when the air contents are so highly compressed that the temperature is sufficiently high to ignite the fuel without the use of the ignition devices employed in engines using the lighter oils.

The first attempt to utilise oil as fuel was made in 1861 by a mechanic named Werner, engaged in a refinery in Russia, who burnt the oil residuum in an open furnace. Then came a number of patents, both in this country and abroad, for oil burners, some of them of a very elementary character. Certain definite types of burners have emerged from a wealth of inventive effort, and the processes of applying fuel oil have crystallised into practically standard and highly efficient methods. In the year 1902 the United States Naval Board commenced a series of exhaustive experiments in the use of fuel oil, and collected much valuable data in the process of their enquiry. The results of this enquiry were on the whole very favourable, and gave a considerable stimulus to the practical application of oil fuel.

Modern Burners and Systems

The remarkable progress made in the application of fuel oil in recent years is due in no small measure to the excellence of the burners supplied by those firms who have specialised in this work, and in some cases burners have been evolved by manufacturing firms in order to meet the requirements of their own industries.

Oil fuel burners are made in various sizes, according to the class of work in which they are employed. Upwards of 1,000 lbs. of oil per hour can be consumed by one burner, although the more usual capacity for steam raising is from 250 to 500 lbs. of oil per burner per hour.

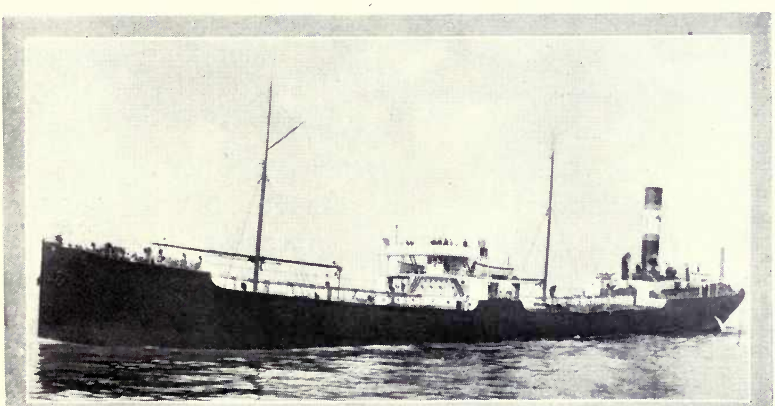
The feature common to practically all burners and systems is the atomisation or pulverising of the oil fuel into a very fine spray, so that each particle of oil shall receive sufficient oxygen to burn completely. Theoretically it requires $13\frac{1}{2}$ to $14\frac{1}{2}$ lbs. of air to effect the combustion of 1 lb. of oil, and on the thorough atomisation of the fuel and its effective mixture with a sufficient supply of air depends the efficiency of the furnace.

The power for thus breaking up the oil is furnished by one of three means, and each method has its advantages and limitations :—

(*a*) Steam.
(*b*) Compressed air.
(*c*) Pressure applied direct to the oil supply.

Steam is generally employed for stationary boilers and locomotives, and is the simplest of the three systems to manipulate. The advantage of steam is that no auxiliary apparatus in the shape of air compressors or oil pumps are required, and it is a simple matter to get an absolutely smokeless flame. With steam burners the chimney stack need not be more than 60 per cent. of the height usual for coal fired furnaces. Against this must be set the fact that from 3 per cent. to 10 per cent. of the steam generated is used for atomising the fuel, and the net evaporation per pound of oil is about 13·6 to 14·8 lbs. from and at 212° Fah., the lowest of the three systems.

Compressed Air is valuable in the case of a battery of boilers where high efficiency is essential. On boilers so fitted the evaporative value rises to between 15·6 and



"SAN RICARDO," EAGLE OIL TRANSPORT CO., LTD.

16·6 lbs. per pound of oil. Comparing these two systems, Mr. W. N. Best says: "Numerous tests have proved that with steam at 80 lbs. pressure and air at 80 lbs. pressure, the latter shows a saving of 12 per cent. in fuel over steam, but of this 12 per cent. it costs 8 per cent. to compress the air (this includes interest on money invested in air compressors, etc.), so that there is a total net saving of 4 per cent. in favour of compressed air." It should be stated, however, that low pressure burners—using only a tenth of the pressure mentioned—are now used and give good service. Most industrial oil furnaces work on compressed air, and it is advantageous when working with air to preheat same as a higher efficiency is developed.

The Pressure System usually involves the heating and filtration of the oil fuel, which is then supplied to the burners under pressure by means of special pumps. It is largely employed on marine boilers operating with forced or induced draught, and other plant where the fresh water consumed in steam burners cannot be spared. This system is also well adapted for use in large land plants as the evaporative efficiency is about the same as secured with compressed air, namely, between 15·6 and 16·6 lbs.

Each of these three systems has its sphere of utility, and it should be remarked that the furnace arrangement in every case largely influences the efficiency of any burner. It is essential to secure that the air supply shall mix with the oil spray, not merely envelop it, and that the flame should fill the furnace space as fully and evenly as possible. It is important to see that no undue excess of air is applied to a burner, for while a little smoke may indicate a loss of, say, 1 per cent. of heat, an excess of air, which has to be heated to the temperature of flue gases, may mean a loss of many times that amount of heat.

Description of Burners

In the following pages short descriptions are given of several of the representative burner systems in use to-day ; these are necessarily brief, but fuller information can be obtained from the makers. Lack of space precludes reference to a number of excellent burners, a description of which would otherwise be found interesting. Attention is directed to the Appendix, page 133, in which a list of burner makers is given.

Kermode Steam Burner.—In this burner the oil is pulverised by a jet of steam from the boiler. The oil enters centrally through the branch B, and has a whirling motion imparted to it by the stem of the oil valve marked G. The steam goes around the whole

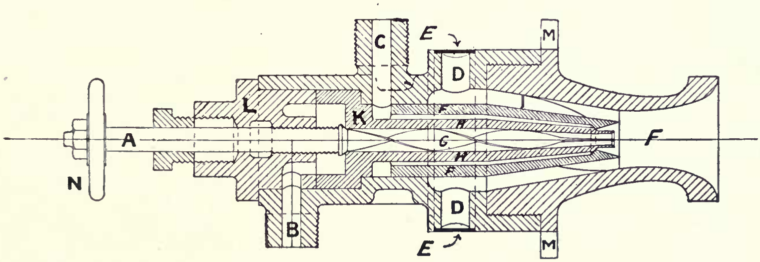


FIG. 3.—KERMODE'S STEAM BURNER.

cone A, passing through slots in the cylindrical portion where this fits into the hollow of the air cone, the whole oil supply being thus steam-jacketed. The air cone is F, and this is also fitted with spiral guides, its amount being adjusted by opening or shutting the openings D by means of the movable perforated strap E.

Kermode Air Jet Burner—In this burner the oil is partially vaporised and sprayed by means of hot air at a pressure of from half a pound to four pounds per square inch. The oil enters branch A, its further flow being regulated by a conical valve and seat. The air previously heated enters the burner at the branches B and C; the air passing through C meets the oil as it passes the oil control valve which is operated by the wheel E, and both travel on together, the oil being rapidly

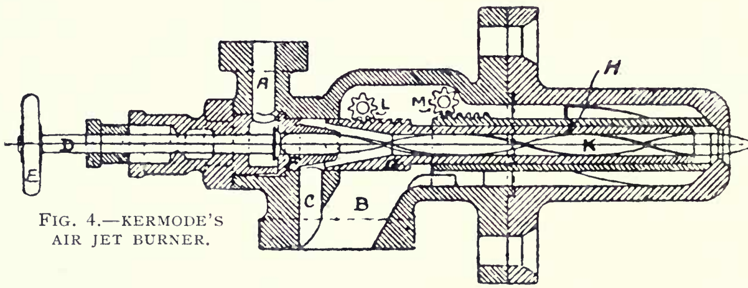


FIG. 4.—KERMODE'S AIR JET BURNER.

vaporised in its passage. There is a helix K in the centre tube which effects a complete commingling of the air and oil vapour, and ensures that none of the vapour will pass through the tube untreated. The supply of air can be regulated at two points by means of hand wheels, pinions, and racks; one pinion L moves the internal tube for the oil-delivering nozzle F and releases the air which enters there. The second pinion M operates the outer tube and varies the amount of air escaping around the mixed jet at the end of the twisted spindle K.

Kermode Pressure Burner.—This burner, designed specially for marine purposes, is recommended for use with forced or induced draft. The oil enters the burner through the channel D and the inner cylinder B, which abuts against the cap nut E. The spindle C serves to contract or enlarge the opening through the cap nut E. The movement of C is indicated on the graduated wheel marked F. The oil fuel is pulverised very completely by being forced through a restricted opening with a rotary

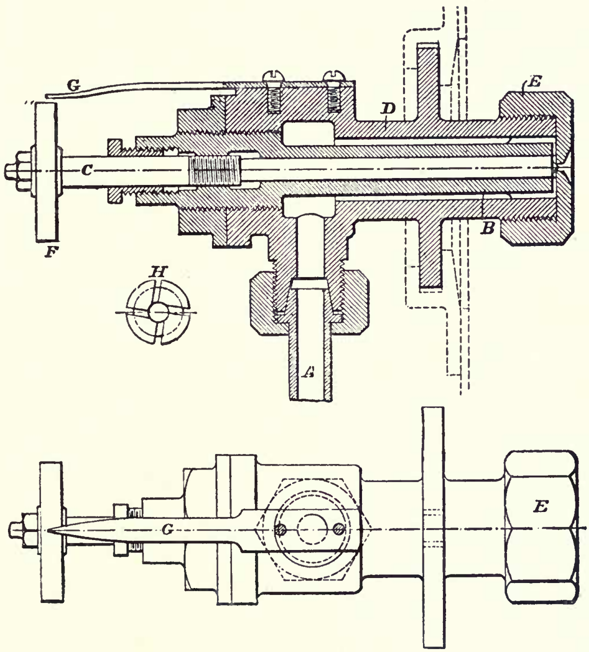


FIG. 5.—KERMODE'S PRESSURE BURNER.

motion imparted to it by tangential grooves in the face of the plug end of B. In this system the oil fuel, which has been previously heated and carefully filtered, is supplied to the burner under pressure by means of a force pump.

Wallsend-Howden System.—This is a well-known pressure system employing oil heaters, filters and pumps. The improved construction of the furnace front constitutes the principal feature of the invention, each burner projecting through a baffleplate on the front plate of the casing into an air trunk having lateral openings at its outer end. This air trunk projects concentrically with a

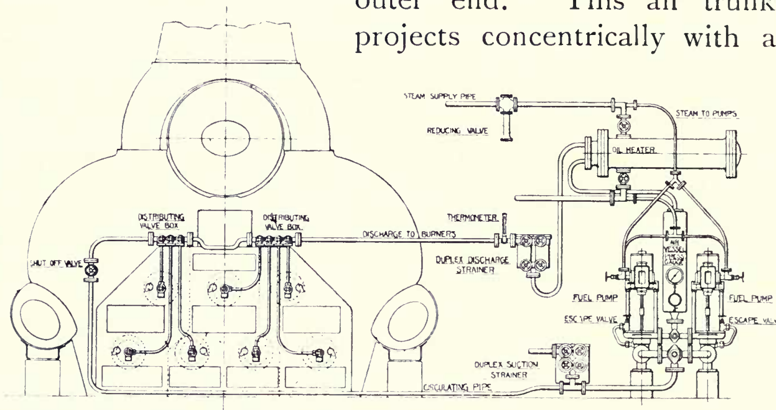


FIG. 6.—ARRANGEMENT OF HEATERS, FILTERS AND PUMPS FOR MARINE INSTALLATION OF WALLSEND-HOWDEN PRESSURE SYSTEM.

second air trunk carried by the furnace front, and the annular space between the inner and outer air trunks is fitted with deflectors constructed so as to give the air passing through the annulus a spiral motion. An evaporative efficiency of 16·22 lbs. has been attained with this system in conjunction with Howden's forced draught.

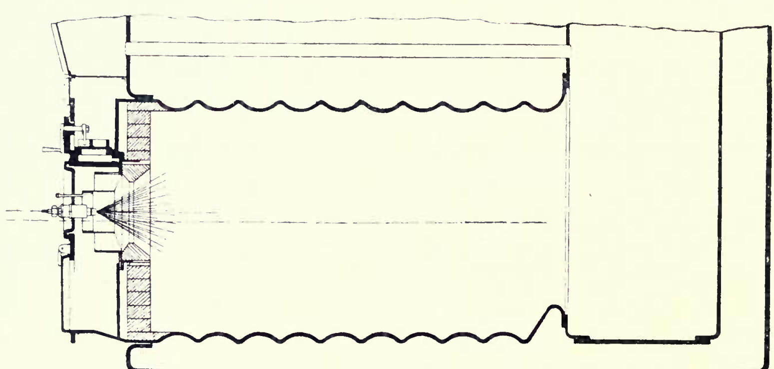


FIG. 7.—ARRANGEMENT OF WALLSEND BURNER FOR MARINE BOILER.

Holden Burner.—The latest improved type of this burner is shown in Fig. 8. The injection of oil is effected by means of steam or air pressure of not less than 60 lbs. per square inch. No pressure is required in the fuel tank, as the oil flows by gravity to the burners through the regulating valve A, and steam or compressed air is admitted at the connection B.

The holes in the nozzle are so arranged that as the streams of oil and steam or compressed air issue from the nozzle they converge towards each other, effecting a thorough distribution and atomization of the oil.

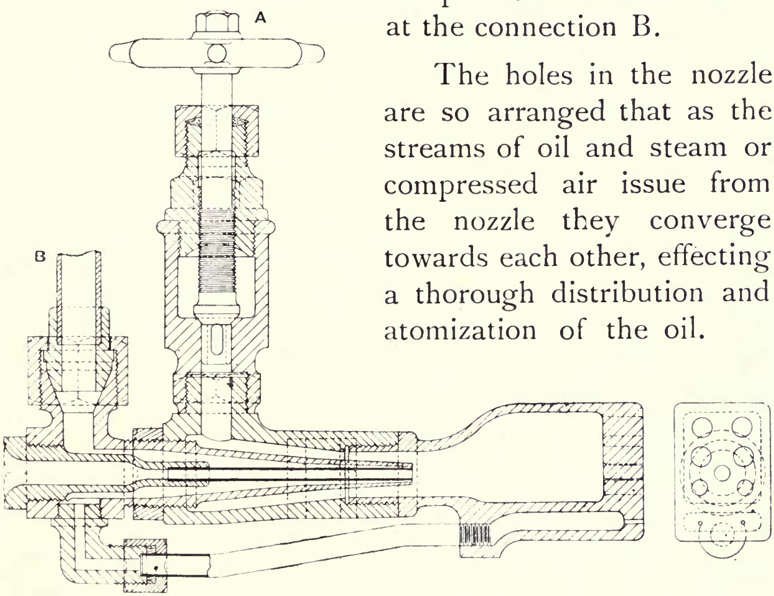


FIG. 8.—HOLDEN BURNER.

On the Holden system oil can be burnt alone, or in conjunction with coal; in the latter case no alteration is required to an ordinary coal burning furnace beyond the addition of the oil burner and valves.

Messrs. Babcock & Wilcox supply oil burning equipment under all three systems, namely, steam, air, and pressure jet. The diagram, Fig. 9, shows the steam burner, which is largely used on account of its simplicity;

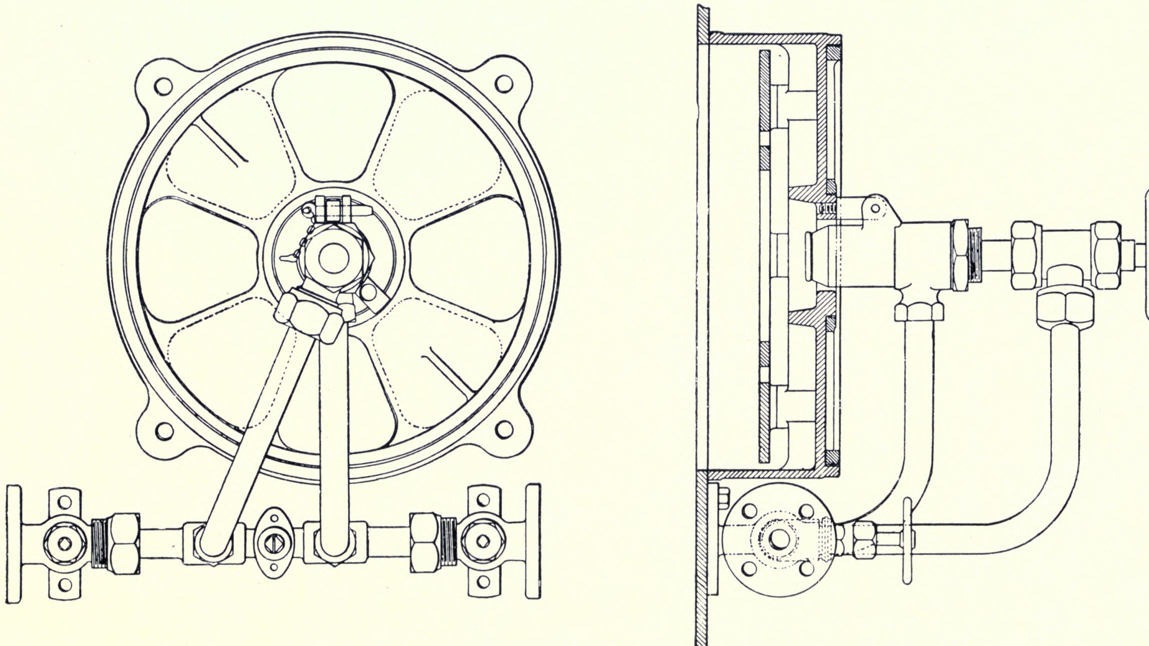


FIG. 9.—BABCOCK WILCOX SPRAYER AND AIR GRID USED FOR STEAM OR AIR ATOMIZING.

while the pressure system is recommended for marine work and wherever high evaporative duty is required.

It is stated that the steam burner will deliver up to about 550 lbs. of oil per burner per hour, and the pressure burner will deliver up to 700 lbs. of oil per burner per hour. The average would be about 250 lbs. per burner for the steam burner, and about 450 lbs. per

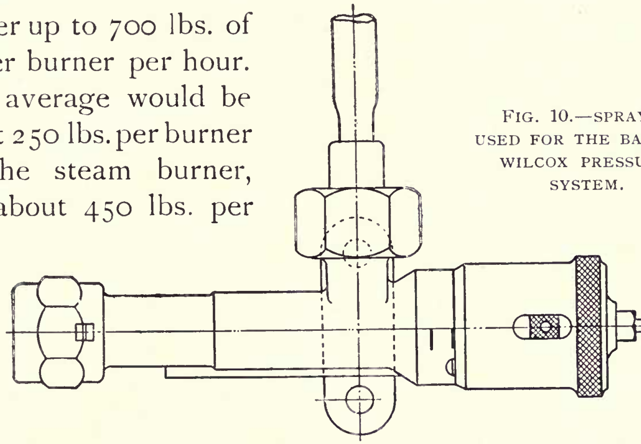


FIG. 10.—SPRAYER USED FOR THE BABCOCK WILCOX PRESSURE SYSTEM.

burner for the pressure burner, but the size of the burners can be varied to meet the conditions of the particular case under consideration.

The Merryweather liquid fuel burner is entirely of gun-metal, and is of the spray type, using steam or compressed air for the atomization of the fuel. The atomizing agent is taken through a central passage, the orifice of which is controlled by a needle valve operated by a milled wheel. An annular space surrounds the centre passage, into which the fuel supply is taken. The orifice of this passage is annular and conical in shape, the oil fuel emerging in a direction across the passage of the atomizing agent. The oil orifice is fully adjustable according to the amount of fuel that it is necessary to burn for a stated duty. The central portion of the burner is mounted in a separate conical piece, through which air is induced to assist combustion: the supply of air is regulated by a perforated disc. The whole burner is arranged so that it can be instantly taken apart by the removal of a single nut, and has lugs for convenient attachment to any form of boiler.

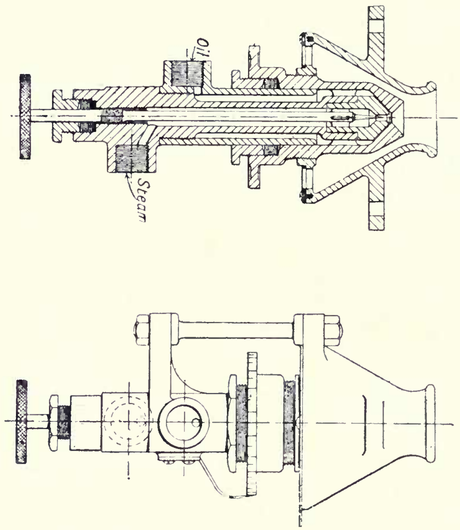


FIG. 11.—MERRYWEATHER BURNER.

The Merryweather oil fuel burner is fitted to the boiler of their well-known motor steam fire engines.

Carbogen Burner.—This burner may be used with either steam or compressed air, and is applied through a combustion chamber either built in the wall of the furnace or specially attached. As will be seen from the diagram, the burner has three orifices, the central one being for induced air, the second one for the fuel, and the outer one for the steam or compressed air used to atomise the fuel. Where an extremely high temperature is required, a stream of oxygen can be introduced through the central

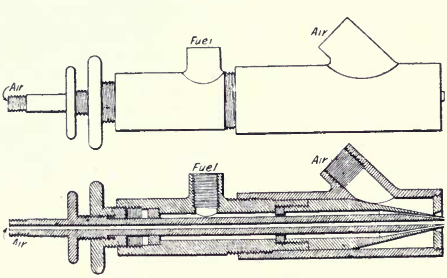


FIG. 12.—CARBOGEN BURNER.

tube. The burner is made in two sizes, ranging in consumption from 10 to 250 pounds of oil per hour.

Messrs. Curle have recently introduced a modified type of the Carbogen burner, which is actuated by air at a pressure of about 12 to 15 inch water gauge. This low pressure type is adaptable for many processes, and the running cost is lower than with air-compressor plant. Mexican fuel oil is now being consumed on a large scale with the Carbogen low pressure burner.

The Thornycroft System.— The system adopted by Messrs. Thornycroft consists in spraying hot oil fuel under pressure into the boiler furnace, the admixture of air and fuel necessary for perfect combustion being obtained by means of special burners and air cones, no steam being required.

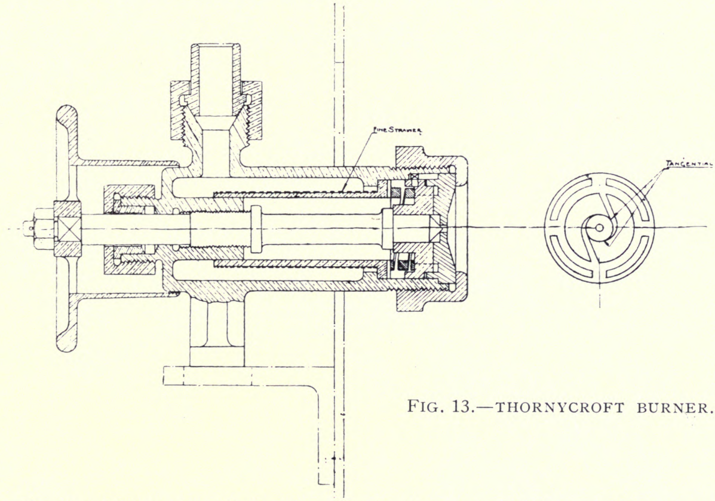


FIG. 13.—THORNYCROFT BURNER.

A small steam-driven pump draws oil from the tanks and discharges it, at a suitable pressure, through filters to a heater. The oil is heated by passing through a number of steel tubes surrounded by a steam jacket.

The condensed steam from the jacket falls to a collector showing when sufficient water has accumulated to necessitate blowing out. In the case of a closed-drain system the condensed water from the heater is led to the reserve feed tank through a special grease extractor.

From the heater the oil passes through another pair of filters, fitted with the requisite change-over valves, to a master valve on the boiler front.

The sprayers are of the Thornycroft patent type, as illustrated, and are arranged to deliver the hot oil thoroughly pulverised to a specially constructed hollow steel mixing chamber, and from thence to the furnace.

A forced draught fan is usually employed, working either on the closed-stokehold system, or through an air trunk connected with the front of the boiler casing as may suit the arrangement in vessel.

This system of oil fuel burning is also suitable for working with natural draught and forced draught under the Howden system.

Best Burner.—This representative American burner is made for use with air or steam, and is very simple in

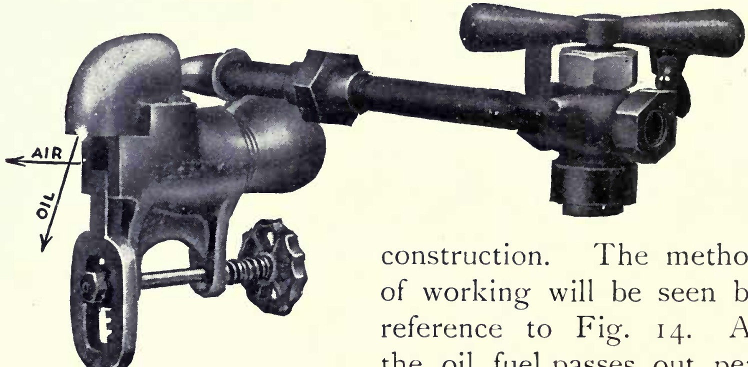


FIG. 14.—BEST'S LOW-PRESSURE BURNER.

construction. The method of working will be seen by reference to Fig. 14. As the oil fuel passes out perpendicularly it is struck by the jet of air or steam coming on horizontally, and converted into a mist of very fine particles. A hinged lip is provided, so that by slackening a set-screw and turning on the atomiser any temporary clogging is readily cleared. The opening of the burner can be shaped so as to throw either a long narrow flame or a fan-shaped blaze nine feet wide.

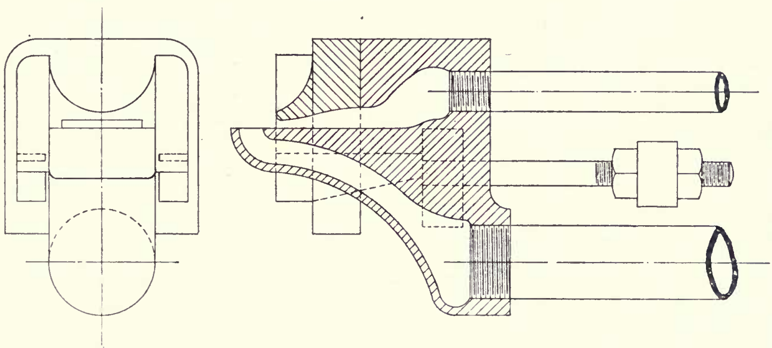


FIG. 15.—SECTION OF BEST BURNER.

Baldwin Burner.—The burner used by the Baldwin Locomotive Works is rectangular in cross section, with two separate ports or chambers (one above the other) running its entire length. Oil is admitted into the upper port, and steam into the lower. A free outlet is allowed for the oil at the nose of the burner; the steam outlet, however, is contracted at this point by an adjustable plate, thus giving a thin, wide aperture. This arrangement tends to wire-draw the steam and increase its velocity at the point of contact with the oil, giving a better atomizing effect. A permanent adjustment of the plate can be made for each burner, after the requirements of service are ascertained.

The burner is made of brass, as an iron casting is found to be sufficiently porous to enable the steam to pene-

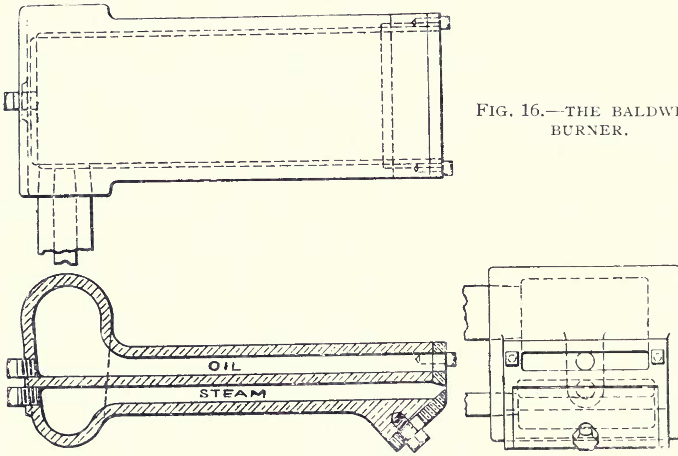


FIG. 16.—THE BALDWIN BURNER.

trate through to the oil passage, thus causing irregularities in the action of the flame. The adjustable plate is of copper, and it is held in place by a set screw. The end of the burner is cut out to receive a second copper plate, having a suitable opening in it for the oil discharge.

Meyer-Smith System.—The Meyer-Smith Pressure System consists of a special type steam fuel pump, suction and delivery oil filters, oil delivery heater, special oil burning front, and a patent mechanical spray burner for atomising the oil.

The pump draws the oil through the suction filter, which has a medium gauze wire strainer, and passes it into the delivery heater at from 50-70 lbs. pressure. In passing through this heater, the oil is raised to the required temperature according to the class of oil being dealt with, the temperatures ranging from 180 deg. Fah. to 240 deg. Fah.

After leaving the heater, the oil is next passed through the delivery filter, which has a very fine mesh strainer, and here it is thoroughly filtered before passing to the burners.

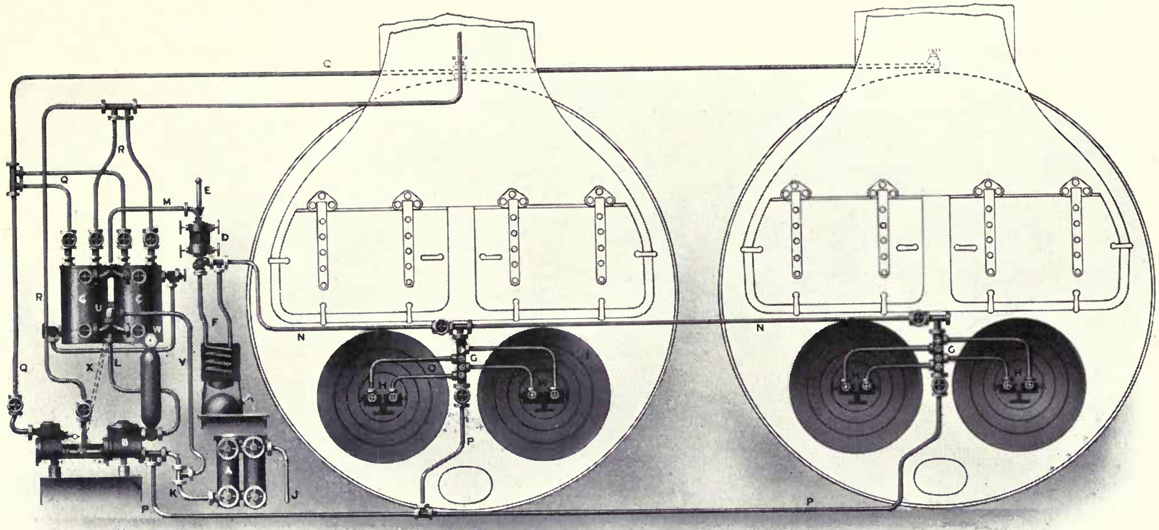


FIG. 17.—MEYER PRESSURE SYSTEM. ARRANGED FOR MARINE BOILERS.

A. Duplex oil suction filter.
B. Two Duplex steam oil fuel pumps
C. Oil delivery heaters (in duplicate).
D. Duplex oil delivery filter.
E. Thermometer,
F. Lighting-up coil and starter.
G. Oil distributing chest to burners.
H. Oil fuel burners.
I. Oil burning furnace front.
J. Oil suction from bunker to suction filter.
K. Oil suction from suction filter to pump.
L. Oil discharge to delivery heaters.
M. Oil discharge from heaters, via delivery filter.
N. Oil supply to boilers.
O. Oil supply to burners.
P. Oil circulating return to pump suction.
Q. Steam supply to pumps and heaters.
R. Exhaust from pumps and heaters.
S. Air vessel.
T. Bye-pass pipe for using heaters in series.
U. Relief valve.
V. Overflow from relief valve to pump suction.
W. Pressure gauge.
X. Hand lever for use when lighting up without use of coal or steam.

The oil delivery pipes across boiler fronts are so arranged with valves, that when lighting up, the oil is byepassed back to the suction side of pump, instead of to the burners until the desired temperature is reached.

When the ignition point is obtained, the circulating valves are shut and the burners opened and lit by means of a torch through a small door on furnace front.

The air passing through the furnace front is thoroughly heated, and has a rotary motion imparted to it from the vanes in the air passages, which ensures complete mixing of the fuel and air, with the result that perfect combustion is obtained.

The Meyers' furnace front has been recently improved, and in place of the heavy cast-iron type which was formerly fitted, a front constructed of sheet steel is now used, which embodies all the advantages of the old type, but is very light to handle when converting from coal or oil burning.

If it is desired to burn oil and coal in conjunction, the Meyer-Smith System is capable of being adapted to suit, and equally good results are obtained by this means.

The system has also been adopted with the highest results to boilers working under Forced Draught. When fitting the apparatus to this type of boiler, the original forced draught fronts are used, but a little alteration is made to regulate the air inlet. The fire-bars can be left in if desired, and covered in a suitable way with firebricks. When this is done three boilers can easily be converted from oil to coal burning, and have coal fires under way in less than two hours. This is of the greatest importance where ships are required to convert in the shortest time possible to save heavy demurrage.

White System.—As applied to natural draught boilers, the system consists of an air-heating front which is fitted over the mouth of the furnace, consisting of a disc casting having a number of projecting vanes forming air passages down which the air must pass, absorbing the heat from these vanes and disc, and becoming heated to over 200° F. These passages conduct the air to the centre of the disc, where it is admitted to the furnace in swirling streams, surrounding the burner, perforated jacket, and sliding cone.

The burner is of simple construction, possessing means, by a series of longitudinal channels formed in the periphery of a cylindrical cone-shaped member, of mechanically dividing the liquid fuel under pressure into a number of separate streams, by this means attenuating and imparting a spiral motion to the said streams, uniting them into a swirling mass prior to their ejection through the burner nozzle; thus setting up a finely atomised condition of the fuel before being ejected from the orifice in a swirling mist. A conical valve fills the said chamber to close the outlet, and is retracted to supply a regulated quantity of fuel to the burner orifice.

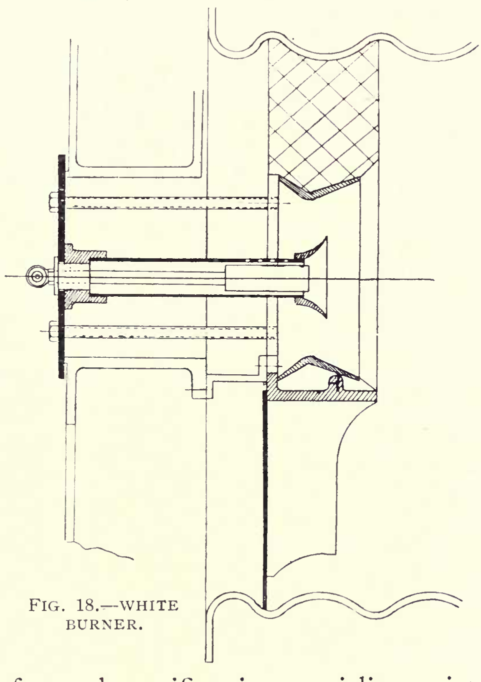


FIG. 18.—WHITE BURNER.

Von Boden-Ingles Burner.—The special feature of this burner is the outside atomization of the oil and steam on the projecting corrugated lip. This does away with the waste and dripping of oil, and also permits cutting down of the fire to a candle flame, and leaving in that condition for any length of time. Another feature is simplicity of construction, the entire burner being cast in one piece, so there are no delicate parts to get out of order, and should foreign substances, such as waste, etc., be carried into the burner, they can be readily blown out with steam by using the blow back valve.

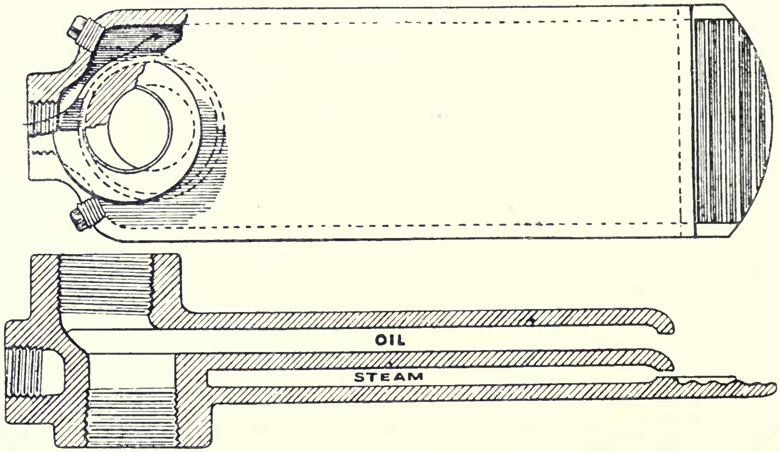


FIG. 19.—VON BODEN-INGLES BURNER.

The oil opening is both on the top and the bottom of the burner ; this enables the piping of the oil to either opening and is an advantage where there is a shortage of room for fitting the oil pipe to the burner.

Lucal Burner.—In the Lucal Combination System a series of burners, each independent, and capable of working separately or all together, are combined in one apparatus, having one inlet for oil and one inlet for steam, or other ejecting agent. The oil is completely treated in the burner, which disintegrates and gasifies the oil, simultaneously drawing in air to mix with the gas, the result being that the vaporised oil lights at once and enters the furnace as a burning flame. As this flame is similar to that from coal, shielding brickwork is unnecessary. The oil is drawn direct from the store tank to the burner and fed by gravitation.

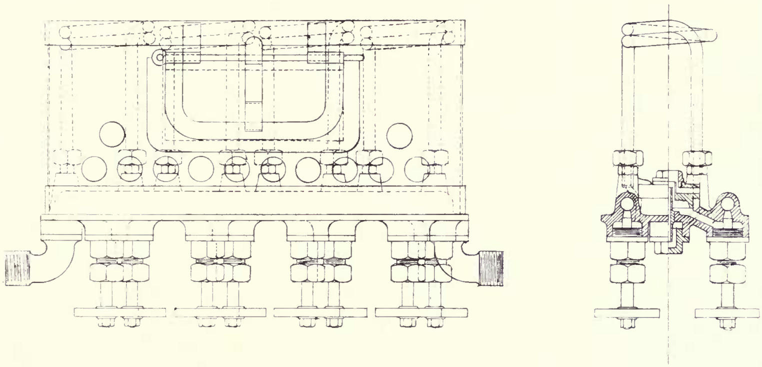


FIG. 20.—LUCAL BURNER.

The Lucal Burner works as well with compressed air as with steam, and, as stated, requires no exterior aid, such as heated brickwork, forced draught, or such, to enable the oil to burn. It burns in the open air as readily as in a furnace, and is stated to consume only 1½ per cent. of the total steam for ejection purposes.

Fuel Oil Equipment

It will be readily understood that the adoption of oil burners operating with either steam, compressed air, or directly applied pressure must entail some slight differences in the equipment and arrangement of the oil storage tanks, piping, heaters and pumps. The size of the fuel oil installation also has a material effect on the piping and tank arrangements.

Generally speaking, fuel oil installations in this country have hitherto been designed with a view to the consumption of fuel oil of a low viscosity, and consequently constructed with supply pipes of small diameter. An ample margin in the capacity of the fuel oil supply pipes is most desirable, as it enables oil of any density to be used, and thus renders the installation available for a much wider variety of fuel oil supplies.

Mexico and California will undoubtedly furnish the principal supplies of fuel oil in the future. The fuel oil from these sources is of a greater density than the lighter and more costly oils which have hitherto been used.

The following table gives the diameter of suction and delivery pipes recommended for installations consuming a given quantity of oil. It is assumed that oil is fed to the furnaces at a pressure of 5 to 15 lbs. per square inch, and at a temperature above 100° Fah.

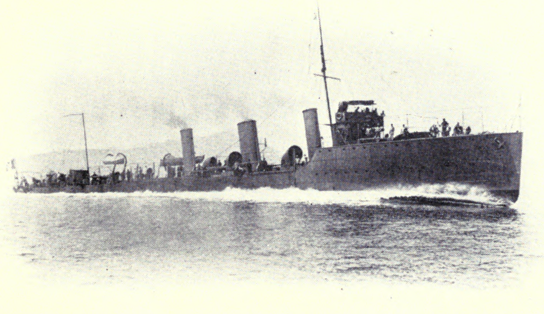
Fuel Oil in Gals. per Hour.	Diameter in Inches of Pump Suction.	Diameter in Inches of Pump Delivery.
50	2½	1½
100	2½	1½
150	3	1½
200	3	2
250	3½	2
300	3½	2½
350	4	3

It is an advantage to arrange for the heating of the oil, in order to facilitate handling. The most usual method is by the provision of steam coils.

The following table of viscosities of Mexican fuel oil at various temperatures will indicate the marked increase in fluidity that takes place as the temperature rises :—

Temperature.	Viscosity. (Redwood No. 2.)
32° F.	8,412 secs.
40° F.	5,096 "
50° F.	2,227 "
60° F.	1,285 "
70° F.	539 "
80° F.	335 "
90° F.	210 "
100° F.	145 "
110° F.	95 "

Where a fuel oil installation is contemplated the Anglo Mexican Petroleum Products Co. will be pleased to offer the services of their technical experts, who will advise respecting the use of Mexican oil by the most efficient methods.



AN ITALIAN OIL-FIRED DESTROYER, "INDOMITO," BUILT BY THORNYCROFTS.

CHAPTER IV.

FUEL OIL AND THE NAVY.

Fuel Oil and the Navy

THE application of fuel oil burning which has certainly caught the popular imagination most vividly is its use in naval vessels. Its advantages in this connection have been strikingly demonstrated, with the result that the Navies of the world have seriously turned their attention to the use of oil in the place of coal.

A large number of battleships, cruisers, and torpedo boats of the British Navy are already fitted to burn liquid fuel. The first battleship of the British Navy to burn oil exclusively, the *Queen Elizabeth*, was recently launched, and four sister ships are building. She is the largest ship yet built for the British Navy, and will have 13½ in. side armour as against 9 in. on the coal burning *Queen Mary*, in addition to carrying eight 15 in. guns instead of 13·5 in. as fitted on the coal fired battleship.

The United States Navy gave the matter their attention many years ago, and their latest and largest battleships, the *Nevada* and the *Oklahoma*, are designed to burn oil exclusively. Dr. D. T. Day, in his annual report recently published, says: "The United States Navy has definitely abandoned the use of coal in future fighting ship design. All new destroyers, submarines and battleships are designed for oil burning; there are now built or building four battleships, forty-one

A BATTLE SQUADRON BURNING COAL, SHOWING THE HEAVY SMOKE TRAILS REVEALING ITS LOCATION TO A DISTANT ENEMY.

destroyers, thirty submarines, one monitor, three tank ships, one collier, one submarine tender, and several tugs and small vessels burning oil exclusively."*

Similar activity in this direction is witnessed on the part of the naval authorities of France, Germany, Italy and Sweden, and it is evident that within the next few years the whole of the navies in the world will not only have appreciated the claims of oil fuel, but will be operating fleets of fighting ships which will be almost exclusively oil-burning vessels.

The following are the chief points which commend oil to naval experts as a substitute for coal :—

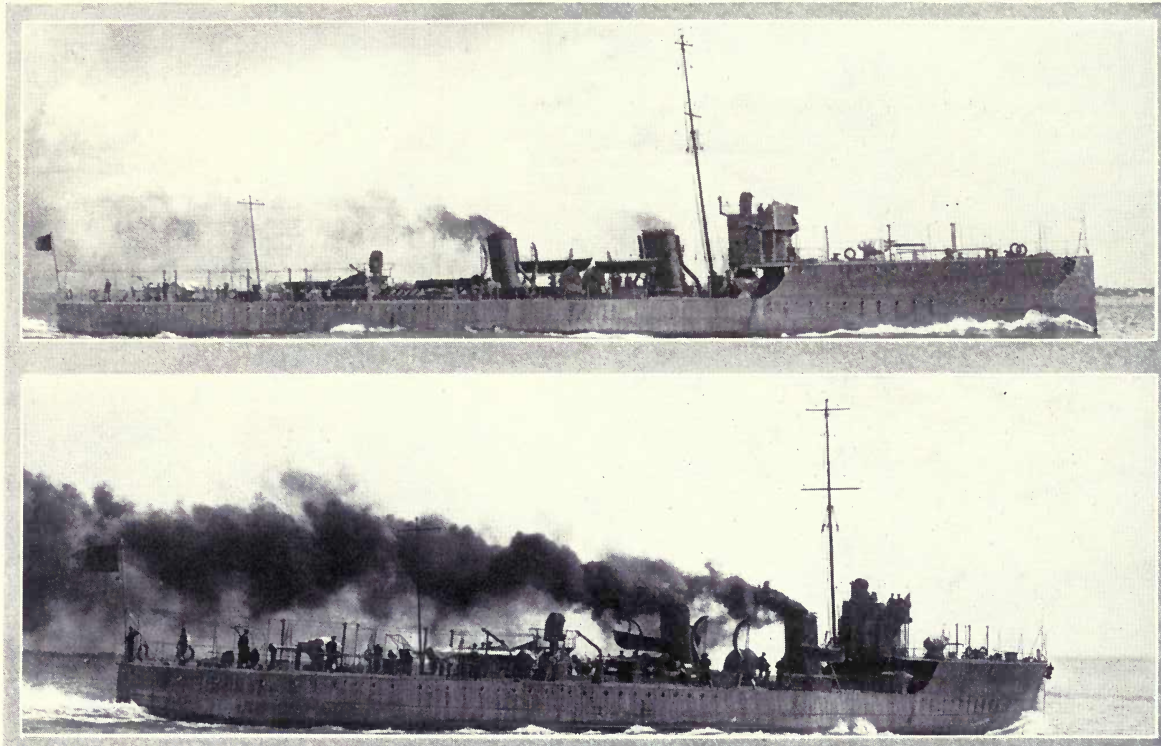
1. **Increased Radius of Action.**—The superior calorific value of fuel oil, as compared with coal, increases the radius of action by 50 per cent. on an equivalent bunker *weight*.

A ton of oil occupies 36 cubic feet, while a ton of coal occupies 43 ; consequently on an equivalent bunker *space* the radius of action is increased 80 per cent. This advantage can be greatly increased by carrying the fuel oil in double bottom tanks, which is the usual practice in oil-fired war vessels.

2. **Increased Evaporative Efficiency.**—With the best types of boilers an evaporation of 10 to 11 lbs. of water from and at 212° F. per lb. of coal is considered good work. With oil firing so complete is the combustion that over 16 lbs. of water per pound of oil can be evaporated, securing up to 83 per cent. of the theoretical heat value of the oil.

3. **Increased Speed.**—The increased speed that can be obtained with oil fuel is an advantage of vital

* Production of Petroleum in 1912 (U.S. Geological Survey).



TWO BRITISH TORPEDO DESTROYERS—ONE RUNNING ON COAL, THE OTHER ON OIL.

importance in warships. When it is remembered that, with oil-fired furnaces, the boilers can be forced to 50 per cent. above normal rating, without any of the enormous strain on the personnel which is necessary in burning coal under forced draught, the superiority of liquid fuel for naval purposes is at once apparent.

4. **Absence of Smoke.**—Owing to the complete combustion of oil fuel there is practically no smoke emitted, as there is on a coal-fired battleship. The emission of dense volumes of smoke, as shown in the photograph (page 47), from a coal-fired warship not only reveal its location to the enemy, but seriously affect its own efficient gunfire.

5. **Improved Steaming Facilities.**—Oil burners give their maximum heat a few minutes after starting. The rapidity and ease with which a full head of steam can be obtained and the boilers forced above normal rating might easily be the determining factor in battle. There is a further advantage that the thermal efficiency of the boilers remains unimpaired over long periods owing to the absence of soot.

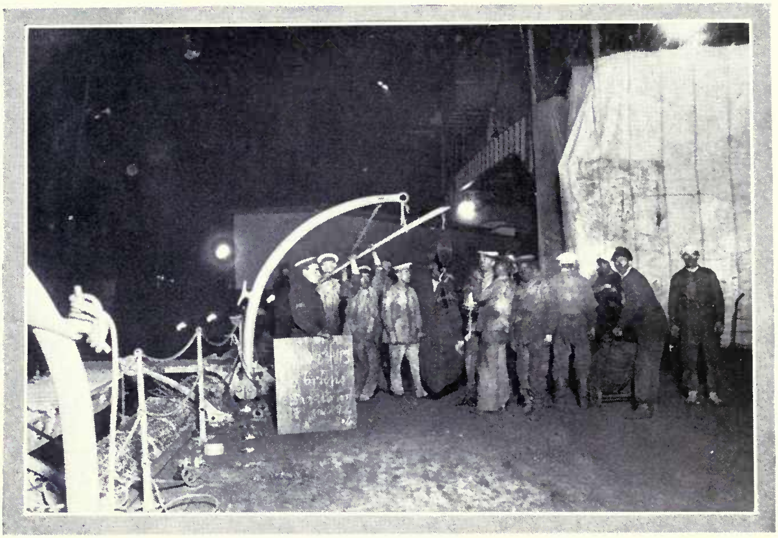
6. **Saving in Labour.**—The use of oil fuel on a battleship reduces the fire-room force required by about 70 to 80 per cent. This reduction in personnel is obviously a very important factor. Moreover, the conditions for the men actually required are enormously improved, as the oil, being mechanically fired, completely eliminates manual labour and only requires supervision and adjustment.

7. **Constructional Advantages.**—As might be readily anticipated, the adoption of oil as the exclusive fuel for a

warship results in important changes in design, all of which make for increased efficiency. Coal and ash handling gear is eliminated, and the piercing of hulls for coal trunks and ash ejectors is avoided. The fact that it is possible to economise in fire-room space and boiler-heating surface when burning oil has already resulted in important changes in warship design in the two latest vessels now building for the U.S.A. navy, the *Nevada* and the *Oklahoma*. In these vessels "the reduction in boiler weights has made possible the use of heavier armour, and the reduction in length of boiler compartments has permitted the grouping of all boilers under one smoke stack, which gives greater clearance on deck and more extensive arcs for turret fire."*

8. **Bunkering.**—It is, perhaps, in bunkering a warship, either in port or at sea, that the advantages which oil offers over coal are most strikingly evident. A warship can take on its supplies of oil in port under cleaner conditions and at a greatly accelerated rate. All the elaborate sheet wrappings for guns, etc., and the special dress required by men and officers when "coaling ship," are dispensed with. Once the hose connections have been made, the oil is pumped at the rate of hundreds of tons per hour, without any of the arduous manual labour attaching to the handling of coal. There is, consequently, a cleaner ship, a saving in time and elimination of labour. In bunkering at sea with oil these advantages are still further emphasised. The delivery of supplies to a fleet at sea from oil-tankers by means of flexible hose connections has solved one of the problems of naval strategy. When coal is taken on, the collier has to be made fast alongside, and a cumbersome transporter is generally

* *Steamship*, May, 1913.



COALING H.M.S. "NEPTUNE" AT NIGHT. WEIGHING IN SACKS OF COAL FROM LIGHTER ALONGSIDE.

utilised to transfer the coal to the warship. When this work is carried out at night the glare of the necessary lights renders the vessel a conspicuous and helpless object for torpedo attack. With the use of oil these difficulties disappear. No lights are required at night—the vessel can lie cleared ready for action, and is separated from the tanker by lengths of hose, through which the oil is rapidly pumped, and the hose can be immediately cast off should an enemy appear. As this work, moreover, may be carried out in all but the roughest weather, it becomes unnecessary for the ships to frequently return to base for fuel supplies, and it has been calculated that, in the case of blockading operations, this advantage augments the strength of the fleet by thirty-three per cent.

CHAPTER V.

OIL AND THE MERCANTILE MARINE.

MOST of the advantages enumerated for Naval purposes are, of course, equally true of the mercantile marine, and need not be recapitulated. Steamships have used oil as far back as 1870, and in recent years considerable impetus has been given to its further adoption by a wider realisation on the part of shipowners of the great improvements which oil effects. Cargo vessels and fast passenger steamers are to-day using oil fuel under boilers, and every month witnesses some fresh developments, or record of notable runs—supported with figures—made by the ever-increasing number of vessels using oil as fuel.

The application of oil fuel to the question of marine transport affects its cost in three ways :—

1. By increased cargo or passenger capacity.
2. By increased speed.
3. By reduction in running costs.

1. **Increased Cargo or Passenger Capacity.**—There are three features which operate in favour of oil fuel—*i.e.*, its superior calorific value, and its better combustion (as a result of which two tons of oil will do the work of more than three tons of coal), and thirdly, its smaller bulk per unit of weight. These three factors

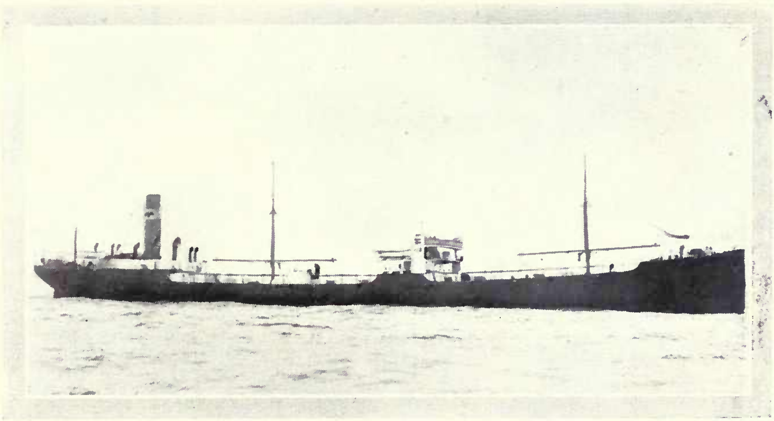
combine to effect a saving of at least forty-five per cent. in the bunker space required for oil, consequently this extra space is available for bulk cargo or other purposes. On the basis of weight of the necessary fuel in bunkers there is a saving of thirty-three per cent., allowing of an increased dead-weight carrying capacity. These savings operate in all cases where oil is carried in coal bunkers, but if, as is generally done, the double bottom tanks of the vessel are used for oil fuel storage, then the entire coal bunker space can be utilised for cargo.

2. **Increased Speed.**—The use of oil fuel generally results in a distinct increase of speed and may consequently add considerably to the earning capacity of the vessel. The increase of speed is, of course, made possible by the larger supply of steam to the ships' engines due to the ease with which the maximum output of the boilers can be maintained without any exertion on the part of the stokehole staff such as would be necessary with coal, this output being even above the rated capacity of the boilers when coal fired.

Other contributing factors are that the fall in steam pressure during the process of cleaning coal fires is entirely eliminated when oil is used, and that it is possible to maintain a perfectly steady steam pressure throughout a voyage owing to the absence of soot and other non-conducting deposits on the heating surfaces of the boilers.

In a coal fired vessel it has been demonstrated that at the conclusion of a twenty day voyage the boiler efficiency had been reduced $12\frac{1}{2}$ per cent. in the time, owing to soot and dust on furnace plates and tubes, resulting in a corresponding reduction in the speed of the vessel.

An instance of this feature of oil burning may be given in a comparison of two sister ships of the Eagle Oil Transport Co. These two vessels, the *San Dunstano* and the *San Eduardo*, are vessels of 9,000 tons dead weight capacity, and are fitted to burn coal and



"SAN EDUARDO," EAGLE OIL TRANSPORT CO., LTD.

Mexican oil respectively. The weight of fuel consumed worked out as two to three in favour of oil, while the indicated horse-power developed shows an 18 per cent. improvement in the case of the oil-fired steamer. But the striking fact of the comparison is that the *San Eduardo* made the round voyage to Mexico and back eight days quicker than the other, and this improved speed means a very important addition to the earning capacity of the vessel.

This fact is very clearly brought out by figures furnished by the American-Hawaiian Steamship Company, relative to two voyages of the s.s. *Arizonan* on coal and oil respectively :—

COMPARATIVE DATA: COAL v. OIL FUEL, SS. "ARIZONAN" ON TWO VOYAGES.

AMERICAN-HAWAIIAN STEAMSHIP COMPANY.

Covering passages from New York, Pacific Coast Ports, Hawaiian Island Ports, and return to Philadelphia, via Straits of Magellan out and home.

Gross tonnage: 8,672, Twin Screw, Three Boilers, Howden Draught, 215 lbs. Pressure, Quadruple Expansion Engines.

	Mean Displacement in tons.	Mean Displacement Home, in tons.	Distance Steamed. Miles.	Steaming Time. Days.	Round Voyage. Days.	Average Speed. Knots.
Voyage No. 3 Using Coal	16,882	16,660	30976	143·33	186	9.01
Voyage No. 4 Using Oil	15,930	17,280	29,861	125·25	161	9.95

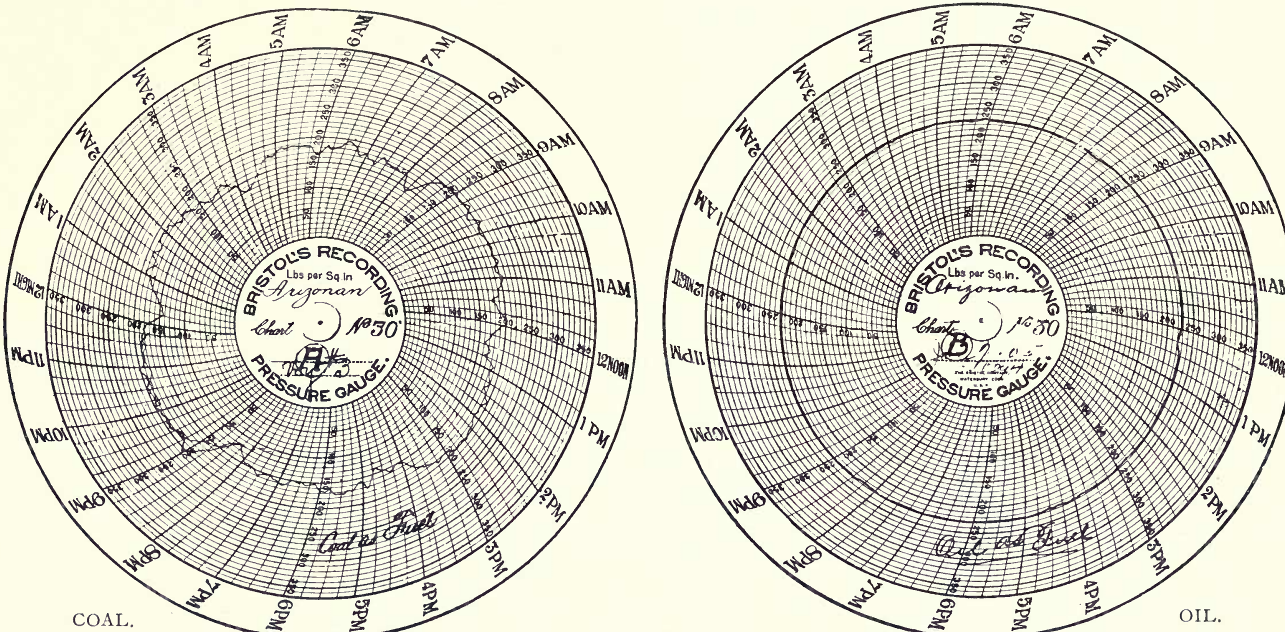
Actual Cost of fuel consumed on these voyages was practically the same.

Twenty-five days saving in time on the round voyage, of which 18 days was owing to increased speed, and 7 days used in coaling ports on Voyage No. 3.

	Saved in victualling and manning	$4,813.00
Increased earnings	Freight earnings increased by 150 tons, Eastbound	1,275.00
	Disbursements at coaling ports	1,000.00
	Total	7,088.00
	25 days saved at $500.00 per day, nett	12,500.00
	Total saving per voyage	$19,500.00 or £4,010

Boilers and engines were operated at their maximum capacities on both voyages.

The above figures represent the saving in expenditure, but it is obvious that the earning capacity of the vessel is increased in direct ratio to the time saved on the voyage.

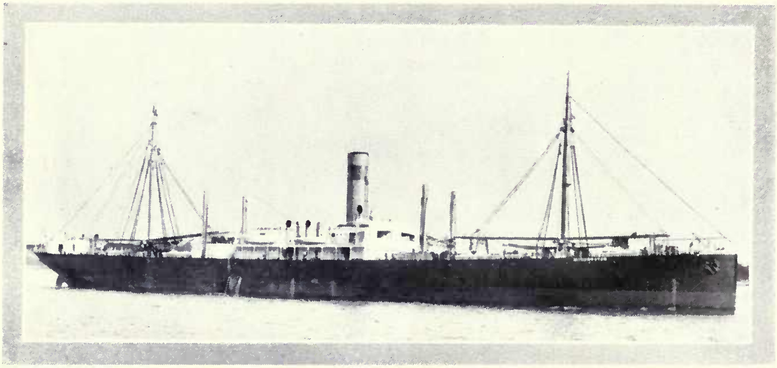


COAL. OIL.

FIG. 21.—STEAM PRESSURE CHARTS OF THE S.S. "ARIZONAN."

These Charts show at a glance the superior uniformity of steam pressure when oil is used.

3. **Reduction in Costs.**—There is a remarkable reduction in the stokehold staff. One man can attend to eighteen furnaces, and the ratio of firemen required for oil is not more than 10 to 20 per cent. of the number required for coal stoking. The resultant saving



OIL-FIRED STEAMER, AMERICAN-HAWAIIAN STEAMSHIP CO.

in wages and food is augmented by the space for accommodation being set free for other purposes. Oil fuel can be bunkered in a much shorter time than coal, and in fact the only time limit is the capacity of the loading pumps and connections.

The labour and gear required for handling ashes is entirely eliminated, and owing to the uniform firing, which is characteristic of fuel oil, there is a reduced wear and tear of the boilers, effecting a considerable saving in repairs and depreciation.

To these items, considerable in themselves, must be added the saving—frequently substantial—in cost of fuel required, when a vessel is trading from ports where coal bunkers are costly.

The following comparative statement clearly illustrates the substantial economies that can be effected by the use of oil on steamers:—

EXAMPLE OF THE COMPARATIVE COST OF COAL AND LIQUID FUEL ON A CARGO STEAMER 20,500 TONS DISPLACEMENT.

Voyage from Trieste to Buenos Aires and back, taking coal bunkers at Trieste, Las Palmas and Rio, and oil bunkers at St. Vincent and Rio.

Burning coal this ship would use **220** tons per day.
Burning oil this ship would use **144** tons per day.

Cost of coal taken on at Trieste, Las Palmas and Rio averages 33/8 per ton.
Cost of oil taken on at St. Vincent and Rio averages 47/9 per ton.

STOKEHOLD EXPENSES PER ROUND TRIP.

Coal.	£	s.	d.	*Oil.*	£	s.	d.
7,175 tons at 33/8 per ton...	12,077	18	3	4,683 tons at 47/9 per ton	11,180	13	3
50 men, 45 days at £5 per month	375	0	0	6 men, 45 days at £5 per month	45	0	0
Food, 45 days at 1/9 per day ...	196	17	6	Food, 45 days at 1/9 per day ...	23	12	6
	£12,649	15	9		£11,249	5	9

	£	s.	d.
Saving in expense by use of liquid fuel	1,400	10	0
To this must be added the freight of increased cargo which can be carried due to the smaller weight of oil required to give the same steaming range. Allowing two days in excess of actual requirements, the maximum bunkers taken on at any one of the ports mentioned above would be :			

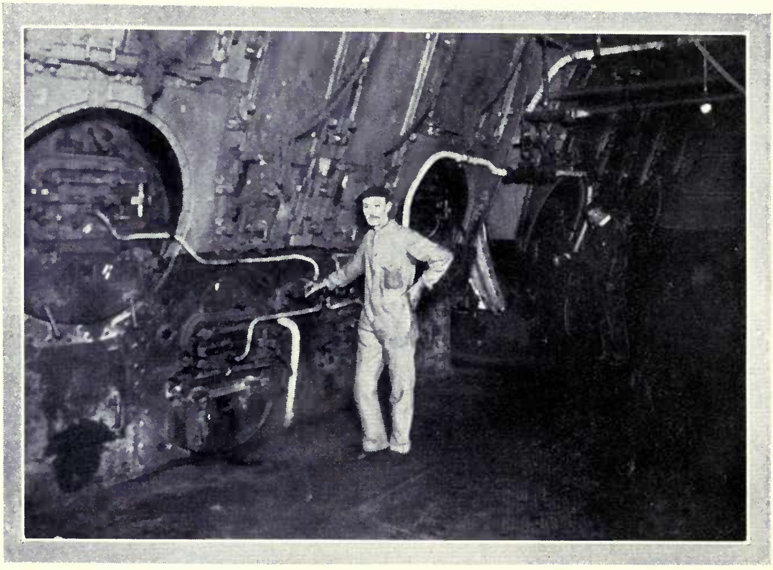
	Coal.	*Oil.*
Maximum bunkers outwards	**2,200**	**1,186**
Maximum bunkers homewards	**2,200**	**2,306**

Difference, 1,014 tons.

	£	s.	d.
Therefore increased cargo space on outward voyage 1,014 tons at 30/- per ton ...	1,521	0	0
	£2,921	10	0
Say six round voyages per year (combined saving and increased earning capacity)	£17,529	0	0

"San Fraterno"

It will be of interest to recount here the very satisfactory performance of the *San Fraterno* (Eagle Oil Transport Co.) on its trial trips off the mouth of the Tyne in April last. This vessel is the largest oil-carrying steamer in the world, and it is of especial significance in the present connection, as the vessel is not only typical of the extensive arrangements which are being made for the marketing and distribution of abundant supplies of fuel oil, but the *San Fraterno* affords in itself a practical demonstration of the advantages of fuel oil burning. The vessel is fitted with the Wallsend-Howden pressure system under each of her four boilers. Although the specified speed was $11\frac{1}{4}$ knots, the average speed attained on the trials with the full load of 15,000 tons water ballast was 12 knots per hour. This was accomplished while using only three of the four boilers. This

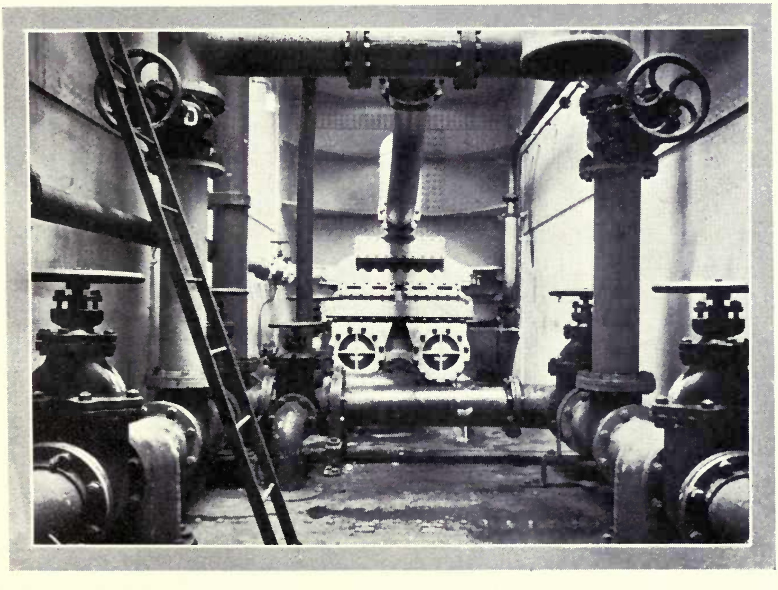


"SAN FRATERNO" OIL-FIRED FURNACES.

photograph was taken when the boilers were being forced, and a glance shows that the fireman's duties are very light indeed when oil is used. The impressions of the *Standard* engineering representative are worth quoting here :—

"On her trials she burned Mexican oil, such as she will transport from the refineries of the Mexican Eagle Oil Company.

"The writer happened to be in the boiler and engine rooms during the earlier portions of the trial. The boiler-room was as unlike the boiler-room of old as it was possible to imagine. There seven 'firemen' stood, arms folded and in spotless overalls, as though they were chefs in the kitchen of a big hotel. They were, indeed, more fortunate, for the air was free from fumes, fresh and cool. The only noise was the muffled roar of the oil flames within the furnaces. Occasionally one would examine the thermometer outside



"SAN FRATERNO" PUMPS, HANDLING 1,200 TONS OF OIL PER HOUR.

the furnace to judge the temperature of the inrushing oil. A second, having adjusted his smoked-glass spectacles, would look through a peephole to see that the jets were working properly, whilst a third would read the pressure gauge on the oil pumps.

"The steam during the compass trials had been standing at 200 lb. to the square inch. Suddenly the indicator bell rang advising preparations for full speed. With a smile of satisfaction the firemen turned small valves and increased the blast of oil and air—within a brief space of time the steam pressure stood at 220 lbs., and the power trials were under way. The vessel had to show a trial of $11\frac{1}{4}$ knots. Her first run over the measured mile revealed 12.62. This was with the tide. The second against the tide, showed 11.57 knots. Her average in the end worked out at 12 knots. Throughout the trials there was a remarkable absence of smoke from her funnel, and a complete absence of smell."

It should be mentioned that most of the "firemen" referred to were on this occasion representatives of the builders of the vessel, engines, and furnaces.

The very favourable indications of satisfactory service which the trials gave have been amply fulfilled on the maiden voyage. The *San Fraterno* arrived in London with her first full cargo of about 15,000 tons of oil from Mexico, having exceeded all the expectations of her owners. She made the round trip on an average speed exceeding eleven knots with three boilers employed, her consumption of Mexican fuel oil being only thirty-eight tons of oil per day, which for a ship of this size is highly satisfactory.

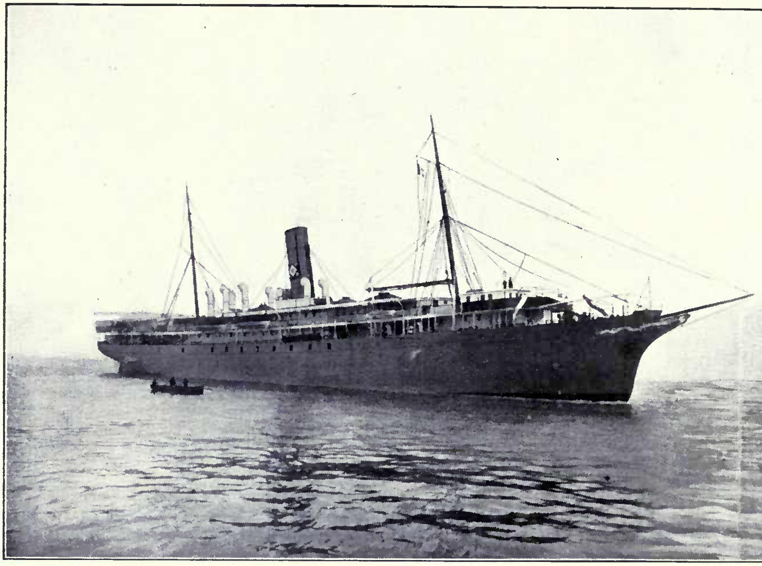
Fuel Oil for Liners

Among well-known steamship companies employing fuel oil in running some of their vessels are the North German Lloyd, the Hamburg-American Line, Austrian-

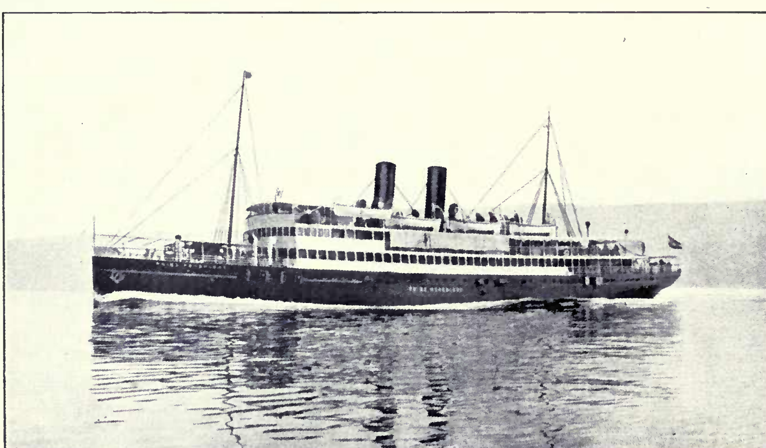
Lloyd, American-Hawaiian, Roumanian State Maritime Service, Toyo Kisen Kaisha Steamship Co., Grand Trunk Railway, Canadian Pacific, the East Asiatic Co., and the Oceanic Union S.S. Co. Several of the great steamship companies in this country have of late given the question favourable consideration, and it may be mentioned that the White Star Line has arranged to experiment with liquid fuel on the *Olympic*. This vessel recently had an inner shell fitted, and the three feet space between the inner and outer shells at the forward and after bunkers has been adapted for the storage of the oil. It is probable that the *Britannic*, which is now being constructed at Belfast for the same company, will also be fitted to burn oil fuel, and the same applies to the Cunard Company's new liner *Aquitania*. It is anticipated that the next few years will witness striking developments in this direction.

It is important to remember that the furnaces of a vessel burning oil may be readily altered to burn coal or *vice versa* when required. If suitable arrangements are made the work can be done at the cost of a few pounds by the ship's own staff without any trouble or delay to the steamer. The advantage offered by this ready conversion is that with vessels which trade between countries where either coal is dear and oil cheap, or the reverse, the cheap fuel can be used on both journeys, resulting in remarkable economies. The Toyo Kisen Kaisha steamship line above mentioned is operated in this way.

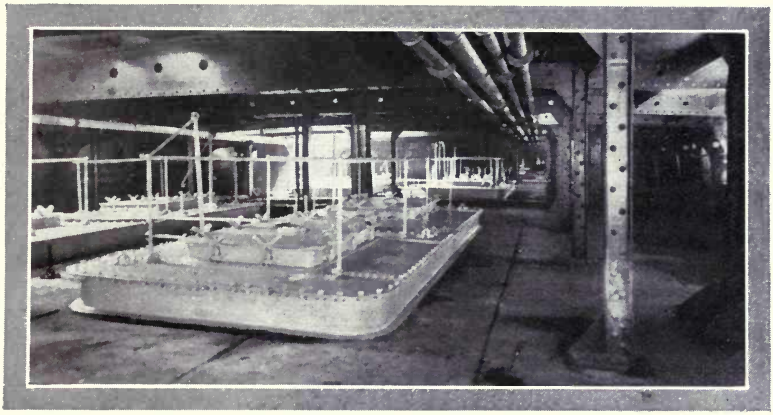
The calculations of Mr. J. J. Kermode, based on the voyages of such vessels as the *Mauretania*, are sufficiently interesting and suggestive to reproduce here. In a



S.S. "PACHIHEA."
Built for the Cia Peruana de Vapores y Dique del Callo, fitted with Wallsend-Howden Fuel Oil System.



TRIPLE SCREW STEAMER "PRINZ HOHENLOHE."
Austrian Lloyds Triple Screw Passenger and Mail Steamer fitted with the Wallsend-Howden System. (Howden's Forced Draught.) Note the absence of Smoke.



'TWEEN DECKS OF THE "SAN FRATERNO."

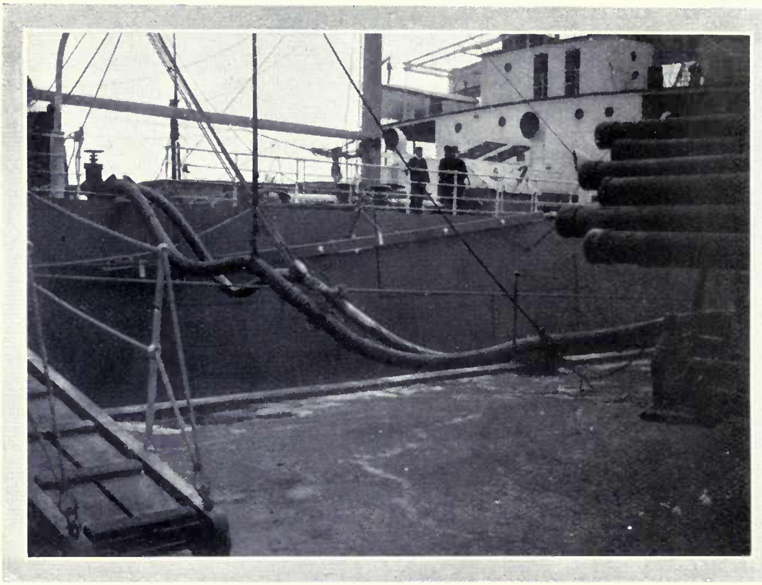
paper read at the Oil Congress in London, 1912, Mr. Kermode said:—

"On an average, to maintain a speed of twenty-five knots, 5,500 tons of coal are consumed upon the voyage between Liverpool and New York by one of these mammoth liners, or 11,000 tons for the round trip. Some 3,300 tons of oil fuel—which would be stored, if necessary, in the double bottom of the vessel, thereby leaving the coal bunkers available for cargo—would, by automatic stoking, do even more work than 5,500 tons of coal.

"Calculating the daily consumption of 600 tons of coal now used for twenty-four hours, this represents about 2,000 tons less fuel on a five days' trip, land to land run, or 4,000 tons less, out and home. The utilising of the vacant space for merchandise at, say, £1 per ton would mean a very substantial increase of income.

"Of the 312 firemen and trimmers now employed on each ship, 285 might be dispensed with, and occupation found for them under healthier conditions ashore, in handling the extra cargo which would be carried.

"Twenty-seven greasers would be able to attend to the oil burners and regulate the feed water of the boilers. At

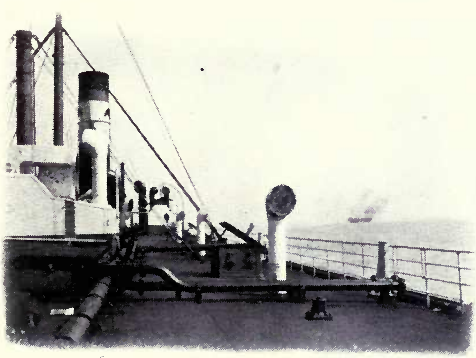


BUNKERING WITH OIL.

least 200 extra third-class passengers at £5 per head, of which 50 per cent. would be profit, could be berthed by altering the accommodation reserved for the 280 firemen and trimmers. Even with coal at 18s. 6d. per ton as against oil at seven dollars per ton on the eastward voyage, and 45s. per ton on the westward passage, the increased earning capacity of such vessels under oil fuel would be over £10,000 for the round voyage out and home. A full supply of oil could be taken on board in three hours, compared with twenty hours for coaling.

"With regard to the factors which determine speed, it must be remembered that the *Mauretania* and the *Lusitania* are each fitted with 192 furnaces in order to produce 68,000 horse-power. On the assumption that thirty-two fires are cleaned every watch, 10,000 indicated horse-power is lost every four hours through burning down and cleaning, an unnecessary operation with oil fuel. Experience on other vessels justifies the belief that the use of oil fuel would reduce the voyage between Queenstown and New York by eight or ten hours. We might look, therefore, to another great era of Atlantic records."

In summarising the advantages accruing from the use of fuel oil in place of coal on steamers, there are some which cannot be well expressed in figures. One point should be mentioned which will appeal to all shipowners, namely, the vastly superior conditions under which men work on oil-fired boilers.



DECK PIPES OF 15,000 TON OIL TANKER.

CHAPTER VI.

FUEL OIL FOR RAILWAYS.

THE locomotives of many European and American railways have for many years past been running on oil fuel. In 1889 Mr. Urquhart used a petroleum residue on 143 Russian locomotives fitted with his burner, and this was the first practical application of oil to railway work.

In those countries which are not favourably situated in respect of coal supply, the question of fuel oil for railways has very inviting aspects. Coal prices have gone up considerably in recent years and are unlikely to recede to any extent. Freights on coal are also higher; consequently, with the abundant oil supplies now available, many foreign railways have already converted some or all of their locomotives to the use of oil fuel. Among such lines may be mentioned the Austrian State Railways, Western Railway of France, Paris, Lyons, and the Mediterranean, Paris and Orleans Railway, South Russian Railway, Roumanian State Railway, Los Angeles Railway, Taltal Railway, Mexican Railway, Chilian Railway, Tehuantepec National Railway, Mexican National and Interoceanic Lines, Southern Pacific, Central Pacific, and other lines in the United States, South America, and the far East.

1. **Reduction in the Cost and Weight of Fuel.**—Most of the above railways have realised large savings, to a greater or lesser degree depending on local conditions, as a

result of the conversion to fuel oil. The following figures, from the returns of the Mexican Railway, are typical of the improved results obtained :—

COAL AND OIL FUEL RESULTS ON MEXICAN RAILWAY.

Year.		Weight of Fuel in lbs. consumed per Train Kilometre.	Percentage of Fuel.	
			Oil.	Coal.
1910	First half ...	91.03	nil.	100 %
	Second half .	91.23	nil.	100 %
1911	First half ...	86.41	22 %	78 %
	Second half...	66.09	80 %	20 %
1912	First half ...	63.37	92 %	8 %
	Second half...	61.91	100 %	nil.

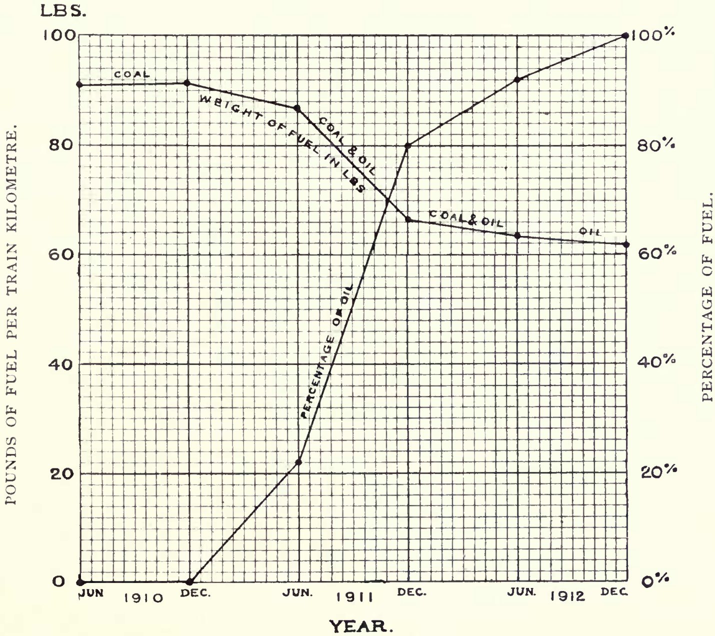


FIG. 22.—COAL AND OIL RESULTS ON MEXICAN RAILWAY.

These figures are given in diagram form (Fig. 22), and show that the weight of fuel consumed per train kilometre has been reduced by 32 per cent. by the change over to oil fuel. The reduction in the weight of fuel consumed has effected a saving of 40 per cent. in its cost.

2. **Saving in Cost of handling Fuel.**—In addition to the saving on the fuel bill many other economies are realised, the effects of which are happily reflected

20,000-GALLON FUEL OIL TANK ON MEXICAN RAILWAY.

in the balance sheets. For instance, with fuel tank installations at suitable points on the line, it is probable that quite 35 to 50 per cent. is saved on fuel haulage. This is due to two factors—the smaller weight of oil required in view of its superior calorific value, and the fact that the engines are able to carry a greater quantity of fuel.

The cost of handling is also reduced. Mr. C. G. Hall, of the American International Railway Fuel Association, says:—"Oil can be handled from tanks cars to storage tanks and thence to locos. for about ·005 cents per barrel, while the average for handling coal runs about 5 cents per ton."

There is usually a wastage of coal in handling between shipment and consumption, estimated from experience at from 8 to 10 per cent.; with oil fuel this loss is eliminated.

No men are required to load up the engine, nor clean out ash-pans; there are no ash-pits to empty or ashes to be loaded up and hauled away to be unloaded on to waste ground. Fuel oil practically handles itself, and the men attending to the water pumps can also supervise the supplies of fuel to the locomotives.

TEN-WHEELED PASSENGER LOCOMOTIVE, SOUTHERN PACIFIC RAILWAY.

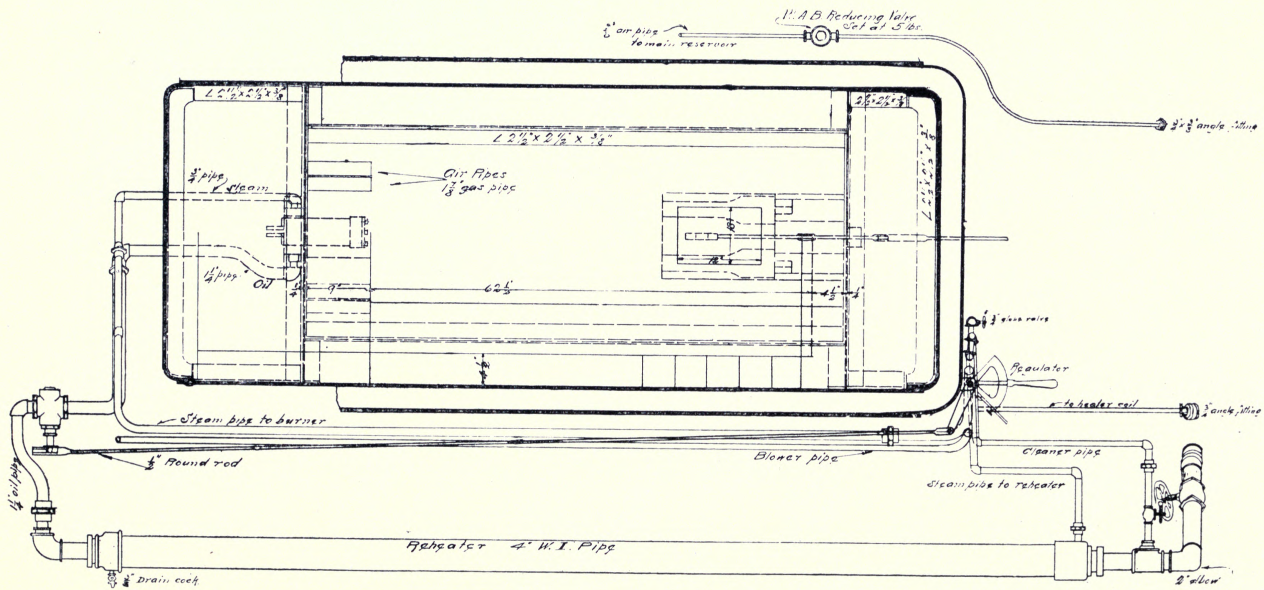


FIG. 23.—FIREBOX ARRANGEMENT ON LOCOMOTIVE, MEXICAN RAILWAY.

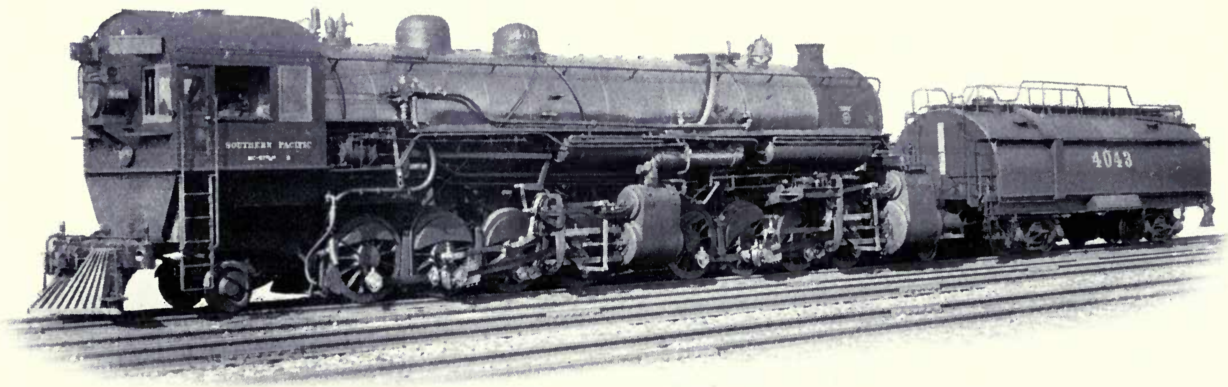
3. **Increased Mileage on one Load of Fuel.**—Another favourable feature is that sufficient fuel can be carried in the tender for a journey nearly double the length of that which would be possible with a tender load of coal, and fresh supplies of liquid fuel can be taken on in a few minutes at the appointed stations.

4. **Greater Power.**—The steaming capacity of the boiler is increased fully fifteen per cent., making it possible for a locomotive to do an amount of work on liquid fuel that would be quite beyond its powers if coal were used.

The use of oil further secures freedom from physical failure of firemen in extremely hot weather, the firemen's work actually being lighter than that of the engineer when oil is used. On some railways with long and heavy gradients the speed is limited solely by the physical capacity of the fireman shovelling coal into the furnace. With oil no effort beyond the turning of a valve is required to produce maximum capacity. There is the additional important advantage that the fireman is available to assist in keeping a look-out ahead, and for signals, far more so than can ever be the case when firing coal.

5. **Rapid Adjustment of Fuel to Suit Varying Load.**—With liquid fuel the fire can be instantaneously adjusted to suit the load, which varies almost from minute to minute with the speed and gradient. So perfect is the control that the steam pressure can be maintained within five pounds total variation, with changes in load of fifty per cent. and over.

6. **Rapidity in Getting Up Steam.**—An important feature is the rapidity in getting up a head of steam,



ONE OF THE LARGEST LOCOMOTIVES IN THE WORLD; MALLET ARTICULATED COMPOUND OIL-FIRED LOCOMOTIVE, SOUTHERN PACIFIC RAILWAY.

Total weight of engine and tender, 620,000 lbs. (277 tons); capacity of fuel oil tank, 3,120 gallons. Owing to its extreme length the engine is only run cab foremost, as shown.

as an engine can be moved under her own steam within thirty-five minutes of the fuel oil burners being lighted up.

The usual practice on railways using oil is to have a stationary boiler always in steam at each round house, from which connection is made to the dead engine through a 3-way cock in the steam-pipe leading from the steam stand on top of the fire box to the burner. By this means the burner can be started from cold until there is sufficient steam generated to keep the burner going from the engine itself.

The cost of firewood for lighting up is entirely eliminated, a handful of oily waste being all that is required.

The advantage of using oil on locomotives is specially noticeable in the round house or shed when squaring up an engine after a day's work. There are no fires to be raked out ; no flue or smoke boxes to be cleaned ; no coal to be stacked, weighed, and otherwise handled. A saving in cost of equipment is represented in the absence of fire rakes, flue brushes, shovels, all of which are unnecessary on an oil-burning locomotive. Furthermore, when engines are engaged in switching and shunting operations they frequently have to stand in steam idle for hours at a time. The burners in such cases can be cut down to the lowest minimum, or even extinguished—as an engine will always retain sufficient steam to start up the burners again when required. This, of course, represents a very considerable saving in fuel.

7. **Elimination of Fires caused by Coal-fired Locomotives.**—One valuable feature of the use of oil fuel on foreign railways is the immunity it affords from the number of compensation claims arising out of fires.

In semi-tropical countries the sparks from wood or coal fired engines frequently set fire to crops and forests, and the railway is liable to pay compensation. With oil there are no sparks and, consequently, this source of danger and expense is entirely eliminated.

It is worthy of note, in connection with the proposed conversion to oil fuel of a prominent American railway, that a petition from the State Forester to the Public Service Commission of the United States strongly urged this step in view of the frequent devastation of the adjoining country by fires caused by sparks from coal-burning locomotives.

8. **Absence of Smoke.**—The absence of smoke adds materially to the comfort of railway passengers when oil-fired locomotives are used, and increases the cleanliness of rolling stock when so hauled.

The Southern Pacific railroad, which is worked on oil, also lays dust on the whole of its 2,600 miles of road between New Orleans and San Francisco by spraying oil on the track.

Comparative Results on Railways—Coal and Oil

In the following pages a selection of comparative results on coal and oil are given, showing the indisputable advantages which are derived from the use of the latter fuel.

Mexican Railways.—Mexico, with its 5,000 miles of railroad, has now a daily consumption of over 10,000 barrels of fuel oil for railways alone, and the following data extracted from the records of the Tehuantepec National and Interoceanic railways show the decided advantage in running on oil obtained by some of these railways :—

COMPARATIVE TESTS WITH COAL AND OIL, TEHUANTEPEC NATIONAL RAILWAY.

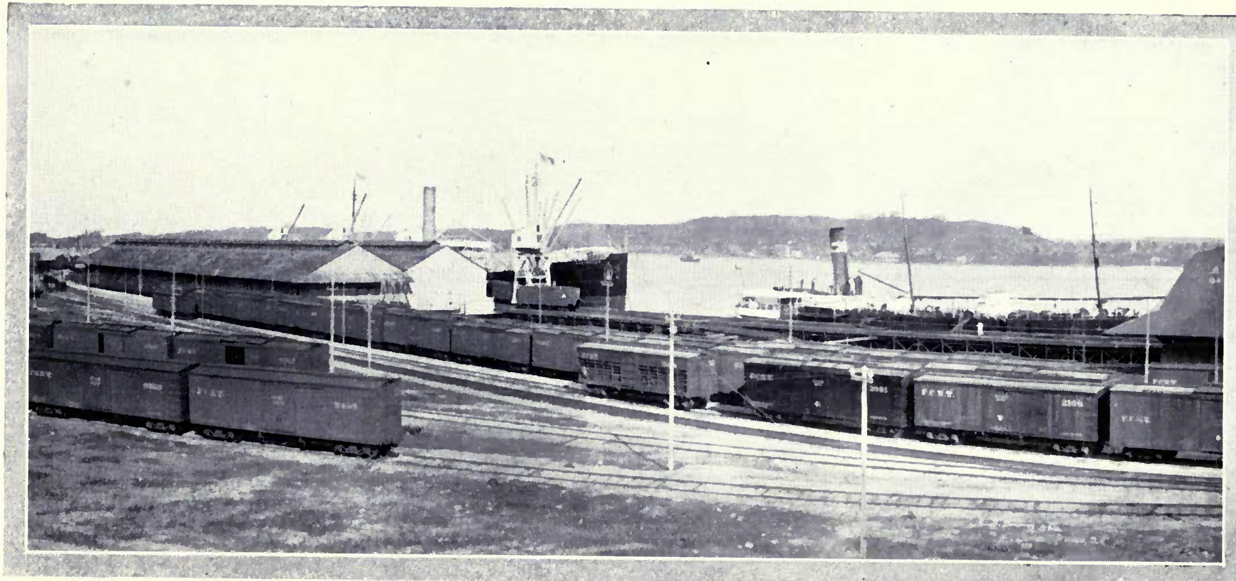
Test No.	Time Running.	Miles Run.	Speed.	Lbs. Water evap.	Lbs. Fuel used.	Water evap. per lb.	Gross Weight of Train in 2,000 lb. tons.
				COAL.			
	h. m.						
1.	7.36	126.5	16.64	75,562	12,188	6.20	461.43
2.	8.13	126.5	15.39	84,007	13,200	6.36	476 08
3.	7.36	126.5	16.64	76,611	12,567	6.08	476.31
				OIL.			
1.	6.31	126.5	19.41	69,472	6,145	11.31	470.69
2.	7.21	126.5	17.21	74,531	6,196	12.03	743.07
3.	6.21	126.5	19.92	71,577	5,896	12.14	410.71

SUMMARY.

Time getting up 180 lbs. steam from cold...	Coal—152 minutes
Time getting up 180 lbs. steam from cold...	Oil—70 minutes.
Improved speed with oil over coal (average)	16.2 per cent.
Improved evaporation per lb. fuel (average)	5.62 lbs. or 90 per cent.
Pounds of coal per 100 ton miles	**20.8 lbs.**
Pounds of oil per 100 ton miles	**10.3 lbs.**

The Tehuantepec Railway is a trans-continental line of standard gauge, 189 miles long, running across the Mexican Isthmus of Tehuantepec from Coatzacoalcos on the Atlantic to Salina Cruz on the Pacific. The grades vary from level to 2.15 per cent., with many curves up to 11 degrees 28 minutes where the speed of train is limited to 15 miles per hour.

The Company reckon 3½ bls. (147 U.S. galls. or 1225 lbs.) of oil equal one ton of coal.



VIEW OF THE PUERTO MEXICO TERMINAL OF THE TEHUANTEPEC NATIONAL RAILWAY.

Alongside the wharf is one of the American-Hawaiian Steamship Co.'s vessels, and on the right one of the Mexican Eagle Oil Co.'s tankers.

COMPARATIVE TESTS WITH COAL AND OIL. INTEROCEANIC RAILWAY OF MEXICO.

Test No.	Time Running.	Miles Run.	Speed.	Lbs. Water evap.	Lbs. Fuel used.	Water evap. per lb.	Gross Weight of Train in Tons of 2000 lbs.
COAL.							
	h. m.						
1.	3.18	35.4	10.73	43,277	8,580	5.04	173.52
2.	3.28	35.4	10.20	41,575	8,140	5.11	173.50
3.	3 29	35.4	10.17	42,985	8,580	5.00	172.37
4.	3.34	35.4	9.92	46,106	10,340	4.46	173.64
5.	3.38	35.4	9.75	43,586	11,220	3.88	184.83
OIL.							
1.	3.04	35.4	11.53	50,612	4,397	11.51	173.77
2.	3.16	35.4	10.81	46,699	4,390	10.64	176.11
3.	2.53	35.4	12.28	39,046	4,073	9.59	175.62
4.	2.33	35.4	13.88	41,591	3,833	10.85	163.74
5.	2.47	35.4	12.73	45,305	4,157	10.90	174.85

Summary.

Time getting up 180 lbs. steam from cold ... ... Coal—98 minutes

Time getting up 180 lbs. steam from cold ... . Oil—70 minutes

Improved speed with oil over coal (average) ... ... 20.2 per cent.

Improved evaporation per lb. oil ... 6.05 lbs. or 130 per cent.

Pounds of coal per 100 ton miles ... 15.07 lbs.

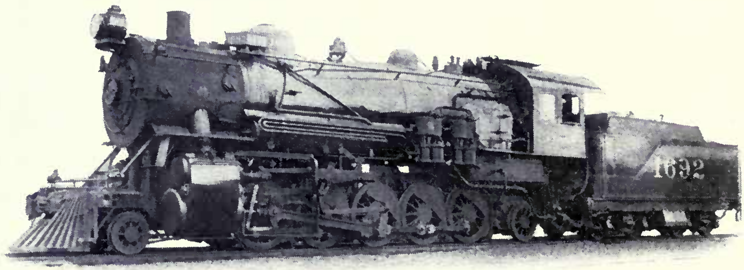
Pounds of oil per 100 ton miles ... 6.85 lbs.

The Interoceanic Railway connects Vera Cruz on the Golf of Mexico with the port of Acapulco on the Pacific, and including leased lines has a total mileage of 1,035.

American Railways.—American railways did not begin to burn oil largely until about 1906. The figures from that year until 1912 are given in the following table:—

Year.	Length of Mileage under Fuel Oil.	Total Mileage made by Oil Locomotives.	Total Barrels Used.
1906	—	—	15,577,677
1907	13,573	74,079,726	18,855,002
1908	15,474	64,279,509	16,889,070
1909	17,676	72,918,118	19,939,394
1910	22,709	89,107,883	23,817,346
1911	30,039	109,680,976	29,748,845
1912	28,451	121,393,228	33,605,598

It may be mentioned that all the passenger locomotives on the Panama Railroad are equipped for burning oil fuel and a number of the dredgers used in the excavating work were similarly equipped.



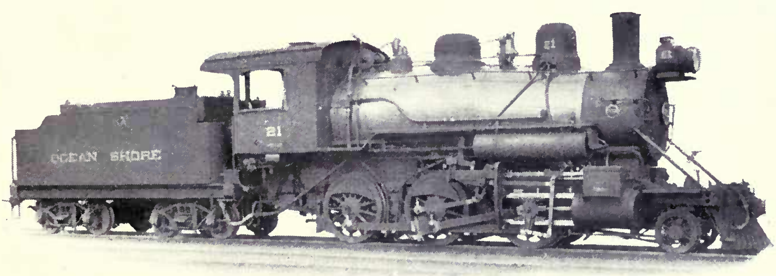
LOCOMOTIVE OF ATCHISON, TOPEKA AND SANTA FÉ RAILROAD.

The following data have been furnished by Mr. John Purcell, Assistant to the Vice-President of the above railway. The figures are based on the results in operating two trains between Kansas City, Mo., and Newton, Kansas:—

THE ATCHISON, TOPEKA AND SANTA FÉ RAILWAY SYSTEM.

	Coal.	Oil.
Average weight of train ...	293	317
Cost per 100 ton miles in cents ...	2.8	2.7
Cost per train mile in cents ...	8.3	8.6
Price per ton and per barrel ...	$1.90	$0.55
Train miles	7,978	5,321
Ton miles	2,339,800	1,687,000
Poundsof fuel consumed ...	698,000	258,517
Tons or barrels	349	832
Cost of fuel	$663.10	$457.60
Average lbs. per 100 ton miles ...	**29.83**	**15.32**

The following comparative data obtained on another of the United States railways are of considerable interest in view of the exhaustive character of the tests made. The same engine was run by the same engineer and fireman, over the same route under like climatic conditions. After burning four different kinds of coal in the several trials, the engine was converted to oil and tried out again with crude oil as a fuel. The results were as follows:—



MOGUL FREIGHT LOCOMOTIVE, OCEAN SHORE RAILWAY.

First Test—Lehigh Coal:—

Ton miles covered	98,420
Coal consumed	20,550 lbs.
Miles run per ton of coal	11.65
Pounds of coal per 100 ton miles ...	**20.36**
Cost in cents per 1,000 ton miles (Coal at $3.45 per 2,000 lbs.) ...	35.05

Second Test—Lehigh Coal Slacked:—

Ton miles	95,439
Coal consumed	26,200 lbs.
Miles run per ton of coal	8.99
(Showing a loss of 25.78 per cent.)	
Pounds of coal per 100 ton miles ...	**27.45**
Cost in cents per 1,000 ton miles (Coal at $3.25 per 2,000 lbs.) ...	44.61

Third Test—Screened Lump Wilburton Coal:—

Ton miles	99,647
Coal consumed	18,100 lbs.
Miles run per ton of coal	13.02
Pounds of coal per 100 ton miles ..	**18.16**
Cost in cents per 1,000 ton miles (Coal at $3.60 per 2,000 lbs.) ...	32.60

Fourth Test—McAllister Mine Run Coal:—

Ton miles	99,262
Coal consumed	17,700 lbs.
Miles run per ton of coal	13.31
Pounds of coal per 100 ton miles ...	**17.83**
Cost in cents per 1,000 ton miles (Coal at $3.50 per 2,000 lbs.) ...	31.21

Fifth Test—Crude Oil Fuel:—

Ton miles		99005
Oil consumed	26.67 barrels or	1120 gals.
Miles run per brl. of oil		4.47
Ton miles per gallon of oil		88.38
Pounds of oil per 100 ton miles ...		**9.92**
Cost in cents per 1,000 ton miles (Oil at 58c. per brl. of 42 gals.) ...		15.62

These results showed that 3.2 brls. of oil equalled on the average the heating value of one ton of coal, or, put another way, one ton of oil equals from 1.79 to 2.76 tons of coal, according to the quality of the coal.

British Railways.—It would not be fitting to close this section without reference to the pioneer work of Mr. Holden, late engineer to the Great Eastern Railway, who has successfully demonstrated that oil is a practical proposition for British railways. Many of their big main line engines, fitted with the burner designed by Mr. Holden, have shown very good running, and only the abundant supply of coal in this country has precluded a more extensive use of liquid fuel.

On the Great Eastern Railway express trains have been hauled on a consumption of 17.6 lbs. of Fuel Oil per mile (7.82 lbs. per 100 ton miles), the coal consumed for similar work being 34 lbs. per mile (15.1 lbs. per 100 ton miles), the weight of the train being 225 tons.

These engines have made the run from London to Cromer - a distance of 138 miles—in 2 hours 55 minutes, including one stop of 4 minutes, on oil fuel or oil fuel burnt in conjunction with coal. In the latter case a thin layer of slow-burning coal is spread over the fire bars with the damper of the ashpan sufficiently opened to give an easy draught and ensure a bright fire.

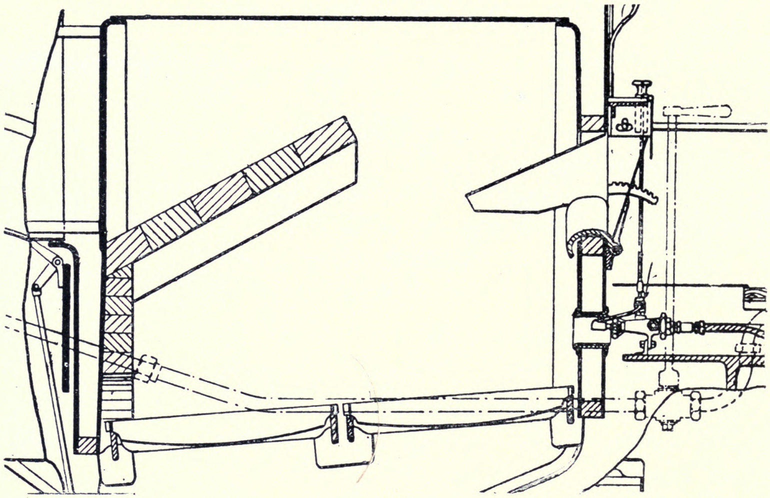


FIG. 24.—ARRANGEMENT OF FIREBOX, HOLDEN SYSTEM.

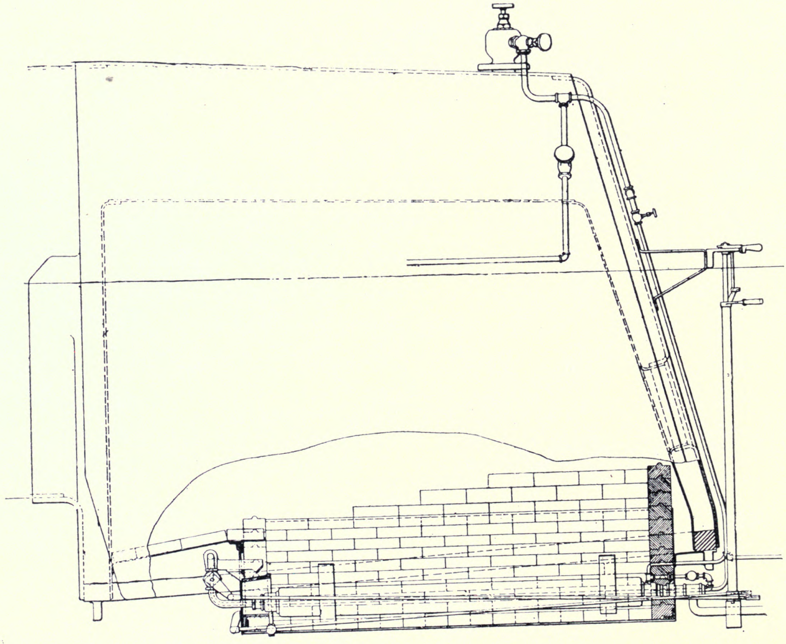
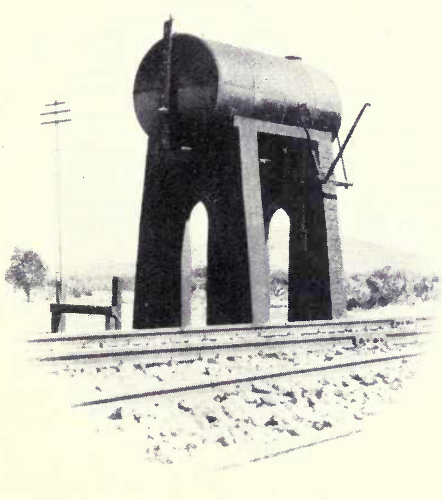


FIG. 25.—ARRANGEMENT OF FIREBOX, BALDWIN SYSTEM.

A difference will be noticed between the Holden system and that of most foreign railways, as, for example, the Baldwin system, in the position of the burner and the fire-box arrangement. As shown in Fig. 24 on the opposite page, the burner in the Holden system is fitted in the mud ring below the fire-box door, directing the flame towards the flue sheet under an arch of fire-brick. In the other it will be seen that the practice is to eliminate the arch entirely, the burner being placed at the flue sheet end of the fire-box as illustrated in Fig. 25.



FUEL OIL SERVICE TANK ON MEXICAN RAILWAY.

CHAPTER VII.

OIL FUEL FOR LAND STEAM PLANTS.

General Advantages

OIL fuel has been successfully applied to all types of boilers for land plants using steam power, and has been widely adopted in those localities where the cost of oil fuel competes favourably with coal. The advantages which it offers are substantially the same as detailed in the references to marine and locomotive practice, and need only be briefly recapitulated.

1. The head of steam required can be rapidly obtained from cold, and maintained with the utmost regularity.

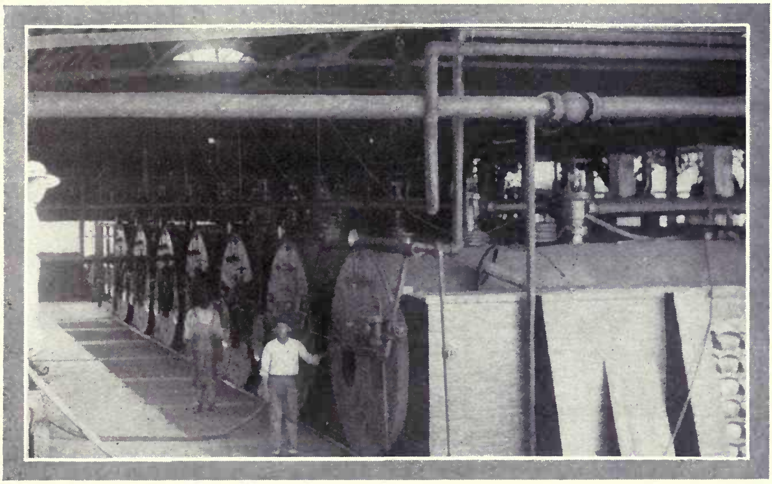
2. The absence of stresses on furnace plates consequent upon the frequent opening of furnace doors, necessary with coal stoking, prolongs the life of the boilers.

3. Considerable saving of labour in stoking, cleaning, and handling fuel and ashes, and cleaner conditions in boiler house.

4. Fires can be started and stopped instantly as required, avoiding standby losses.

5. The output of boilers can be augmented by 30 per cent. to 50 per cent. by substituting oil for coal. In some cases this conversion has rendered it unnecessary to put down additional plant when increased steam power is required due to the growth of the undertaking.

6. The perfect smokeless combustion of the fuel obviates the smoke nuisance in closely populated districts. The Public Health Act in 1871 made it an offence to

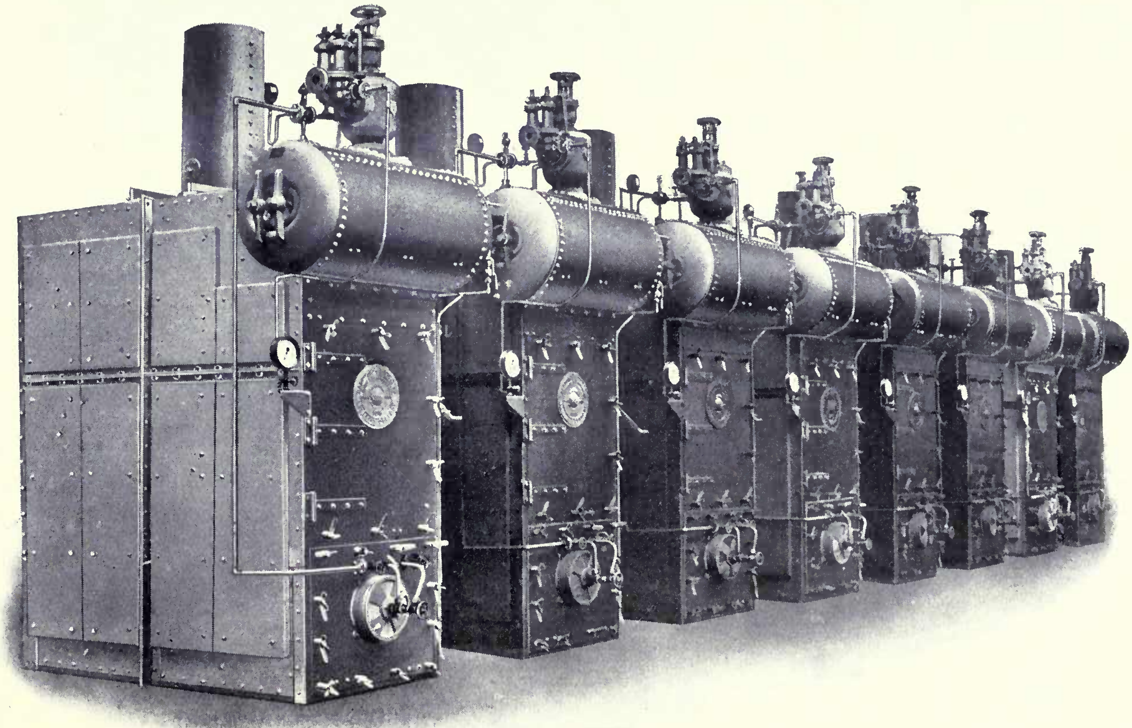


LANCASHIRE BOILERS FITTED WITH WALLSEND BURNERS AT MINATITLAN REFINERY.

emit black smoke from factory chimneys, and in many instances the local authorities insist on its provisions being carried out, although much remains to be done, as is shown by the statement that in the Administrative County of London 76,000 tons of soot descend every year. A great deal of this smoke nuisance could be abated by the use of oil fuel.

Electric Plants

Special mention should be made of the value of fuel oil installations in the case of electric lighting and power plants. While oil fuel cannot, in this country, be expected to entirely replace coal in large electric generating stations on the present relative prices, yet its use as an auxiliary to meet the recurring peak loads can be shown to effect substantial savings over the exclusive use of coal in such installations. This phase of the oil question is receiving increased attention from engineers. The sudden and heavy demands that are made upon a power station can readily be met by having the whole or a portion of the



BATTERY OF BABCOCK AND WILCOX OIL-FIRED BOILERS, PORTABLE TYPE, AS INSTALLED IN CENTRAL AFRICA.

boilers fitted with an auxiliary oil-burning equipment. They are enabled by this means to meet the peak load promptly, without interfering with their normal operation as coal-fired boilers.

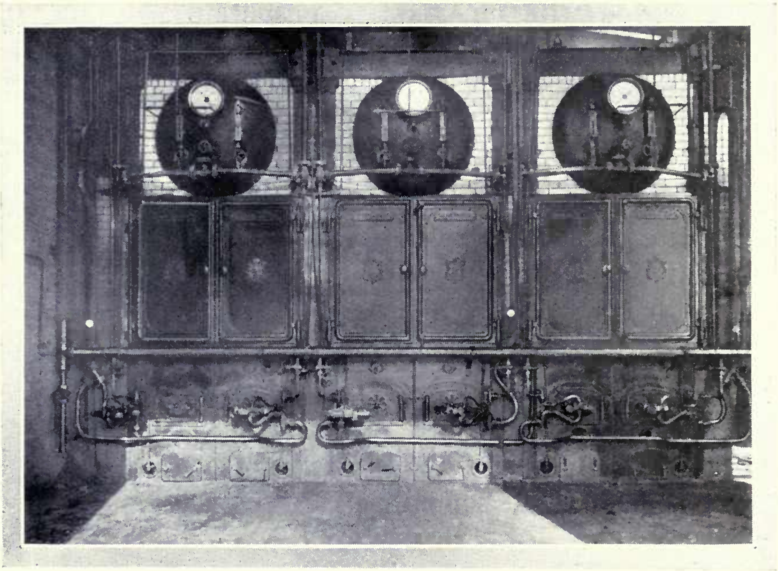
The use of a supplementary oil burner on a coal furnace is found to greatly improve the combustion of the latter fuel. It has been established by careful tests that when a constant rate of coal burned per square foot of grate area was maintained for many hours, the addition of 40 per cent. of oil increased the total evaporation by over 100 per cent. and at the same time increased the evaporation obtained per lb. of fuel burned by 35 per cent.

Oil for Peak Loads

In some cases it is possible for the peak load to be carried without increasing the number of boilers under steam by utilising, during the peak load period, either a combination of coal and oil-firing, or oil-firing to the exclusion of coal.

In America, where formerly a battery of boilers carried banked coal fires to meet sudden demands, "a number of plants have been changed to oil by placing the burner in the front end setting of the boiler, the grates being covered with a checker-work of fire-brick and the openings in the checker-work being of such proportion as to admit sufficient oxygen for the consuming fuel. A gas pilot light is constantly kept burning, and when the boilers are suddenly called into service, the oil burner is started in five seconds by simply opening the operating valves—and in 10 minutes 150 lbs. of steam is on the boiler. Of course, when not under fire, hot water is constantly passing through these boilers—this being the same practice as is used in fire-engine stations."*

* W. N. Best.



BOILER PLANT OF LIVERPOOL GAS CO., FITTED WITH KERMODE BURNERS.

Oil versus Coal

That fuel oil will effect the economies claimed for it in land plants generally is evidenced by the data given in the following pages. For industries operated in countries not possessing an abundant coal supply the superiority of oil is indisputable, while there are frequently instances where the heavier first cost of fuel oil as compared with coal in this country is outweighed by the advantages inherent in the latter fuel.

There have not been many tests carried out on the comparative merits of coal and oil fuel in stationary plants in this country, and the following tests made at the works of the Wallsend Slipway and Engineering Co,, Ltd., Wallsend-on-Tyne, with an ordinary factory boiler, are therefore of interest.

COMPARATIVE TEST ON BOILER AT WALLSEND.

COAL VERSUS OIL.

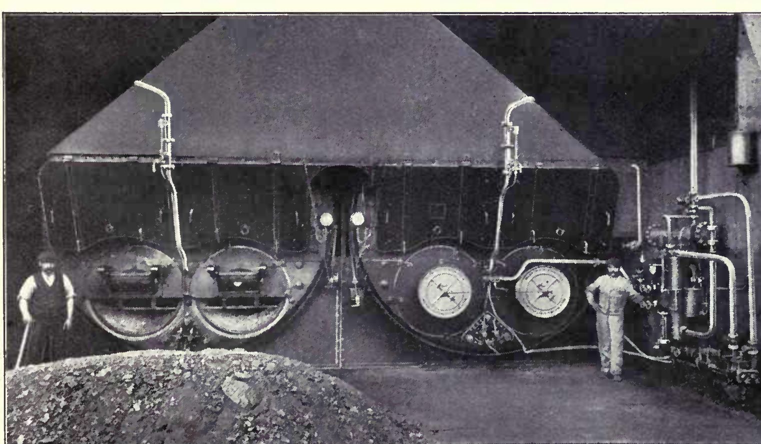
Mexican Fuel Oil.

Fuel Oil:—	Sp. Gr. at 60° F.	·953
	Viscosity at 100° F. (Red No. 1)	2,130 secs.
	Flash point (close) ...	above 160° F.
	Calorific value	18,430
Water evaporated	Lbs. of water per lb. of oil...	12.15
	Lbs. of water per lb. of oil (from and at 212° F.) ...	**14.38**
Boiler efficiency		75·37%

Coal.

Coal:—	Calorific value in B. T. U. ...	14,432
Water evaporated	Lbs. of water per lb. of oil...	7·76
	Lbs. of water per lb. of oil (from and at 212° F.) ...	**9.31**
Boiler efficiency		62.28%

Both the above tests were made with natural draught; the boiler had been in service for a number of years.



COAL-FIRED BOILER. OIL-FIRED BOILER, WALLSEND SYSTEM.

Coal versus Oil

The following figures, extracted from report made on the proposed conversion from coal to oil of the boiler plant of a large steel works in Mexico, show the saving that can be obtained by the use of fuel oil. The prices quoted for both oil and coal in this report are both very low, and are not operative to-day.

The plant consist of eleven 400-H.P. and two 300-H.P. Babcock and Wilcox boilers, having one smoke stack, 10 feet inside diameter by 175 feet high.

The boilers are worked at their full capacity during the twelve hours' day shift, and at half power during the night shift, over the whole year. The coal in use is obtained from mines owned by the Steel Works Co., has an average calorific value of 11,500 B.T.U., and the cost per metric ton, delivered at the plant ready for firing, $8.50 Mexican currency.

37,000 metric tons were used during 1911. Sixty men were employed on the boiler plant alone as firemen and coal-passers, and are paid at the rate of $1.50 Mexican per day.

Estimate of Economy in Fuel and Labour.

Taking a working year of 350 days, and the boilers working at full capacity for twelve hours' day shift and half capacity for twelve hours' night shift, then the quantity of coal burned per hour averages

$$\frac{37{,}000 \times 2{,}000}{350 \times 18} = 11{,}740 \text{ lbs.}$$

With a calorific value of 11,500 B.T.U., and assuming a thermal efficiency of 72 per cent., then the water evaporated from and at 212° Fah. per pound of coal equals :—

$$\frac{11{,}500 \times 72}{966 \times 100} = 8.5 \text{ lbs.}$$

The average total water evaporated per hour with coal equals 11,740 × 8.5 = 99,790 lbs.

To achieve the same average hourly evaporation with oil having a calorific value of 18,500 B.T.U., .953 specific gravity (333 lbs. to the barrel), and a thermal efficiency of 80 per cent., then the oil burned per hour equals :—

$$\frac{99.790 \times 966 \times 100}{18,500 \times 80} = 6,517 \text{ lbs.}$$

Then the total oil consumption per year of 350 days with boilers working the same as for coal would be :—

$$\frac{6.517 \times 18 \times 70}{2,000} = 20\ 530 \text{ metric tons.}$$

or at 333 lbs. to the barrel = 123,302 barrels.

Assuming the cost of oil delivered at the plant to be $2.05 Mexican per barrel of 42 American gallons (333 lbs.), then the total cost per year of fuel and labour in running the boiler plant under coal or oil is as follows:—

UNDER COAL.

37,000 metric tons at $8.50 ...	...	$314,500
60 men for 350 days at $1.50	...	31,500
Total	...	$346,000

UNDER OIL FUEL.

123,302 barrels at $2.05 ...	...	$249,070
8 men for 350 days at $1.50 ...	...	4,200
Total	...	$253,270

Shewing an estimated saving in cost of fuel and labour of :—

$92,730 or £9,273 per annum.

Land Plant Tests

SUMMARY OF TRIAL WITH MEXICAN FUEL OIL

MADE AT WALLSEND WITH WALLSEND PRESSURE SYSTEM, JULY 24-26, 1912.

Type of Boiler	Scotch Marine.
Duration of trial	7 hours.
Specific Gravity of fuel oil at 60° F. ...	.953
Flash Point of fuel oil (open)	290° F.
Viscosity at 100° F. (Red No. 1)	2,000 secs.
Calorific value of fuel oil in B.T.U. ...	18,902
Total quantity of fuel oil consumed in lbs...	3,409
Total quantity of fuel oil consumed in lbs. per hour	487
Lbs. of fuel oil consumed per sq. ft. of grate area per hour	12.17
Steam pressure in lbs. per square inch ...	121
Temperature of Feed Water	74° F.
Temperature of fuel oil in tanks	80° F.
Temperature of Flue gases at bottom of uptake	425° F.
Draft of water at bottom of uptake ...	3′ 10″
Steam used by pressure system in lbs. per hour	162
Steam used by pressure system as percentage of total steam generated	2.63%
Total quantity of water evaporated in lbs.	43,000
Total quantity of water evaporated in lbs. per hour)	6,143
Total quantity of water evaporated per lb. of fuel oil (actual)	12.61
Total quantity of water evaporated per lb. of fuel oil (from and at 212° F.)	**14.97**
Lbs. of water evaporated per sq. ft. of heating surface	3.63
System of Draft	Natural
Thermal Efficiency	76.5%
Oil pressure in lbs. per sq. in.	150
Oil Temperature in degrees F.	260

Land Plant Tests

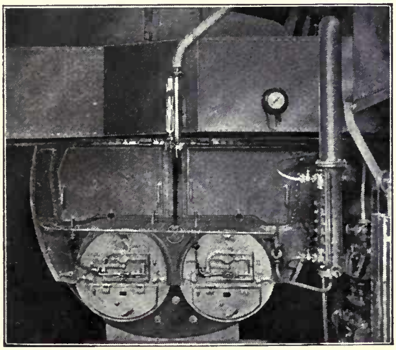
SUMMARY OF TRIALS WITH OIL FUEL.

KERMODE'S PRESSURE JET SYSTEM, ON WATER TUBE BOILERS, ARRANGED IN CLOSED STOKEHOLD.

	No. 1.	No. 2.
Duration of trial (in hours)	2	2
Specific gravity of Oil	·955	·955
Average feed temperature °F.	44	44
Steam Pressure, lbs. per square inch ...	250	250
Air Pressure, inches of water	.61	2.25
Description of Smoke	Trace	Trace
Weight of Oil burned per hour in lbs. ...	1195	3720
Weight of water evaporated per hour in lbs.	15,530	41,540
Equivalent Evaporation. From and at 212° F. per lb. Fuel	**16.00**	**13.8**

We give on next page summary of tests made with the Wallsend System, carried out under the direction of Professor Barr, of Glasgow University, at the works of Messrs. James Howden and Co., in October, 1910.

The boiler on which the tests were made is of the Marine Return Tube Type, 11′ 0″ diameter by 11′ 6″ long, with two furnaces, each 3′ 3″ inside diameter.



BOILER ON WHICH THE TEST GIVEN ON PAGE 96 WAS MADE.

No firebrick lining was used, other than a wall built against the furnace front to protect it from the flames. The total heating surface was stated to be 1,358 square feet.

The boiler was fitted with Howden's Hot Air System of Forced Draught.

Land Plant Tests

SUMMARY OF RESULTS OF TRIALS.

Wallsend-Howden Fuel Oil System, Working with Howden's Forced Draught.

Duration of trial in hours ...	$3\frac{1}{2}$	2
Number of burners per furnace...	One No. 18	One No. 16
Calorific value (nett) of the oil B.T.U.	18,770	18,770
Specific value of the oil at 60° F.	0.868	0.868
Steam pressure ... lbs. per sq. in.	155	155
Average temperature of feed water ... ... deg. F.	115	120
Pressure of air entering furnaces ins. of water	$2\frac{1}{4}$ in.	$\frac{7}{8}$ in.
Temperature of air entering furnaces ... ... deg. F.	190	185
Description of smoke at chimney top	Very light to none	Very light to none
Temperature of gases at the foot of chimney ... ...deg. F.	488	420
Weight of oil burned per hr....lbs	932	633
Weight of oil burned per hour per burner ... ... lbs.	466	316 5
Weight of water evaporated per hour ... ... lbs.	13,050	9,000
Total moisture in steam (by surface condensing calorimeter)	1%	None
Weight of water evaporated per lb. of oil burnt... ... lbs.	14.00	14.22
Equivalent evaporation from and at 212° F. ... ... lbs.	15.91	**16.22**
Equivalent evaporation from and at 212° F. per sq. ft. of heating surface per hour ... lbs.	10.92	7.55
Thermal efficiency of boiler ...	82.3%	83.9%

Heat Radiators.

Another purpose for which liquid fuel will undoubtedly be extensively used in the near future is that of hot water and steam installations for heating large buildings, schools, theatres, churches, institutes, etc. One of the disadvantages of modern coal or coke fired systems is that it takes some considerable time to raise the temperature of the building, and when once the temperature is raised it is difficult to regulate it to any fine degree. With liquid fuel the necessary temperature can be reached in less than half the time required with coal or coke, and the required

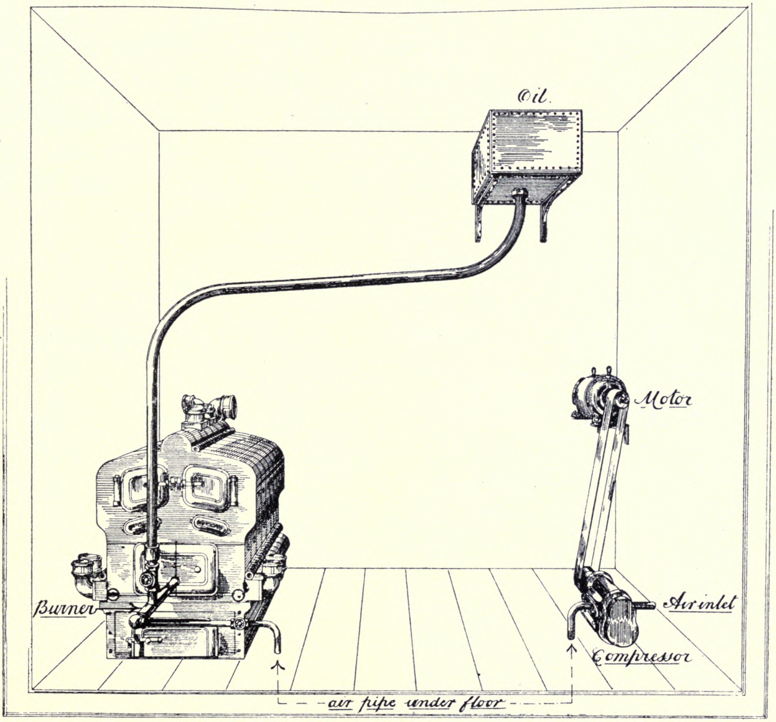
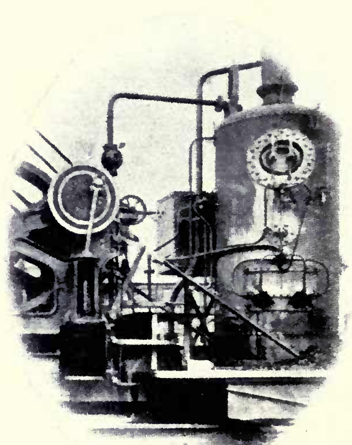


FIG. 26.—BOILER FITTED WITH CRUDALL BURNER FOR HEATING BUILDING.

degree of heat can also be maintained regularly throughout the day or night quite irrespective of external influences, such as sunshine, frost, etc. No stoking is required, the only condition being the adjustment of the burner from time to time as more or less heat is required. The illustration (Fig. 26) shows a small hot water apparatus in use in London where the fuel used is Mexican Fuel Oil. With this apparatus, it has been found that the required temperature can be reached in forty-five minutes, whereas when coke was employed two to three hours was necessary. During the day time, should heat not be required, the burners can be immediately extinguished, and if in the cool of the evening the apparatus should be required again, it can be started without any of the labour involved in making up coal or coke fires, while there is also, of course, the great advantage that the furnace does not require cleaning out after use. Heating a building with liquid fuel will usually effect a reduction in the cost, the quantity of oil required being so much less than coal or coke, and the results being so much more satisfactory, that the slightly increased cost of the installation is soon justified.



STEAM CRANE FITTED WITH HOLDEN'S BURNER.

Oil-fired Steam Cranes

Oil is a very suitable fuel for steam cranes, as the intermittent character of their work is readily

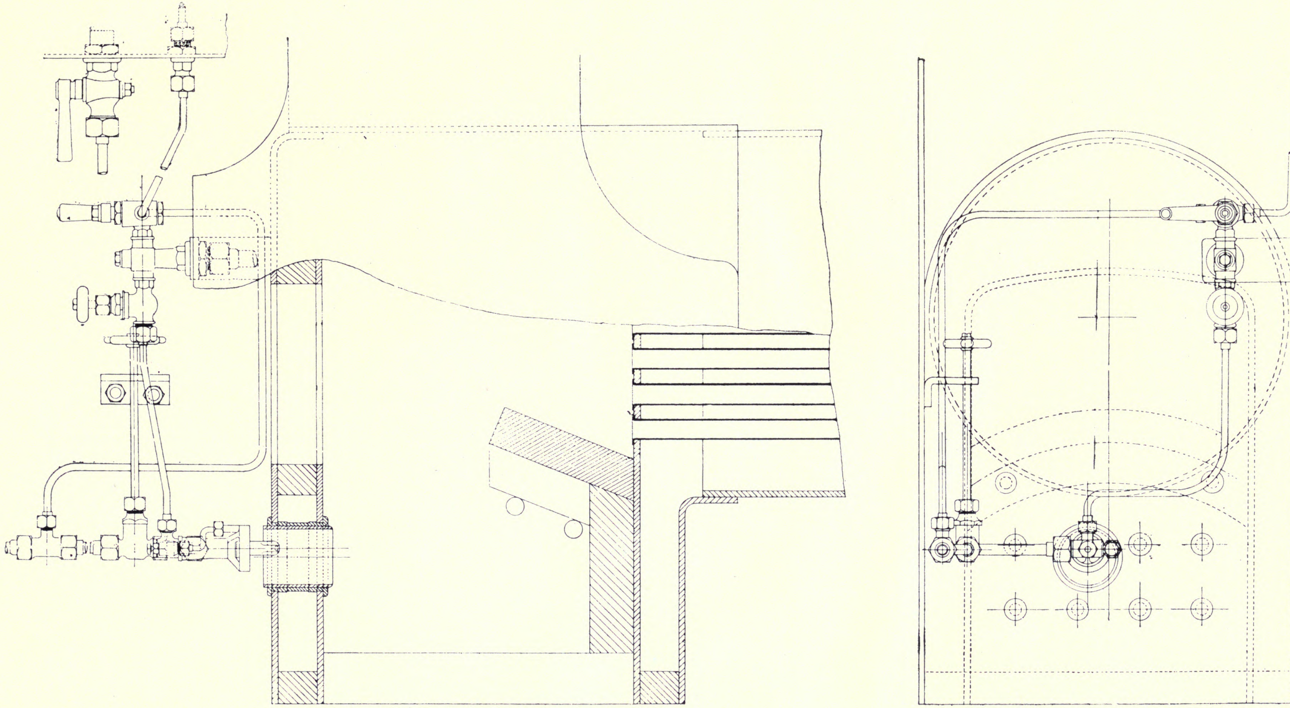
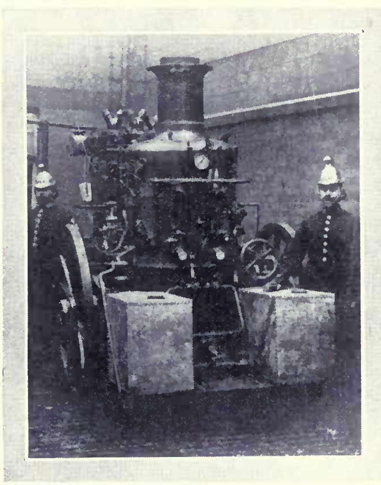


FIG. 27.—INSTALLATION OF HOLDEN'S FUEL OIL BURNER ON BOILER OF STEAM WAGON.

met by the flexibility of an oil burner, which is instantly adjusted to the requirements. The illustration shows a crane boiler fitted with Holden's burner.

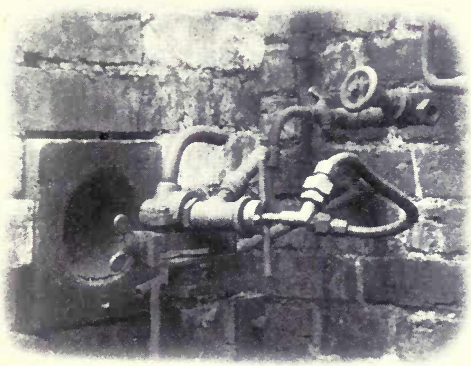
Fuel Oil for Road Vehicles

The application of fuel oil burners to road vehicles has so far made comparatively small progress. It is probably because the value of the economies effected by fuel oil are not so obvious in small portable boilers as for large installations, and the tendency seems to be to use a different type of burner which consumes kerosene to generate steam in a small water tube boiler. Steam motor-cars are run on this principle, which, however, is outside the scope of the present book. Yet oil fuel offers decided advantages for motor buses, steam lorries, and such vehicles in the rapidity with which steam can be generated, the absolute control possible, and steadiness with which fullest steaming power can be maintained.



FIRE ENGINE FITTED FOR OIL BURNING.

The Holden burner has been supplied for a number of vehicles of this class, one installation of which is illustrated on page 99, while the Kermode steam burner has been applied to fire engines for the London, Liverpool, and other fire brigades with satisfactory results. The engine illustrated herewith belongs to the Liverpool Fire Brigade, and the steam generated by oil furnace propels the vehicle, and in pumping gives a constant delivery of 1,400 gallons per minute. In connection with fire engines it may be mentioned that the fire floats of the London Fire Brigade, like their land engines, are equipped to burn fuel oil.



CHAPTER VIII.

OIL FURNACES.

APART from the use of fuel oil for steam raising there are a vast number of industries using direct heat in which oil is rapidly displacing coal, coke and expensive gas firing. We refer to metallurgical and industrial processes such as brass melting, case hardening, annealing, tempering, glass making, rivet and bolt making, rivet heating, lead refining, crucible furnace work, tyre heating, etc. The use of fuel oil for some of the above purposes was one of its earliest applications; to-day oil furnaces have been brought to a very high point of efficiency and are being extensively and increasingly employed, both in this country and abroad.

General Advantages

Briefly stated, the advantages realised in the use of oil for the above purposes are :—

1. Increased output of plant.

2. Reduction in cost of fuel required for a given amount of work.

3. Saving in time taken by the operation resulting in reduced labour cost, and increased output of plant.

4. More uniform results owing to perfect control of furnace temperature.

5. Less waste owing to imperfect work, breakage, loss of metal, etc., according to the class of work for which the furnace is employed.

6. Individual heats can be run and furnace shut down without waste of fuel.

7. No cleaning out of furnaces is necessary after a day's run, there are no ashes to dispose of, and the whole manipulation of the furnaces is less irksome to the operator.

8. Prolonged life of crucibles.

9. Less floor space required and cleaner conditions in factories.

Some of the leading applications of oil firing to industrial processes are illustrated in the following pages, and representative furnaces are shown in connection with the processes described. The limits of space preclude a full reference, but the examples given may be taken as typical, and a list of most of the industries in which oil fuel has been successfully used will be found in the appendix. It should be further mentioned that most burners can be used for any of the purposes enumerated in the list above mentioned.

A Typical Industrial Burner

Fig. 28 illustrates a typical burner as fitted to industrial furnaces. This burner works with an air jet, the air being previously heated. The oil flow is regulated by a needle valve and the air by a cone valve, the air pressure employed varying from 5 inches water gauge to 2 or 3 lbs. per square inch, according to the class of work and size of burner. Dry steam may be used instead as the atomising agent, but this will not give

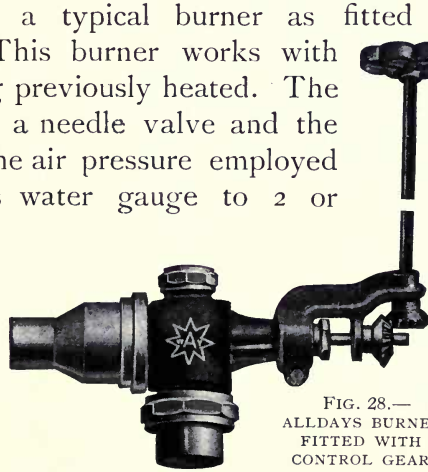


FIG. 28.—ALLDAYS BURNER, FITTED WITH CONTROL GEAR.

such a hot fire as when air is employed. These burners are adapted for hardening, annealing, melting, and smelting, rivet heating, forging, tyre heating, glass melting furnaces, etc. A temperature of over 3,000° F. (1,700° C.) is obtainable by their use. Fig. 29 illustrates

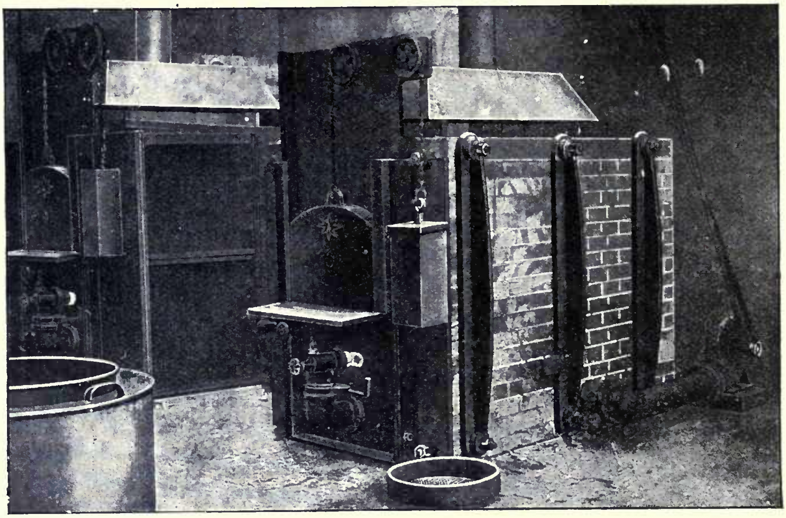


FIG. 29.—ALLDAYS CASE-HARDENING AND ANNEALING FURNACE.

Case Hardening

this burner applied to a case-hardening and annealing furnace, with which a temperature of over 1,100° C. can be obtained in one hour. A similar furnace with a totally enclosed muffle is also made, suitable for enamelling hollow-ware, etc., and with this latter type a muffle 7 ft. 6 in. by 2 ft. 6 in. can be fired on four gallons of oil per hour.

Rivet Heating

The illustration (Fig. 30) shows an oil-fired rivet heating furnace. It is fitted with an injector to work off compressed air, and would use about 20 cubic ft. of free air per minute. The air is partially heated by passing through the top chamber. This furnace is particularly adapted for pneumatic tool riveting, and the rivets can be left in the top for any length of time without fear of overheating. By using an oil furnace there is little or no scale on the rivet, and much less waste of rivets due to scale and burning. 8,000 rivets in a ten-hour day can be heated by means of one oil-fired rivet heater.

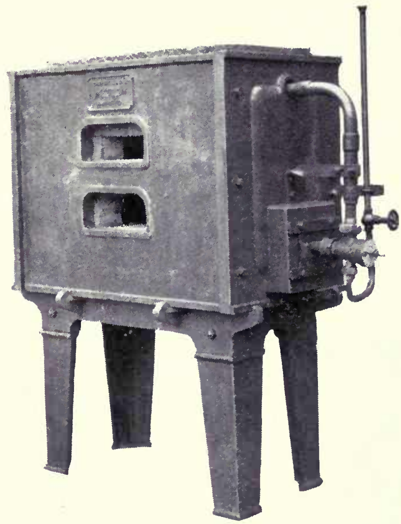


FIG. 30.—CHURCHILL RIVET HEATING FURNACE.

Bolt and Nut Making

The burner shown in Fig. 31 is the outcome of practical experience on the part of Messrs. Richard Davies, Victoria Bolt and Nut Works, Manchester, and

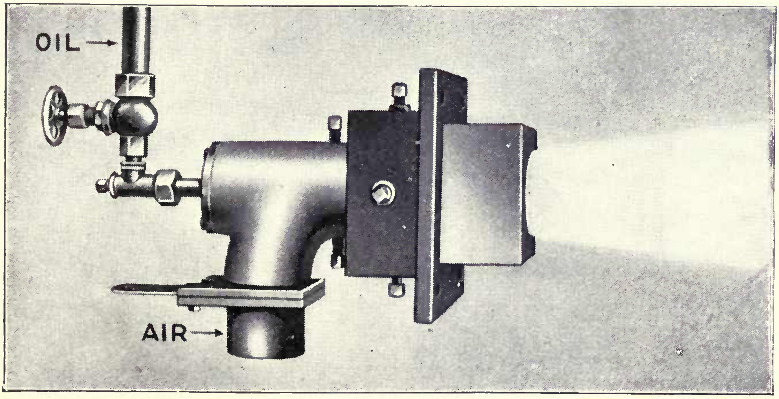


FIG. 31.—DAVIES BURNER.

has been used for years past in conjunction with their furnace for nut and bolt making and other purposes.

As a result of the use of oil they find that the output of work is from 50 per cent. to 100 per cent. greater than with coal or coke. There is a greater radiation, and a softer, cleaner heat, which saves the tools on the machines.

In a ten-hour working day an output of from 50 to 70 gross of bolts is obtained on an oil consumption of between 35 to 40 gallons of fuel oil. As a matter of fact, the capacity of the furnaces is in advance of the speed of the operators. The furnace will bring to a welding heat a 1 inch round bar of iron 2 ft. 6 in. long in three minutes, and as the furnace takes a number of these bars there is a continuous supply of hot metal for working.

Wire and Rolled Strip Annealing

The illustration (Fig. 32) shows an oil-fired furnace designed and used for annealing wire and cold rolled strip iron, which is being used extensively in the wire industry in Belgium. The steel pan holding the wire is heated uniformly from top to bottom, and there is no loss from under or overheated material. The furnace can be built at about two-thirds of the cost of an ordinary coal furnace ; no chimney is required when oil is used. A recent test gave the following results :—

MATERIAL ANNEALED—COLD DRAWN STRIP IRON.

Weight of crucible	$39\frac{1}{2}$ cwts.
Weight of material annealed	$33\frac{1}{2}$ cwts.
Time taken to anneal	$1\frac{3}{4}$ hours.
Oil consumption	$11\frac{3}{4}$ gallons.
Cost of operation at 3d. per gall. Approx.	3s.
Relative cost per ton of material annealed	1s. 11d.

The furnace is ready for use in twenty minutes to half an hour's time from starting up, and once the burner is set no further attention is required; very

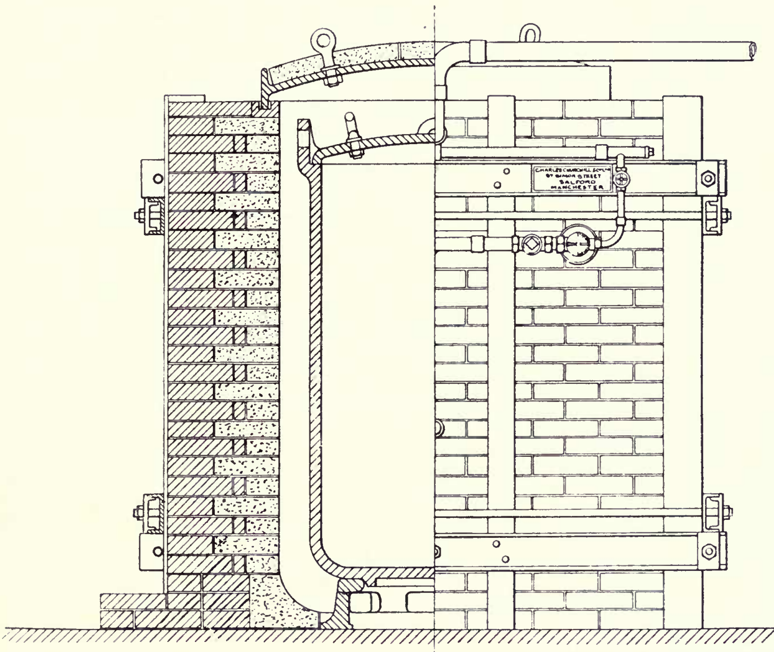


FIG. 32.—CHURCHILL WIRE ANNEALING FURNACE.

accurate and steady heats are obtained, and there is a large saving of space as compared with coal or coke furnaces.

The furnaces for wire annealing illustrated above are manufactured by Messrs. Charles Churchill & Co , Ltd., of Salford, Manchester, who also supply their burners separately from their furnaces when required. Some of the furnaces above illustrated may be seen at Messrs. Churchill's works running on Mexican Fuel Oil.

Forging Furnaces

This furnace, Fig. 33, is used in connection with bolt heading and forging machines, small power hammers, eye bending machines, etc., and is adapted for rods and bars up to $1\frac{1}{2}$ inch. It will heat $\frac{3}{4}$ inch bolts for heading at the rate of 4,000 per day. When used instead of a coal or coke furnace it will more than double the output of the machine.

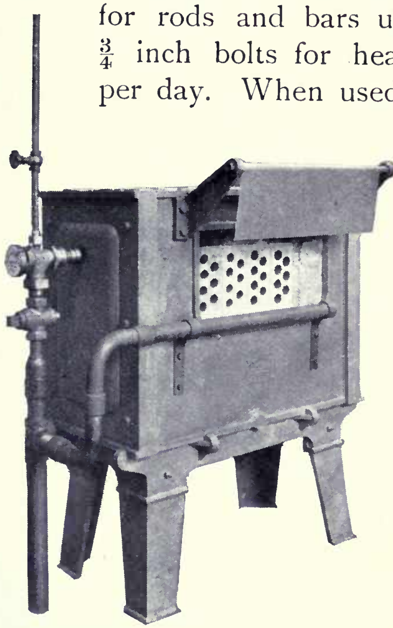


FIG. 33.—CHURCHILL FORGING FURNACE.

The furnace shown in operation on the next page (Fig. 34) is used in connection with Messrs. Churchill's Ajax forging machine, and a few examples of the work performed are shown. This particular furnace is at work at Messrs. P. and W. MacLellan's, Wagon and Bridge Builders, Glasgow. High and steady heats are a special feature. It is also used in connection with drop hammers from 800 to 1,500 lbs. weight and heats bars from three to four inches diameter. It works on an air blast at 8 oz. pressure. The illustrated items can be made by this method at one-quarter the cost incurred formerly when made under steam hammer and drop stamp. For instance, the second item on the right is made from a fairly high carbon steel, and to get the material to flow and so form the lug is no easy matter. When previously forged from a billet under steam hammer and drop stamp the labour cost was 9d., whereas it can now be made for 2d.

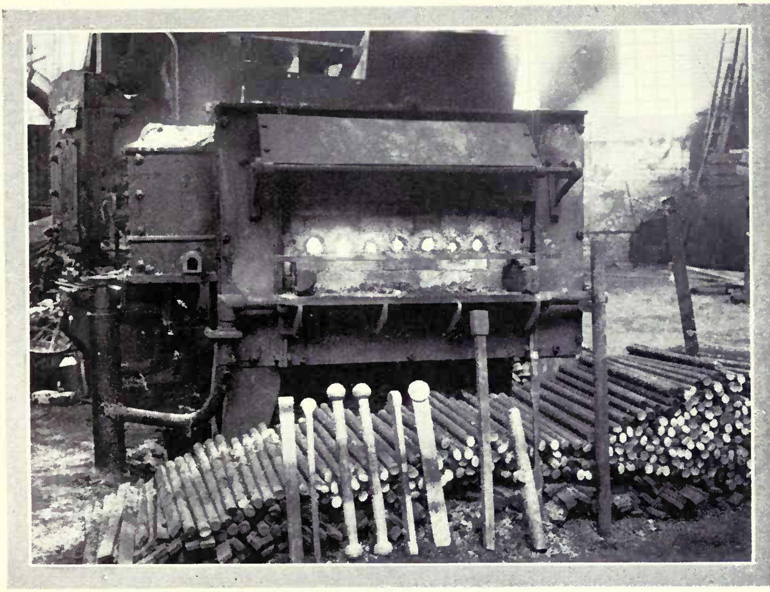


FIG. 34.—OIL-FIRED FORGING FURNACE (CHURCHILL).

Drop Forging

Another type of burner designed for use in connection with furnaces is illustrated on the next page (Fig. 35), and shows the general outline of the blast connection, oil feed and combustion chamber. There is only one connection to the main blast pipe, and before passing through the oil feed pipe the blast circulates round an air jacket and is thus heated before being used.

The supply of oil is regulated by turning a hand-wheel which allows the fuel to spurt out through a round knife-edge valve immediately in front of the small blade; the blast drives round this blade at a very high speed, and also impels forward the oil, which is thus perfectly atomised and mixed with air.

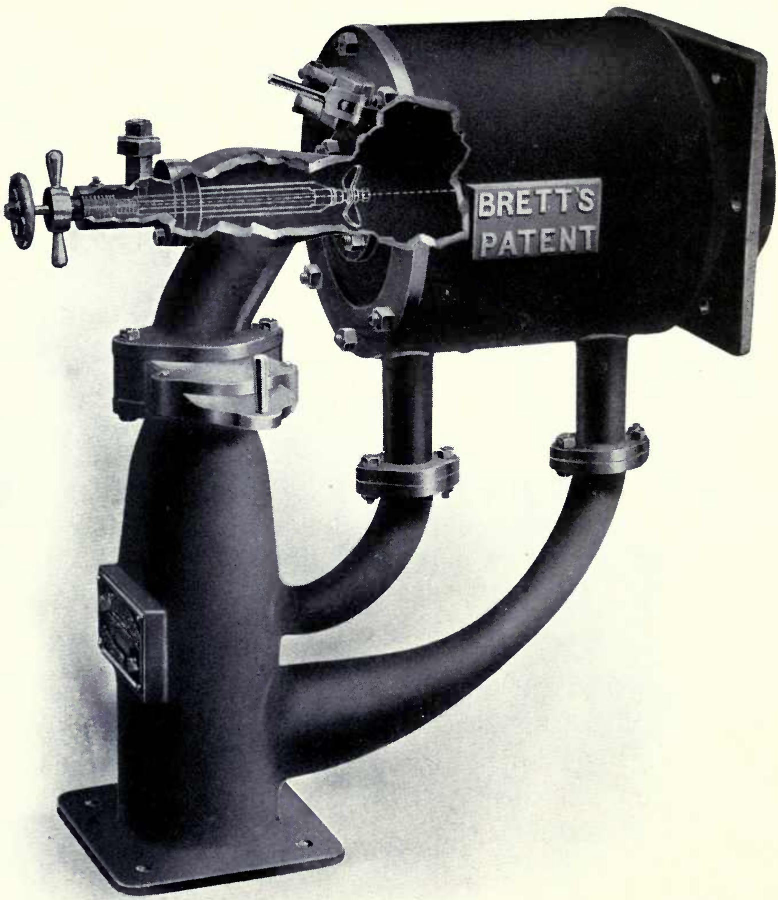


FIG. 35.—THE BRETT BURNER.

Drop Forging

Fig. 36 on the next page illustrates the above burner attached to a furnace supplied for heating bars for drop forging purposes. It can also be used for a variety of processes, including smithy work. A very intense

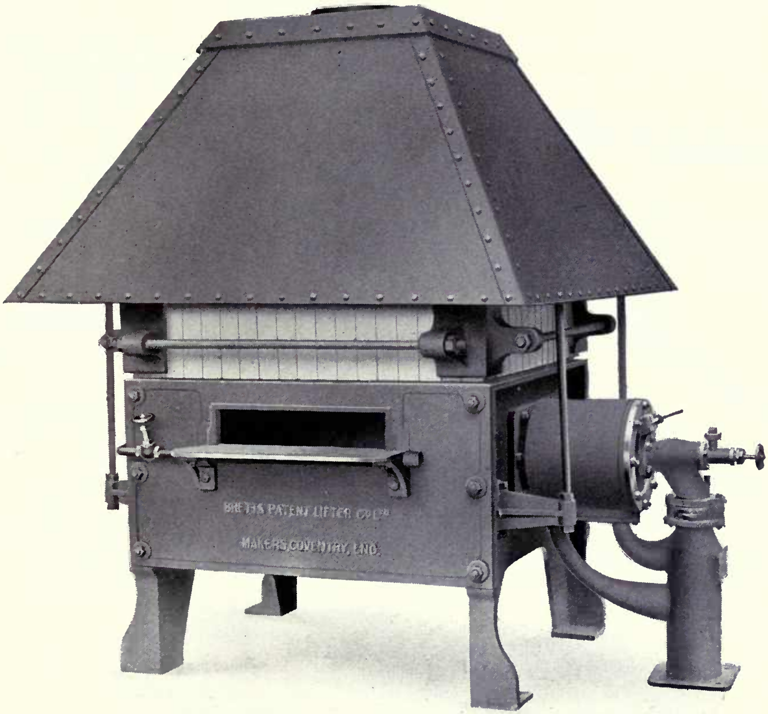


FIG. 36.—DROP FORGING FURNACE (BRETT).

heat is obtained, and bars can be got ready in a much quicker time than by any other fuel, while the heat of an oil furnace, unlike coal or coke, has no deteriorating effect upon the metal.

One great value of oil in drop forging is the remarkable softness of the heat obtained as compared with coal or coke. This heat is of a *penetrative* quality, heating and softening the metal equally throughout instead of mainly on the surface. Consequently the drop forging is accomplished quicker and with less power, and with an appreciable saving of wear on the dies.

Billet Heating

With an oil-fired billet heating furnace, a 12-inch billet charged into the furnace after it has been closed down over night, can be brought to a forging heat in 45 minutes, and a 10-inch ingot or billet can then be brought to forging heat in 32 minutes. These figures, quoted by Mr. W. N. Best, illustrate the rapidity of work possible when oil is used.

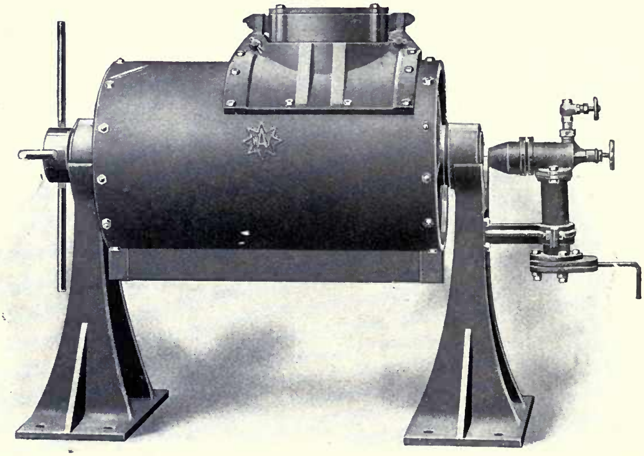


FIG. 37.—ALLDAYS-CHARLIER ROLLING FURNACE.

Rolling Furnaces

An interesting application of the Alldays burner is its use with the Alldays-Charlier patent rolling furnace, which will be seen from Fig. 37 to be of cylindrical form, and can be used for melting any class of metal. An advantage claimed for this furnace is that it allows of heats of different mixtures being taken successively without contamination. The following results are of interest in showing the capacity of this oil furnace:—

600 lbs. gunmetal melted in 1 hour.
600 lbs. yellow brass melted in 40 minutes.
500 lbs. steel scrap melted in 3 hours.
500 lbs. cast iron scrap melted in 1 hour 40 minutes.

The Alldays-Moody oil-fired tyre heating furnace shown in Fig. 38 is a great improvement on similar furnaces fired with coal. It is automatic in action, **Tyre Heating**

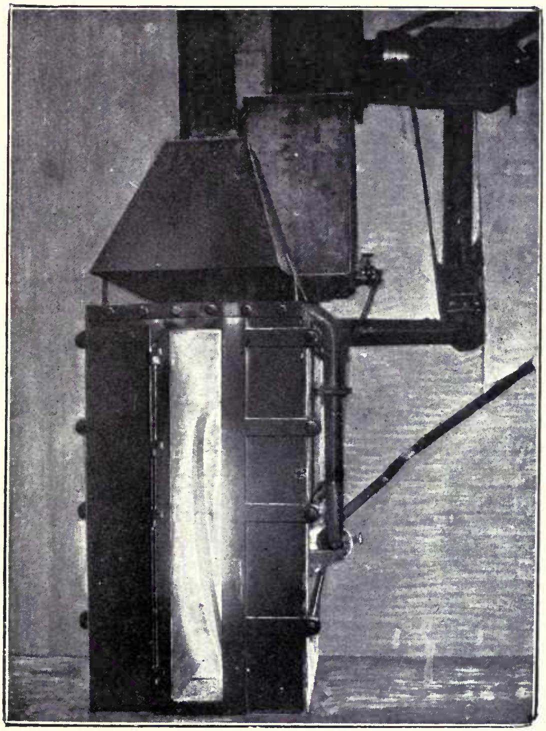


FIG. 38.—TYRE HEATING FURNACE.

and the requisite heat is promptly attained, doubling the output of work and producing uniform expansion of the tyres. It is so constructed that the flame plays all round the tyre, consequently a uniform heat is obtained.

The work that can be done with this furnace is enormous, ranging from 8 tyres of 4 inch by $\frac{3}{4}$ inch up to 30 tyres of lighter iron per hour, and the heating power can be instantly increased or diminished, according to the class of tyres to be heated. The above figures are by no means exceptional.

The consumption of crude oil used being four to six gallons per hour, according to class of work and size of furnace, at a cost of 2d. to 2½d. per gallon, is a great saving over either coal or wood, when it is taken into consideration that four times the work can be accomplished in the same time. The furnace works on forced draught, being fitted with fans giving 600 cubic feet of air per minute at a pressure of not less than ½ lb. The air is preheated to ensure more complete vaporisation of the oil.

Messrs. Alldays and Onions have carried out a series of tests with Mexican oil for their furnaces with entire success. A small furnace fitted by them with patent air heater and jacketed fuel tank is shown on this page (Fig. 39). In this arrangement both the air blast and the fuel supply are heated to a high temperature by the waste gases of the furnace. Using Mexican fuel oil a temperature of 1,400° C. is readily attained on furnaces fitted as shown. These oven furnaces are used principally for hardening tools, and they may be seen in operation at the works of the makers at Birmingham.

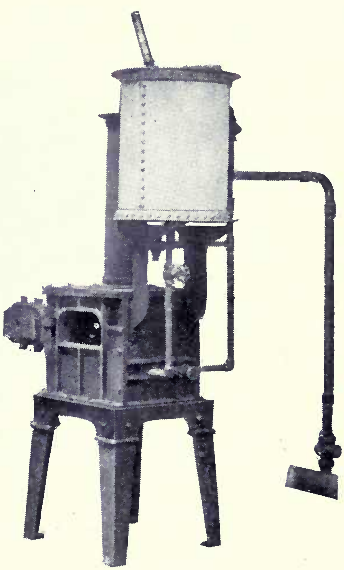


FIG. 39.—OVEN FURNACE WITH PATENT AIR-HEATER AND JACKETED TANK.

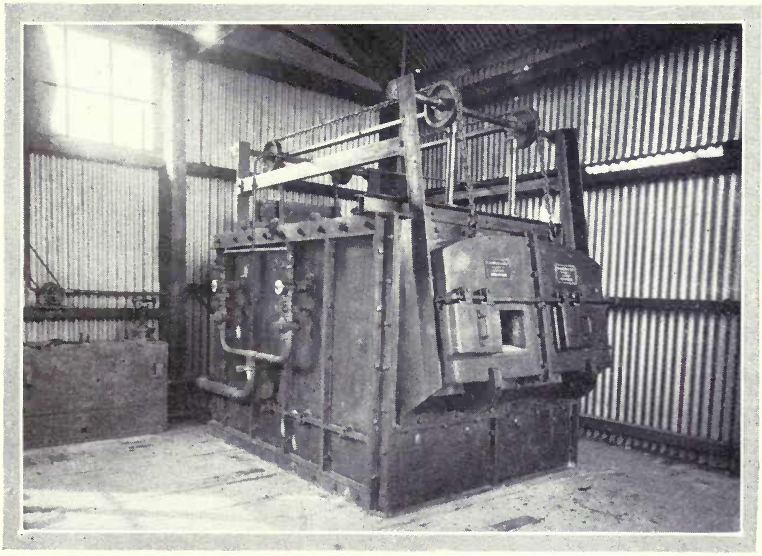


FIG. 40. —CHURCHILL'S OIL-FIRED SPRING FITTER FURNACE.

Oil Fired Spring Fitter Furnace

The illustration shows an oil-fired Spring Fitter Furnace arranged for Mexican fuel oil. On the side of the building is shown a small rotary belt-driven oil pump, which is in continual operation and arranged to pump the oil from an underground supply tank and deliver it to a small subsidiary overhead tank. This subsidiary oil tank is fitted with an overflow to the underground storage tank, and a sufficient supply of oil is thus ensured to the furnace, without any trouble on the part of the operator.

Cloth Singeing

Fig. 41 shows an oil-fired cloth singeing machine which is used by Bleachers, Dyers, and Calico Printers for the process of singeing, and is manufactured by Messrs. Mather and Platt, Ltd., Manchester, to whom we are indebted for the information given. This machine has now been working very successfully for the past ten years.

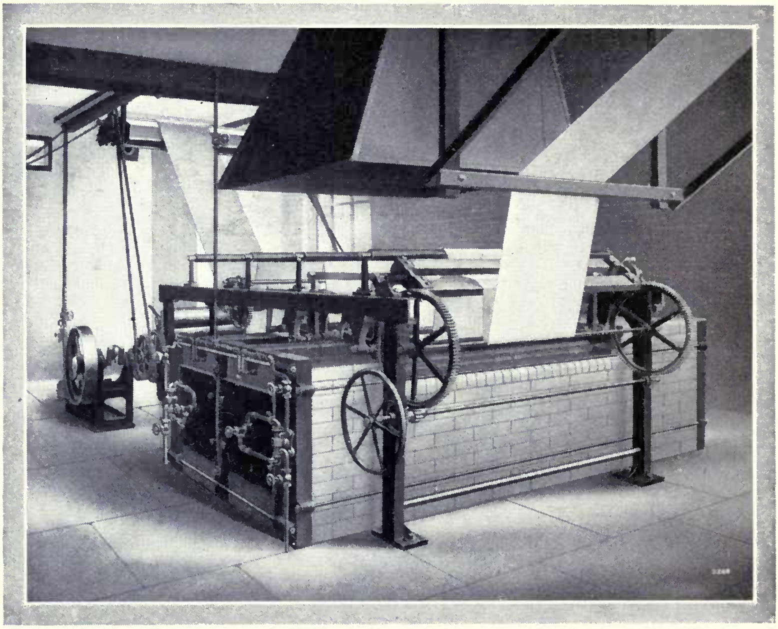


FIG. 41.—OIL-FIRED CLOTH SINGEING MACHINE.

For this class of machine oil firing possesses many advantages over coal. The saving in labour is very considerable, as, when once the oil has been pumped into the storage tank, no further labour is necessary except to turn on the oil and steam valves to each furnace and to apply a light to the burner. Copper plates 2 inches in thickness and 72 inches wide can be heated up ready for working in twenty minutes. After the plates are once heated they can be kept at an even heat for any length of time without the cloth having to be run out of the machine. In the case of coal firing, anything between one and two hours may be taken to heat up the plates, and periodically the cloth has to be run out and the machine stopped, as the plates cannot be kept at the heat required by coal firing except for a limited time.

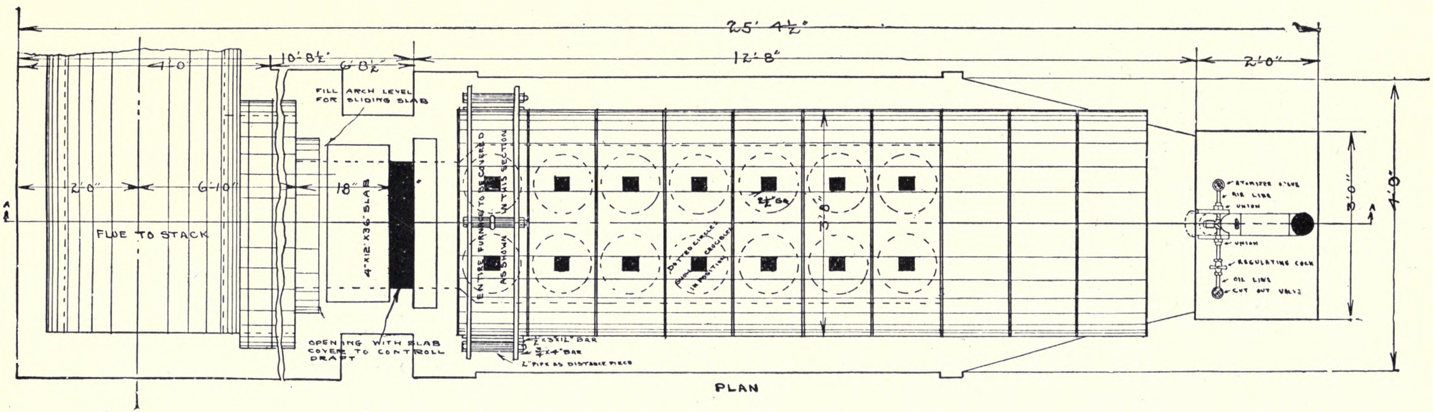


FIG. 42.—COPPER REFINING FURNACE (BEST BURNER).

One burner is used which spreads a flame over the entire surface of the charging space, which is in this case 14 feet wide by 26 feet long.

Metal Melting

The value of oil for melting metal has in the last few years been brought prominently to the front, and its advantages strikingly demonstrated. Owing to the superior calorific value of the oil the metal is melted in much less time than with coal and coke, and the fluidity requisite for the smallest castings is readily attained. In addition to this the quality of the metal is undoubtedly improved, as numerous tests and chemical analyses have shown that the castings contain no more sulphur than before the metal entered the furnaces, consequently the tensile strength is greater than when the furnaces are coal fired. As the oil fires are under perfect control heats can be taken off quicker, and the temperature maintained within about 25° F. until all the metal is run off. With most metal melting furnaces the chimney stacks which are necessary with coal can be dispensed with, thus obviating the variations in temperature which outside atmospheric conditions would otherwise entail. As a consequence the time when the charges will be ready for tapping can be easily estimated. Furthermore, skimming the metal is materially decreased.

It is possible with an oil furnace to attain in a few minutes an intense heat, which, with coal, would take some hours to secure. In addition to the saving in time taken in getting the charge ready for tapping there is a saving in floor space ; the fire-brick lining of the furnaces lasts 20 per cent. longer, and the same figure is applicable to the increased service of the crucibles, while imperfect castings, owing to cooled metal, are eliminated. The valuing of a perfectly controlled fire is nowhere more clearly exemplified than in this class of work. In steel treatment every variation in temperature is reflected in differences in the grain of the metal. In copper refining a reducing flame is at times necessary, and at other times an oxydising flame is required. These exacting requirements are fully met by modern oil-fired furnaces, as described in these pages.

Brass Melting Data

The following figures from results obtained at the works of Messrs. Holman Bros., Camborne, are illustrative of the difference between using oil and coke for melting metal. In this instance 40 lbs. of machine brass were melted with a Bickford crucible furnace.

COMPARATIVE COST OF FUSION OF 40 LBS. BRASS.

Coke.

$\frac{1}{4}$ cwt. of oven coke at 1s. 3d.	3 75d.
$3\frac{1}{2}$ % waste of brass	8.4
Crucibles (20 charges at 5s. per crucible) ...	3
	15.15

Oil.

$\frac{3}{4}$ gall. oil at $2\frac{1}{2}$d., say	2.0d.
$1\frac{1}{2}$ % waste of brass	3.6
Crucibles (30 charges at 5s. per crucible) ...	2.0
	7.6

The above figures show a saving of over 50 per cent., to which should be added something for saving in labour.

Tilting Crucible Furnaces

The accompanying illustration shows Morgan's Patent Tilting Furnaces, which are fitted with Salamander Crucibles, and are adapted for use with liquid fuel. This is one of the many types of oil furnaces manufactured by the Morgan Crucible Company, Ltd., for melting metals for alloys required in Mints, Rolling Mills, Railway Shops, Dockyards, Brass Foundries, etc. The furnace shown is of the tilting description, from which the crucible is not withdrawn to be poured, but by means of hand gear

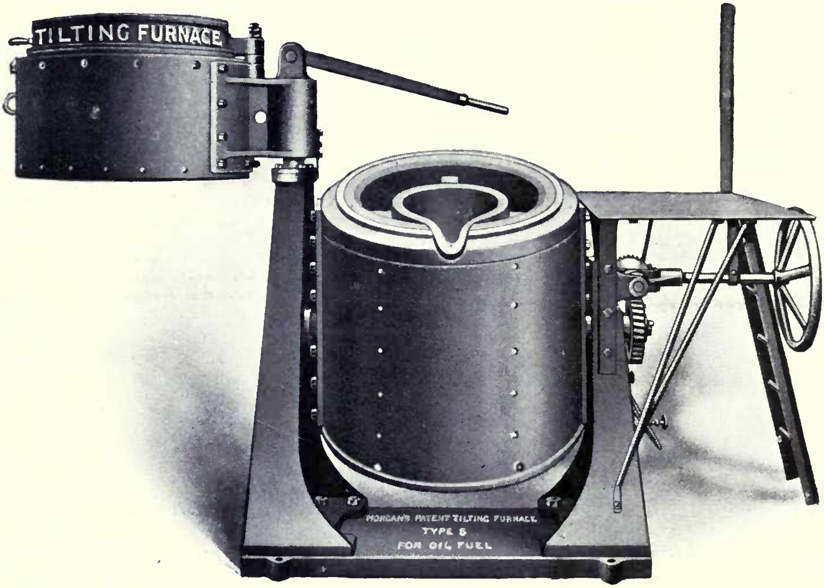


FIG. 43.—MORGAN TILTING CRUCIBLE FURNACE.

the body of the furnace is tilted, and the charge emptied either direct into sand or ingot moulds, or into a ladle. When metal is to be poured direct from the furnaces, either the portable or the stationary design can be used; the former permits of the removal of the furnace body by an overhead crane, the furnace being operated in the same manner as a foundry ladle; the latter or stationary type is so arranged to tilt that a constant pouring point is maintained, and metal can be poured direct into moulds brought up to the furnace.

As distinct from tilting furnaces, "lift out" furnaces are also made for use with liquid fuel; from these the crucibles are removed in the usual way for pouring the metal.

The following figures show the economical results obtainable with this system of melting:—

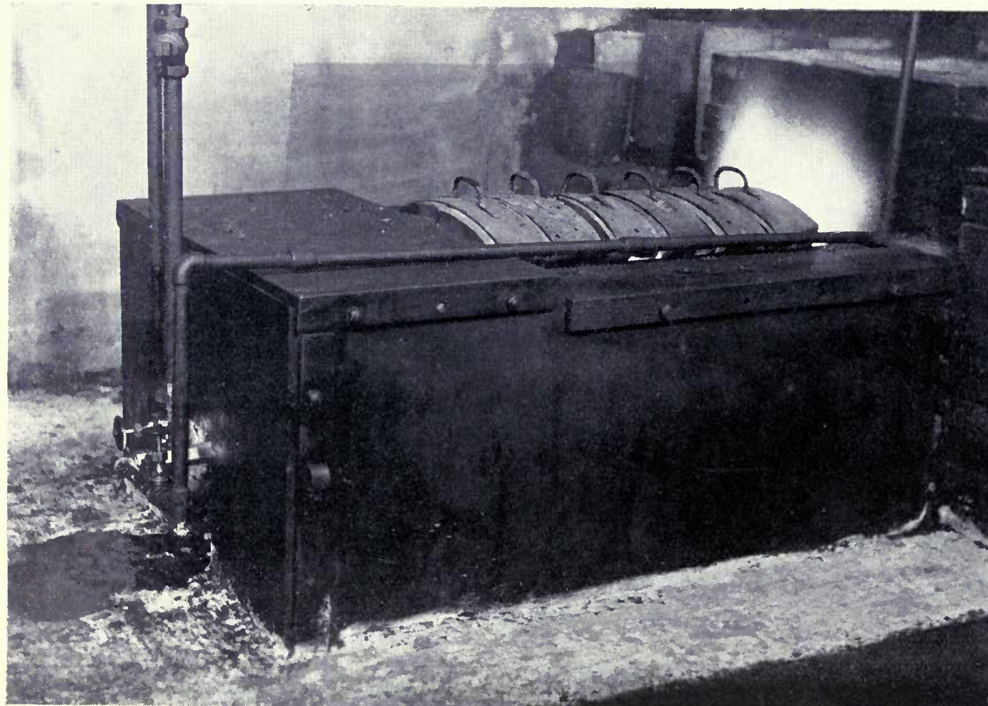
WORKING RESULTS OBTAINED WITH MORGAN'S PATENT TILTING AND "LIFT-OUT" FURNACES.

Class of Metal.	Weight of Metal lbs.	No. of Hts. per Day (9 Hours).	Time of Melting after the 1st Heat. hrs. mins.	Gals. of Oil used per 100 lbs. of Metal Melted.	Fuel Consumption.
MORGAN'S PATENT TILTING FURNACE, 400 LBS. SIZE.					
White Cast Iron	350	4	2.05	2.5 to 3.	25 to 30%
Grey ,, ,,	350	4	1.45	2.50	25%
Copper ...	450	5 or 6	1.15	1.75	17.5%
Gunmetal or Red Brass ...	450	6 or 7	1.00	1.50	15%
Yellow Brass ...	450	8 or 9	0.50	1.25	12.5%
Yellow Brass (Scrap or Ingot)	450	8 or 10	0.40	1.0 to 1.1	10 to 11%
MORGAN'S "LIFT OUT" FURNACES.					
(*a*) Steel ...	132	3	2.15	14.00	130%
(*b*) Nickel ...	114	4	1.50	13.25	120%
(*c*) Malleable Iron	170	4 or 5	1.45	5.00	46%

(*a*) According to proportion of scrap used.
(*b*) Two Crucible Furnace.
(*c*) Single Crucible Furnace.

The following data has been furnished by the Crudall Liquid Fuel Burner and Furnace Co., Ltd., from heats run with Mexican fuel oil.

Furnaces for melting aluminium, holding three 500 lbs. crucibles, burning not more than 4 gallons of oil per



CRUDALL FURNACE.

hour. Melted in 20 days 33 tons, 3 cwts., 2 qrs., 201 lbs. of metal, using approximately $1\frac{1}{4}$ gallons of oil per cwt., and the oil furnace doing the work of 9 coke furnaces, the crucibles lasted 16 days, in comparison with coke or gas furnaces lasting 12 to 15 days.

Furnaces for melting gold, silver, etc., erected in Sheffield and London, using the Crudall Burner and Mexican Oil. A furnace burning under 4 gallons of crude oil per hour is capable of melting 1,000 ozs. of silver in 45 minutes starting cold, and a similar weight every 30 minutes in one crucible. This furnace is built to hold three 100 lbs. crucibles, and so would give an output of about 30,000 ozs. of silver or gold in one working day.

Furnaces corresponding to the above have been erected in Huddersfield for melting copper and brass, and are giving every satisfaction.

As showing the saving which oil effects over gas, the following figures obtained on Mexican Fuel Oil by the Sterling Metals Co., Coventry, are of interest:—

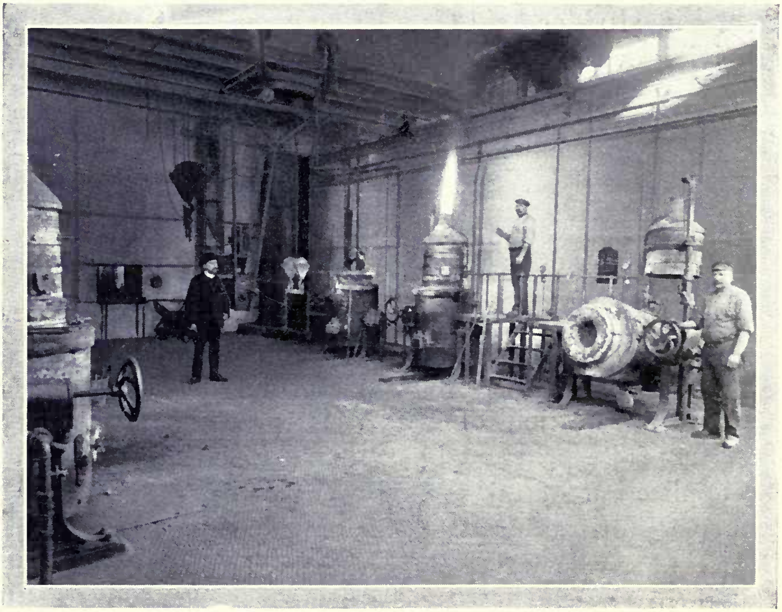
Cost of Fuel Oil per lb. of Aluminium melted		·03	pence.
Cost of Town Gas per lb. of	„ „	·09	„

In addition to the foregoing there is a great range of smelting, roasting, and melting furnaces used successfully in the numerous ramifications of the metallurgical industry, illustration of which is precluded by lack of space. The progress being made in all countries in the application of oil to these processes points to its exclusive use in a few years, for the necessity of keeping abreast of rivals will induce the most conservative to avail themselves of the superior efficiency of oil-fired furnaces.

Buess Furnaces

The figures relative to the Buess Furnace given on the next page are supplied by the London Emery Works Company. The design of this furnace is arranged so that cold compressed air is led into the base of the furnace, and by keeping it cool, prevents the formation of slag It is then led through a small reservoir under the bottom of the furnace in which the oil is circulating, and the air warms this before it reaches the burner.

The burner is so arranged that a reducing atmosphere can be obtained at any time, so that when metals of low melting point, such as aluminium, zinc and lead, are in the furnace the quantity of air can be regulated by a scale fixed behind the burner head, in order to change the heating power and time of melting.



INSTALLATION OF OIL-FIRED BUESS FURNACES.

TABLE SHOWING THE COMPARISON BETWEEN THREE POT FIRES EACH OF 1½ CWTS. CAPACITY, AND ONE "BUESS" FURNACE OF 3 CWTS. CAPACITY, FOR A DAILY OUTPUT OF ABOUT 1½ TONS (1 TON GUNMETAL—½ TON BRASS).

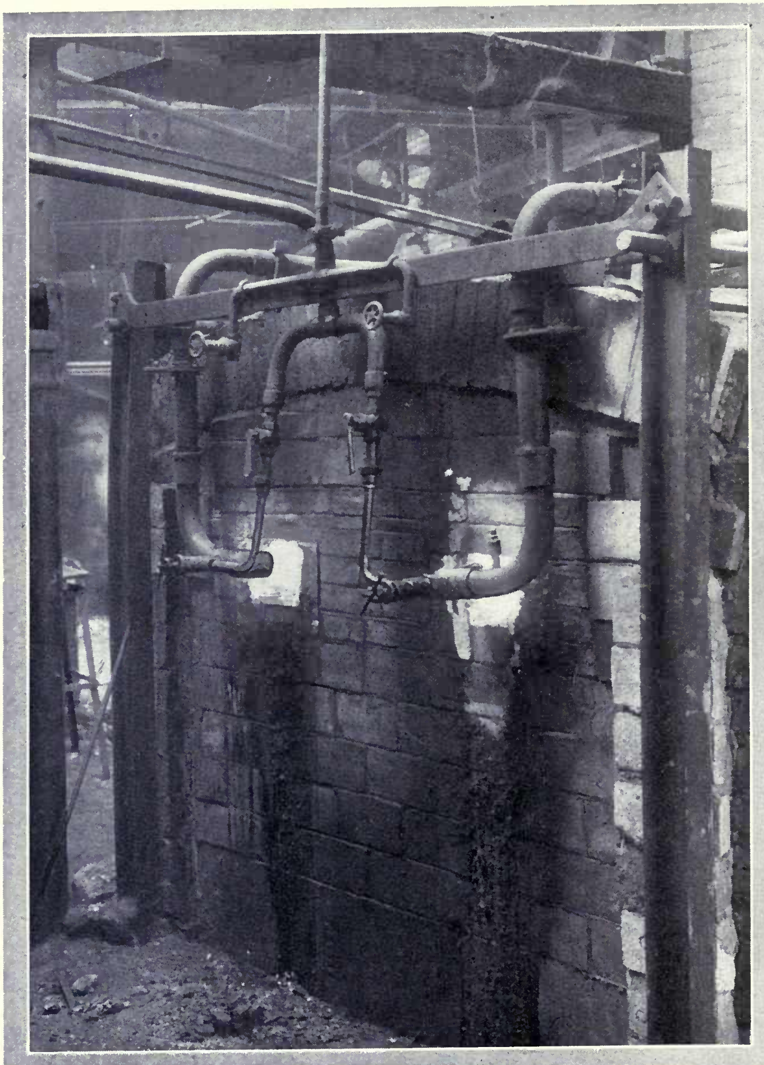
POT FURNACES.

	£	s.	d.
Cost for 1 *ton gunmetal*—			
Time of melting 13 charges at 1¼ hrs. each = 16 hrs. at 6d.	0	8	0
Coke consumption at about 40 per cent. = 8 cwts. at 25s. per ton ...	0	10	0
Charge on crucible 20 charges = 20s., therefore 13 charges = ...	0	13	0
Loss in melting at 3 per cent. = 67 lbs. at 9d. per lb. ...	2	10	3
	£4	1	3
Cost for 9 *cwts. brass*—			
Time of melting 6 charges at 1 hr. each = 6 hrs. at 6d.	0	3	0
Coke consumption at about 30 per cent. = 2½ cwts. at 25s. per ton ...	0	3	1
Charge on crucible 20 charges = 20s., therefore 7 charges = ...	0	7	0
Loss in melting at 4 per cent. = 40 lbs. at 7½d. per lb.	1	5	0
	£5	19	4

"BUESS" FURNACE.

	£	s.	d.
Cost for 1 *ton gunmetal*—			
Time of melting 7 charges at 1 hr. each = 7 hrs. at 6d.	0	3	6
Oil consumption 10 per cent. = 2 cwts. at 60s. per ton	0	6	0
Charge on crucible 50 charges = 40s., therefore 7 charges = ...	0	5	7
Loss in melting about 2 per cent. = 45 lbs. at 9d. per lb.	1	13	9
	£2	8	10
Cost for 9 *cwts. brass*—			
Time of melting 3 charges at ¾ hr. each = 2¼ hrs. at 6d.	0	1	2
Oil consumption 9 per cent. = 91 lbs. at 60s. per ton ...	0	3	5
Charge on crucible 50 charges = 40s., therefore 3 charges = ...	0	2	5
Loss in melting about 3 per cent. = 30 lbs. at 7½d. lb. ...	1	18	9
	£3	14	7
Power 3½ B.H.P. for 9¼ hrs. ...	0	2	8
	£3	17	3

Saving with "Buess" per day £2 2s. 1d. Less interest and depreciation on plant, £220, at 15 per cent. = 2s. 2d. per day = £1 19s 11d. net saving. = A net profit of 33⅓ per cent by installing "Buess" furnace.

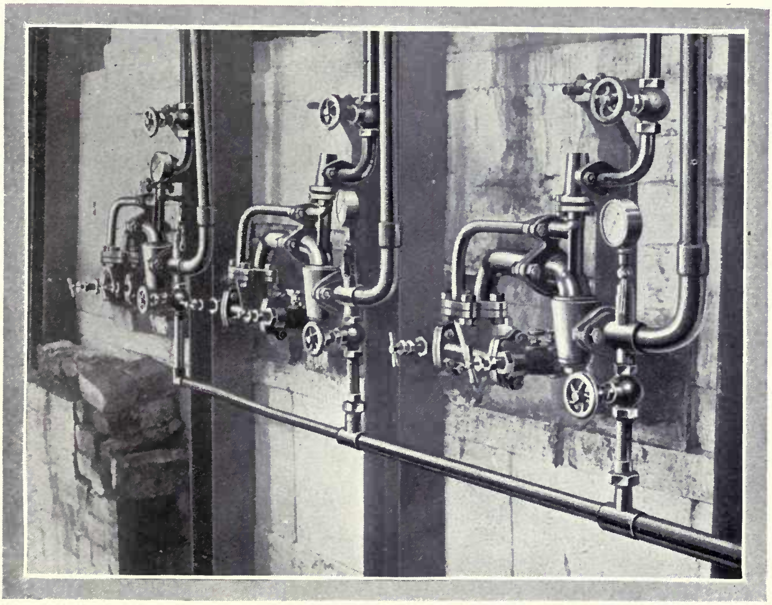


GLASS TANK HOLDING $6\frac{1}{2}$ TONS OF METAL FIRED WITH CARBOGEN BURNERS.

Glass Works

When oil was first mooted for use in glass making some considerable doubt was expressed as to its suitability for this purpose as compared with coke. The experience of many years, however, has proved its entirely satisfactory service, and the accompanying illustration shows the Carbogen burner firing a glass tank holding 6½ tons of glass. The Carbogen burner was designed by Mr. F. S. Stackard in the first place for the glass works of his firm of Messrs. J. A. Curle, Ltd., of South Hackney.

These furnaces were first worked with an air compressing plant, but Messrs. Curle have now installed fan blowers, which work the burners equally well without increased consumption of oil and with about one-fourth of the cost for producing the compression previously employed.



GLASS TANK AT PENDLETON, FITTED WITH KERMODE BURNERS.

Messrs. Curle have installed Carbogen burners at various other glass works in London and the Provinces, and the common experience is a much speedier melting, more uniform heating of the metal, cleaner work, absence of smoke, dust and ashes, and saving of labour handling fuel ash and clinker. In annealing the bottles oil fuel has been found, by reason of its complete uniformity and ease of control, to reduce the breakages to a minimum.

Portable Burners

Not the least of the many advantages of oil fuel for industrial purposes is the facility it affords for bringing intense heat under perfect control to any part of the factory or works by means of portable burners. The examples given are illustrative of a class of furnace which is finding increasing use, especially in America. The oil and compressed air can be piped through the factory to any point required by means of flexible tubing, the air blast being usually taken from the supply for pneumatic tools, suitably reduced to required pressure.

Among other purposes these portable burners are used for mould drying, cupola lighting, firing boilers in boiler shops for testing purposes, welding, brazing, filling castings, plate heating, pipe bending, and for a great variety of other purposes in boiler shops and shipyards

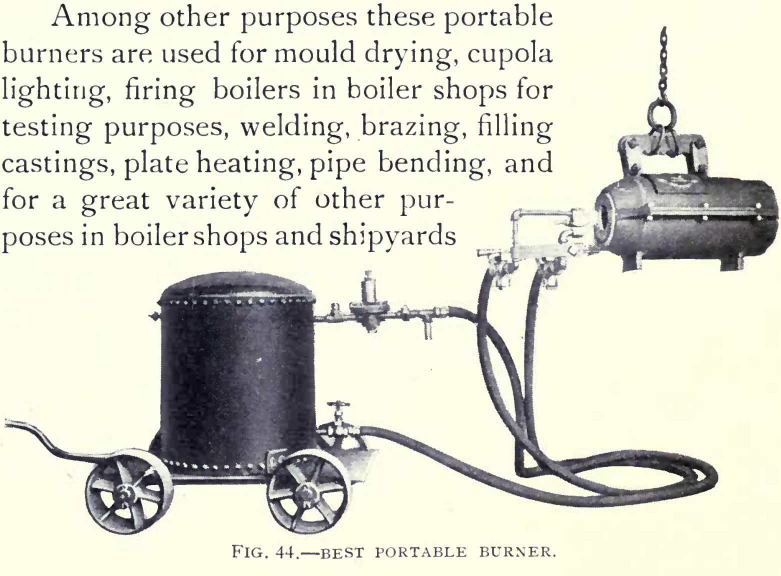


FIG. 44.—BEST PORTABLE BURNER.

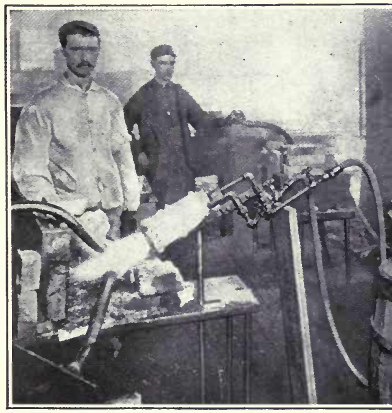
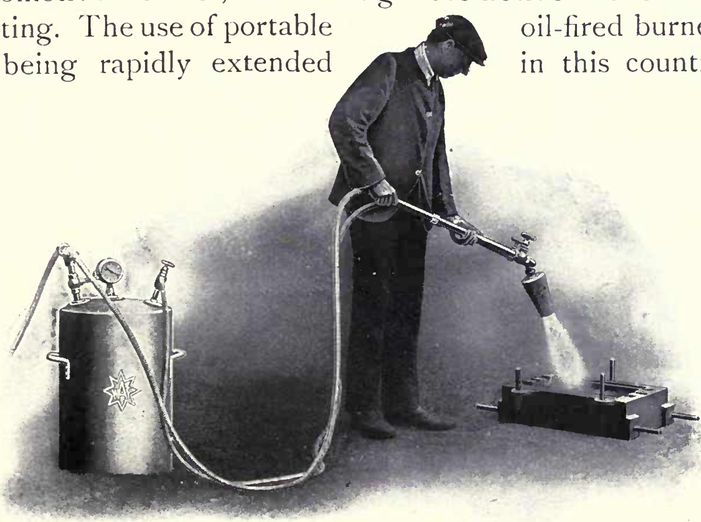


FIG. 45.—BRAZING THE EXHAUST PIPE OF AN AUTOMOBILE ENGINE WITH THE BEST PORTABLE BURNER.

and locomotive works. In Fig. 45 the Best portable burner is shown brazing the exhaust pipe of an automobile engine.

The Best portable burner is lined with refractory materialwhich becomes incandescent, which aids combustion and ensures a steady flame even when oil supply is cut very low. It is largely used in erecting shops of locomotive works, being used for setting up corners of fire-box sheets to mud rings. flanging, laying on patches, heating crown sheets, heating and welding locomotive frames, and firing locomotive boilers for testing. The use of portable oil-fired burners is being rapidly extended in this country.



DRYING A MOULD. ALLDAYS PORTABLE BURNER.

APPENDIX.

APPENDIX I.

LIST OF PURPOSES FOR WHICH FUEL OIL IS USED.

Annealing Furnaces
Asphalt Mixers
Assay and Fusion Furnaces
Billet Heating
Biscuit Baking
Boiler Making
Bolt Furnaces
Brazing and Dip Brazing
Breweries
Bullion Melting
Case Hardening
Cement Works
Ceramics
Cloth Singeing
Continuous Heating
Copper Melting
Core Drying
Crucible Furnaces
Cupellation Furnaces
Cycle Making
Drop Forging
Electric Power Works
Enamelling
Fire Engines
Foundries
Galvanising
Glass Making
Glass Melting
Glass Bending
Gold Cyanide Smelting
Japanning
Ladle Heating
Lead Baths
Lead Melting
Locomotives
Nut Making
Ore Smelting
Petroleum Distillation
Pipe Bending
Plate Heating
Pottery Baking
Pumping Works
Rivet Heating
Rivet Making
Rolling Furnaces
Rotary Kilns
Sand Drying
Screwmaking
Shaft Heating
Shipbuilding
Shovel Making
Silver Refining
Smithy Work
Spring Tempering
Steam Boilers
Steel Melting
Sugar Refining
Tea Drying
Tempering
Tilting Furnaces
Tinplate Making
Tin Smelting
Tractors
Tool Making
Tube Making
Tyre Heating
Welding
Wire Annealing
Wire Making
Zinc Distillation

APPENDIX II.

LIST OF MANUFACTURERS OF OIL BURNERS, SYSTEMS AND FURNACES.

ALLDAYS.—Alldays and Onions, Great Western Works, Birmingham.

BABCOCK.—Babcock and Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.

BALDWIN.—The Baldwin Locomotive Works, Philadelphia, U.S.A.

BARRON.—Thos. Barron, Ltd., Phœnix and Don Glass Works, Mexborough, nr. Rotherham.

BEST.—W. N. Best, 11, Broadway, New York, U.S.A.

BICKFORD.—W. J. Tyack and Co., Ltd., Cambourne, Cornwall.

BRETT'S.—Brett's Patent Lifter Co., Ltd., Coventry.

BUESS.—The London Emery Works Co., Park, Tottenham, N.

CARBOGEN.—J. A. Curle, Ltd., Homer Road, South Hackney, N E.

CHURCHILL.—Chas. Churchill and Co., Ltd., St. Simon Street, Salford, Manchester.

CROSBIE.—Crosbie Bros. and Co., Ltd., Bounds Green Road, New Southgate, London, N.

CRUDALL.—The Crudall Liquid Fuel Burner and Furnace Co., Ltd., 13, Great Queen Street, Kingsway, London, W.C.

DAHL.—Union Ironworks Co., San Francisco, Cal., U.S.A.

DAVIES.—Richard Davies and Sons, Bilberry Street, Manchester.

EVANS.—34, Gresley Road, London, N.

HAMMEL.—Hammel Oil Burner Co., 640, North Main Street, Los Angeles, Cal., U.S.A.

HOLDEN.—Tait and Carlton, Ltd., 63, Queen Victoria St., London, E.C.

HÖVELER.—Hövelers Liquid Fuel Appliances, Ltd., Merton Abbey, London, S.W.

KERMODE.—Kermodes, Ltd., 35, The Temple, Dale Street, Liverpool.

KOERTING.—Gebr. Koerting, A. G., Körtingsdorf, bei Hannover.

LUCAL.—Lucal Liquid Fuel Co., 203, Hope Street, Glasgow.

MASSEY.—B. and A. Massey, Ltd., Steam Hammer Works, Openshaw.

MERRYWEATHER.—Merryweather and Sons, Greenwich, S.E.

MEYERS-SMITH.—Smith's Dock Co., Ltd., Bull Ring Docks, N. Shields.

MORGAN.—The Morgan Crucible Co., Ltd., Battersea, London, S.W.

OSBORN.—John Wilson and Co., 39, Lime Street, London, E.C.

ROCKWELL.—W. S. Rockwell and Co., 50, Church St., New York, U.S.A.

SAVERY.—T. A. Savery and Co., Ltd., Newcomen Works, Bracebridge Street, Birmingham.

SMOKELESS ECONOMISER.—28, Victoria Street, London, W.

STOCK-CONVERTER.—Thwaites Bros., Ltd., Bradford.

TATE-JONES.—Tate-Jones & Co. (Inc.), Pittsburgh, Pa.

THORNYCROFT.—John I. Thornycroft and Co., Ltd.

WALLSEND-HOWDEN.—Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne.

WHITE.—Messrs. Brigham and Cowan, South Shields.

APPENDIX III.

DEFINITIONS.

The Calorific Value of fuel oil is that number of units of water by weight which would be raised one degree in temperature by the complete combustion of one unit by weight of liquid fuel, and is expressed in either Calories or British Thermal Units.

A British Thermal Unit (B.Th.U.) is that quantity of heat required to raise one pound of water through one degree Fah. at or near 39.1° Fah.

A Calorie is that quantity of heat required to raise one kilogram of water through one degree Centigrade at or near 4° Cent.

The calorific value of Mexican fuel oil as derived from the heat values of its principal constituents, obtained by chemical analysis, is as follows:—

83.52 %	of Carbon	×	14,647 =	12,240	B.Th.U.
11.68 %	of Hydrogen	×	62,100 =	7,260	,,
3.27 %	of Sulphur	×	4,500 =	147	,,
1.37 %	Undetermined			—	
100 %	Total ...		...	19,647	B.Th.U.

No allowance is made in the above figures for the heat lost in the formation of the compound, but the result compares fairly closely with 18.900 B.Th.U., the figure obtained by actual calorific test.

The Specific Gravity of an oil is the ratio of the weight of a given volume of the oil to the weight of the same volume of water at the same temperature.

The specific gravity of water at 39° Fah. is unity, while that of fuel oil varies between 0.85 and 1.00, depending on its composition and source of origin. An oil of low specific gravity usually has a low flash point.

The specific gravity of fuel oil is frequently given in terms of Beaumé degrees, obtained by means of the Beaumé Hydrometer, 10 degrees Beaumé being equal to the unit of Specific Gravity of Unity.

The Viscosity of an oil is a measure of its fluidity, and is usually determined in this country by Redwood's Viscometer, and is expressed in seconds. The viscosity of an oil is ascertained by comparing with the rate of flow of rape oil through a Viscometer under identical conditions. The fluidity of oil fuel increases very much with an increase of temperature; that is to say, the viscosity decreases. See table xvi, page 150.

The Viscosity figures vary, depending on the Viscometer that is used; for instance, a reading from Redwood No. 1 of 1,400 seconds compares with Redwood No. 2 reading 145 seconds.

The Flash Point of an oil is the temperature at which the oil commences to give off inflammable vapour. There are two ways of determining this temperature, namely, by the "open" and the "closed" test; the latter is the more reliable, and an instrument devised by Sir Frederick Abel is generally used for the purpose.

In the British Navy the flash point is 175° Fah., while the usual flash point in the mercantile marine is 150° Fah. Fuel oil for land purposes is used with a flash point ranging from 80° Fah. upwards.

Co-efficient of Expansion of Fuel Oils, etc.—The co-efficient of expansion of Mexican fuel oil is .00036 per unit of volume per degree Fah. or .00065 per degree Centigrade.

The co-efficient of expansion of most fuel oils varies very little from these figures.

The co-efficient of expansion for water is .04775, while that of the majority of metals is between .001 and .002 per degree Fah.

The Thermal Efficiency of a steam boiler is the ratio of the heat units usefully absorbed in generating steam, compared to the theoretical total of heat units contained in the fuel supplied to the boiler furnaces.

Factor of Evaporation.—In order to conveniently compare the performance of different types of boiler or of different classes of fuel it is usual to reduce the evaporation figures obtained to a common basis, namely, the number of pounds of water which would be evaporated under the same conditions into steam at atmospheric pressure at 212° Fah. from water at 212° Fah., that is, 966 B.Th.U. per pound.

Table xii, giving the factors of evaporation for various steam pressures, will be found useful in this connection.

APPENDIX IV.

SUMMARY OF OIL FUEL RESULTS AND COMPARATIVE DATA WITH COAL AND OIL FUEL MENTIONED IN THIS BOOK.

Coal and Oil Fuel Results.		Ratio of Results Obtained.		Remarks.	For Further Details Refer to	
Coal.	Oil.	Coal.	Oil.		Chap.	Page
General Section.						
Theoretical Value of Fuel.						
11,500 B.T.U. to	18,900 B.T U	1	: 1.6	Theoretical values based on Calorific and Thermal efficiencies.	II.	19
14,500 ,,	18,900 ,,	1	: 2.			
Burner Section.						
Pounds of Water Evaporated from and at 212° F. per lb. of Fuel.						
—	13.6 lbs. to 14.8 lbs.	—	—	Average Results. Steam System.	III.	25
—	15.6 lbs. to 16,6 lbs.	—	—	Average Results. Compressed Air.	III.	25
—	15.6 lbs. to 16.6 lbs.	—	—	Average Results. Pressure System.	III.	26
—	16.22 lbs.	—	—	Wallsend-Howden Test.	III.	30
Naval Section.						
10 lbs.	16 lbs.	1	: 1.6	Average Result.	IV.	48
Marine Section.						
—	—	1	: 1.5	Results obtained on *San Dunstano* and *San Eduardo* burning Coal and Oil respectively: plus 18% increase in I.H.P. of *San Eduardo.*	V.	55
Tons of Fuel per Day or Voyage						
220 tons	144 tons	1	: 1.5	Cargo Steamer.	V.	59
5,500 ,,	3,300 ,,	1	: 1.6	*Mauretania* (Estimated).	V.	65

APPENDIX IV.—*continued.*

Coal and Oil Fuel Results. Coal.	Oil.	Ratio of Results Obtained. Coal.	Oil.	Remarks.	For Further Details Refer to Chap.	Page
Railway Section.					Chap.	Page
Pounds of Fuel per Train Kilometre.						
91.03 lbs.	61.91 lbs.	1	1.47	Mexican Railway.	VI.	69
Pounds of Fuel per 100 Ton Miles.						
20.8 lbs.	10.3 lbs	1	2.	Tehuantepec Railway.	VI.	77
15.07 ,,	6.85 ,,	1	2.2	Interoceanic Railway of Mexico.	VI.	79
29.83 ,,	15.32 ,,	1	1.9	Atchison Topeka and Santa Fé.	VI.	81
20 36 ,,	9.92 ,,	1	2.05	Comparative Tests Coal and Oil on a U.S. Railway	VI.	82
27.45 ,,		1	2.7			
18.16 ,,		1	1.8			
17.83 ,,		1	1.7			
15.1 ,,	7.82 ,,	1	1.9	Great Eastern Railway.	VI.	83
Land Section.						
Pounds of Water Evaporated from and at 212° F. per lb. of Fuel						
9.31 lbs.	14.38 lbs.	1	1.5	Wallsend Test.	VII.	91
8.5 ,,	15.3 ,,	1	1.8	Mexican Steel Works (Estimated).	VII.	92-3
—	14 97 ,,	—	—	Wallsend Pressure Test.	VII.	94
—	16 0 ,,	—	—	Kermode ,, ,,	VII.	95
—	13.8 ,,	—	—	Kermode ,, ,, (Boiler overloaded).	VII.	95
—	15.91 ,,	—	—	Wallsend Howden Test.	VII.	96
—	16.22 ,,					
Furnace Section.						
Weight of Fuel in Pounds per Charge.						
28 lbs. (Coke)	7.4 lbs.	1	3.9	Brass Melting Furnace.	VIII.	119
895 ,, ,,	224. ,,	1	4.	Gunmetal ,, Buess Furnace.	VIII.	125
280 ,, ,,	91. ,,	1	3.	Brass ,, ,, ,,	VIII.	125

APPENDIX V.

BEAUMÉ, SPECIFIC GRAVITY AND WEIGHT TABLES FOR FUEL OIL.

Beaumé.	Specific Gravity.	Pounds in 1 American Gallon.	Pounds in 1 Imperial Gallon.	Pounds in 1 Barrel* (41 Imp. Gals.)	Barrels to the Ton (2,240 lbs.)
10	1.000	8.33	10.00	410.00	5.46
11	.9929	8.27	9.929	407.08	5.50
12	.9859	8.21	9.859	404.22	5.54
13	.9790	8.16	9.790	401.39	5.57
14	.9722	8.10	9.722	398.60	5.62
15	.9655	8.04	9.655	395.85	5.65
16	.9589	7.99	9.589	393.15	5.69
17	.9523	7.93	9.523	390.44	5.73
18	.9459	7.88	9.459	387.82	5.77
19	.9395	7.83	9.395	385.19	5.81
20	.9333	7.78	9.333	382.65	5.85
21	.9271	7.72	9.271	380.11	5.80
22	.9210	7.67	9.210	377.61	5.93
23	.9150	7.62	9.150	375.15	5.96
24	.9090	7.57	9.090	372.69	6.01
25	.9032	7.53	9.032	370.31	6.04
26	.8974	7.48	8.974	367.93	6.09
27	.8917	7.43	8.917	365.57	6.12
28	.8860	7.38	8.860	363.26	6.16
29	.8805	7.34	8.805	361.00	6.20
30	.8750	7.29	8.750	358.75	6.24
31	.8695	7.24	8.695	356.49	6.28
32	.8641	7.20	8.641	354.28	6.32
33	.8588	7.15	8.588	352.11	6.36
34	.8536	7.11	8.536	349.97	6.40
35	.8484	7.07	8.484	347.84	6.43
36	.8433	7.03	8.433	345.75	6.48
37	.8383	6.98	8.383	343.70	6.50
38	.8333	6.94	8.333	341.66	6.55
39	.8284	6.90	8.284	339.64	6.59
40	.8235	6.86	8.235	337.63	6.63
41	.8187	6.82	8.187	335.67	6.67
42	.8139	6.78	8.139	333.69	6.71
43	.8092	6.74	8.092	331.77	6.75
44	.8045	6.70	8.045	329.84	6.79
45	.8000	6.66	8.000	328.00	6.82

* One barrel contains approximately 41 Imperial gallons or 50 American gallons, and the two last columns are based on this figure.

For statistical purposes it is usual to calculate on a barrel capacity of 35 Imperial gallons or 42 American gallons.

APPENDIX VI.

TABLE GIVING AVERAGE HEATING VALUES OF VARIOUS COALS AND OIL FUELS.

	Specific Gravity.	Heating Value in	
		Cals. per kilogram.	B.T.U.'s per lb.
Coal.			
South Wales Anthracite ...	—	8,300	15,000
Best Yorkshire, Eng.	—	8,000	14,500
Midlands, Eng.	—	6,400 / 7,200	11.500 / 13,000
Canada	—	6,100 / 7,800	11,000 / 14,000
United States	—	6,100 / 8,500	11,000 / 15,000
Russia	—	6,100 / 7,500	11,000 / 13,500
Oil.			
Russian Fuel	0.956	10,800	19,400
Oklahoma Crude	0.863	10,800	19,400
Texas Sour Lake	0.933	10,500	18,900
Mexican Fuel Oil	0.950	10,500	18,900
Roumanian Residuum ...	0.946	10,500	18,900
Borneo Fuel	0.963	10,400	18,800
California	0.962	10,400	18,800
Texas Residuum	0.945	10,200	18,400
Trinidad Crude	0.945	10,200	18,400
Shale Oil	0.875	10,100	18,200
Blast Furnace Oil	0.979	8,900	16,100
Heavy Tar Oil or Creosote ...	1.084	8,900	16,100

APPENDIX VII.

USEFUL DATA.

Measurement.

Length—

1 inch	25.4 millimetres.
1 foot	.305 metre.
1 yard	.914 metre.
1 mile	1609.31 metres.
1 millimetre	.039 inches.
1 centimetre	.3937 inches.
1 metre	39.37 inches.
1 kilometre	3280.9 feet.

Area—

1 square inch	6.451 square cms.
1 square foot	.093 square metre.
1 square yard	.836 square metre.
1 square centimetre	.155 square inch.
1 square metre	10.76 square feet.

Cubic Contents—

1 cubic inch	16.386 c. cms.
1 cubic foot	.028 c. metre.
1 cubic yard	.764 c. metre.
1 cubic centimetre	.061 c. inch.
1 cubic metre	35.32 c. feet.

Weight—

1 pound...	454 kilograms.
1 cwt. (112 lbs.)	50.80 kilograms.
1 ton (2240 lbs.)	1016 kilograms.
1 kilogram	2.204 pounds.
1 pood (Russian)	40 pounds (Russian) or 36.11 pounds (British).

Pressure and Area—

1 pound per square inch ...	.0703 kilogr. per sq. cm.
1 pound per square foot ...	4.88 kilogr. per sq. metre.
1 kilogram per square cm. ...	14.2 lbs. per sq. inch.
1 kilogram per sq. metre ...	0.2 lb. per sq. foot.

APPENDIX VII.—*continued.*

Temperature and Heat Units—

1 degree Fahrenheit	5/9 degree Cent.
1 degree Centigrade	9/5 degree Fah.
1 British Thermal Unit ...	0.252 calories.
1 calorie	3.968 B. Th. Units.
1 B. Th. Unit per pound ...	.554 calories per kilogr.
1 calorie per kilogram	1.8 B. Th. per pound.
1 B. Th. U. per square foot ...	2.713 calories per sq. metre.
1 calorie per square metre ...	0.369 B. Th. U. per sq. foot.

Water and Quantity Measurements—

1 gallon (Imperial)	0.16 cubic feet, or 4.54 litres.
1 gallon (American)	0.13 cubic feet, or 3.6 litres.
1 Imperial gallon	0.8332 American gallon.
1 cubic foot	6.24 Imperial gallons.
1 cubic foot	28.32 litres.
1 cubic metre	1000 litres.
1 cubic metre	220 gallons.
1 litre equals	.22 gallons.
1 gallon of water	10 lbs.
1 litre of water	1.0 kilograms.
1 litre of water	61.0 cubic feet.
1 ton of water	1000 litres (approx.).
1 ton of water	35.97 cubic feet.
1 ton of water	224 gallons.

General—

1 atmosphere	14.7 lbs. per square inch.
1 atmosphere	29.92 in. of mercury at 32° Fahr.
1 atmosphere	1.0335 kilograms per sq. cm.
1 grain per gallon	0.014 grammes per litre.
1 gramme per litre	70.02 grains per gallon.
1 B. Th. Unit	778 foot pounds.
1 calorie	426.84 metre kilos.
1 foot pound	0.1382 metre kilo.
1 metre kilogram	7.231 foot pounds.

APPENDIX VIII.

TABLE OF BRITISH THERMAL UNITS AND CALORIES.

B.T. Units per lb. of Fuel.	Calories per lb. of Fuel.	Calories per kilogram of Fuel.
9,000	2,270	5,000
9,500	2,495	5,275
10,000	2,520	5,560
10,500	2,645	5,830
11,000	2,775	6,110
11,500	2,900	6,380
12,000	3,025	6,660
12,500	3,150	6,950
13,000	3,275	7,220
13,500	3,400	7,500
14,000	3,530	7,780
14,500	3,650	8,050
15,000	3,780	8,330
15,500	3,910	8,620
16,000	4,030	8,880
16,500	4,160	9,160
17,000	4,280	9,450
17,500	4,410	9,720
18,000	4,530	10,000
18,500	4,660	10,280
19,000	4,790	10,560
19,500	4,915	10,820
20,000	5,045	11,110
20,500	5,170	11,400
21,000	5,295	11,680
21,500	5,420	11,930
22,000	5,550	12,220
22,500	5,670	12,500

1 B. Th. Unit = ·252 Calories.
1 B.Th.U. per lb. = ·554 Calories per kilogram.
1 Calorie = 3·968 B.Th.U.
1 Calorie per kilogram = 1·8 B.Th.U. per lb.

APPENDIX IX.

TABLE SHOWING NUMBER OF BRITISH THERMAL UNITS CONTAINED IN ONE POUND OF WATER AT VARYING TEMPERATURES AND POUNDS PER IMPERIAL GALLON.

Tem-pera-ture. Deg. Fahr.	Thermal Units per pound.	Pounds per Gallon.	Pounds. per Cubic Foot	Tem-pera-ture. Deg. Fahr.	Thermal Units per Pound.	Pounds per Gallon	Pounds per Cubic Foot
35	35.000	10.0102	62.422	130	130.192	9.873	61.563
40	40.001	10.0112	62.425	135	135.217	9.859	61.472
45	45.002	10.0103	62.422	140	140.245	9.844	61.381
50	50.003	10.0087	62.409	145	145.275	9.829	61.291
55	55.006	10.0063	62.394	150	150.305	9.815	61.201
60	**60.009**	**10.0053**	**62.372**	155	155.339	9.799	61.096
65	65.014	9.9982	62.344	160	160.374	9.781	60.991
70	70.020	9.9933	62.313	165	165.413	9.757	60.843
75	75.027	9.9871	62.275	170	170.453	9.748	60.783
80	80.036	9.980	62.232	175	175.497	9.728	60.665
85	85.045	9.972	62.182	180	180.542	9.711	60.548
90	90.055	9.964	62.133	185	185.591	9.691	60.430
95	95.067	9.955	62.074	190	190.643	9.672	60.314
100	100.080	9.947	62.022	195	195.697	9.654	60.198
105	105.095	9.937	61.960	200	200.753	9 635	60.081
110	110.110	9.922	61.868	205	205.813	9.611	59.93
115	115.129	9.913	61.807	210	210.874	9.594	59.82
120	120.149	9.897	61.715	212	212.882	9.565	59.76
125	125.169	9.887	61.654				

APPENDIX X.

PROPERTIES OF SATURATED STEAM.

(English basis.)

Pressure in Pounds per Square Inch above Vacuum.	Temperature in Degrees Fahr.	Total Heat in B.T.U. from Water at 32° Fahr.	Volume of 1 Pound of Steam in Cubic Feet.	Weight of 1 Cubic Foot of Steam in Pounds.	Pressure in Atmospheres above Vacuum
1	101.99	1113.1	334.6	0.0039	.068
3	141.62	1125.1	118.4	c.0057	204
5	162.34	1131.5	73 22	0 0136	.340
7	176.90	1135.9	53.37	0.0187	.476
10	193.25	1140.9	38.16	0 0262	.680
*14.7	**212.00**	**1146.6**	**26.37**	**0.0379**	**1.000**
15	213.03	1146.9	26.15	0.0382	1.020
20	227 95	1151.5	19.91	0.0502	1.360
30	250.27	1158.3	13.59	0.0736	2.040
40	267.13	1163 4	10.37	0.0964	2.72
50	280.85	1167.6	8.41	0.1188	3.40
60	292.51	1171.2	7.09	0.1409	4.08
80	311 80	1177.0	5.42	0.1843	5.44
100	327.58	1181.9	4 40	0.2271	6.80
120	341.05	1186.0	3.71	0.2695	8.16
140	352.85	1189.5	3.21	0.3113	9.52
160	363 40	1192.8	2.83	0.3530	10.88
180	372.97	1195.7	2.53	0.3945	12.24
200	381.73	1198.4	2.29	0.4359	13.60
220	389.84	1200.8	2.09	0.4772	14.96

* Atmospheric pressure.

APPENDIX XI.

PROPERTIES OF SATURATED STEAM.

(Metric Basis.)

Pressure in Kilos per sq. cm. above Vacuum.	Temperature in Degrees Centigrade.	Total Heat in Calories from Water at 0° Cent.	Volume of 1 Kilo in Cubic Metres.	Weight of 1 Cubic Metre in Kilos.	Pressure in Pounds per Square Inch above Vacuum.
1.0	99.09	636.72	1.70	0.59	14.22
1.5	110.76	640.28	1.16	0.86	21.33
2.0	119.57	642.97	0.89	1.13	28.45
2.5	126.73	645.15	0 72	1.39	35.56
3.0	132 80	647 00	0 60	1.65	42.67
3.5	138.10	648.62	0.52	1.91	49.78
4.0	142.82	650 06	0.46	2.16	56.89
5.0	150.99	652 55	0.37	2.67	71.11
6 0	157.94	654.66	0.31	3.16	85.34
7.0	164.03	656.53	0.27	3.66	99.56
8.0	169.46	658.18	0 24	4.14	113.78
9.0	174 38	659.69	0.21	4.63	128.01
10.0	178.89	661.06	0.19	5.11	142.23
11.0	183 05	662 23	0.18	5.59	156.45
12.0	186 99	663.52	0 16	6.06	170.68
13.0	190 57	664.63	0.15	6.53	184.90
14.0	194.00	665.69	0.14	7.00	199 12
15.0	197.24	666.66	0 13	7.48	213.34
16.0	200.32	667.60	0.12	7.94	227.57

APPENDIX XII.

FACTORS OF EVAPORATION

FOR CALCULATING THE EQUIVALENT EVAPORATION FROM AND AT 212° FAH. OF SATURATED STEAM AT VARIOUS PRESSURES AND TEMPERATURES OF FEED WATER.

Temp. of Feed Water in Degs. Fah.	Gauge Pressure of Steam in Pounds per Square Inch.									Temp. of Feed Water in Degs. Fah.
	0	60	80	100	120	140	160	180	200	
32	1.187	1.217	1.222	1.227	1.231	1.234	1.237	1.240	1.243	32
40	1.179	1.209	1.214	1.219	1.222	1.226	1.229	1.232	1.234	40
50	1.168	1.198	1.203	1.208	1.212	1.215	1.218	1.221	1.224	50
60	1.158	1.188	1.193	1.198	1.202	1.205	1.208	1.211	1.214	60
70	1.148	1.178	1.183	1.188	1.191	1.195	1.198	1.200	1.203	70
80	1.137	1.167	1.172	1.177	1.181	1.184	1.187	1.190	1.193	80
90	1.127	1.157	1.162	1.167	1.170	1.174	1.177	1.180	1.183	90
100	1.117	1.147	1.152	1.157	1.160	1.164	1.167	1.170	1.172	100
110	1.106	1.136	1.141	1.146	1.150	1.153	1.156	1.159	1.162	110
120	1.096	1.126	1.131	1.136	1.140	1.143	1.146	1.149	1.151	120
130	1.085	1.115	1.120	1.125	1.129	1.132	1.135	1.138	1.141	130
140	1.075	1.105	1.110	1.115	1.119	1.122	1.125	1.128	1.131	140
150	1.065	1.095	1.100	1.105	1.109	1.112	1.115	1.117	1.120	150
160	1.054	1.084	1.089	1.094	1.098	1.101	1.104	1.107	1.110	160
170	1.044	1.074	1.079	1.084	1.088	1.091	1.094	1.096	1.099	170
180	1.033	1.063	1.068	1.073	1.077	1.080	1.083	1.086	1.089	180
190	1.023	1.053	1.058	1.063	1.066	1.070	1.073	1.076	1.078	190
200	1.013	1.043	1.048	1.053	1.056	1.060	1.063	1.065	1.068	200
210	1.004	1.033	1.038	1.043	1.046	2.050	1.053	1.055	1.057	210

APPENDIX XIII.

MELTING POINTS OF METALS.

Metal.	Degrees Cent.
Aluminium	658
Cobalt	1490
Copper	1083
Gold	1063
Iron (pure)	1520
Lead	327
Magnesium	651
Manganese	1225
Mercury	—38
Nickel	1452
Platinum	1755
Silver	960
Tin	231
Zinc	419

APPENDIX XIV.

LLOYD'S RULES FOR THE BURNING AND CARRYING OF OIL FUEL.

1. In vessels fitted for burning oil fuel, and having the Society's classification, the following records will be made in the Register Book:—"Fitted for oil fuel F.P. above 150° F." in cases in which approval has been given for the use of high flash point oil only; and "Fitted for low flash oil fuel" in cases in which the approval covers the use of oil with low flash point.

2. The following 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° F. For oil fuel with a lower flash point the arrangements must be submitted for special consideration.

3. Oil fuel, the flash point of which by Abel's close test does not fall below 150° F., may be carried in ordinary cellular double bottoms either under engines or boilers or under ordinary cargo holds, also in peak tanks or in deep tanks, or in oil bunkers specially constructed for the purpose.

4. Cellular double bottoms when fitted for oil fuel are to have oil-tight centre line divisions, and the lengths of these compartments are to be submitted for approval.

5. Peak tanks, deep tanks, bunkers specially constructed for oil fuel, and settling and other service tanks must be fitted with bulkhead sub-divisions or wash plates to the Committee's satisfaction, and be strenghtened so as to efficiently withstand the stresses brought upon them when only partly filled and in a seaway. The riveting of these spaces is to be as required by the Rules in the cases of vessels carrying petroleum in bulk, and the scantlings and arrangements must be to the Committee's satisfaction.

6. All compartments intended for carrying oil fuel 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 greatest.

7. Each compartment must be fitted with an air pipe to be always open, discharging above the upper deck. It is recommended that all double bottom compartments used for oil fuel should have suitable holes and doors of approved design fitted in the outer bottom plating.

8. Efficient means must be provided by wells or gutterways, and sparring or lining, to prevent any leakage from any of the oil fuel compartments from coming into contact with cargo or coal, and to ensure that any such leakage shall have free drainage into the limbers or wells.

9. If double bottoms under holds are used for carrying oil fuel, the ceiling must be laid on transverse battens, leaving at least 2 inches air space between the ceiling and tank top, and permitting free drainage from the tank top into the limbers.

10. The pumping arrangements of the oil fuel compartments must be absolutely distinct from those of other parts of the vessel, and must be submitted for approval.

11. If it is intended to carry sometimes oil fuel and sometimes water ballast in any of the compartments, the valves or cocks connecting the suction pipes to these compartments with the ballast donkey pump and those connecting them with the oil fuel pump must be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast donkey is being used on any other compartment.

12. All oil fuel suction pipes should have valves or cocks fitted at the bulkheads where they enter the stokehold, capable of being worked both from the stokehold and from the deck. Valves or cocks similarly worked are to be fitted to all pipes leading from the settling or service tanks.

13. Oil fuel pipes should, where practicable, be placed above the stokehold and engine room plates, and where they are always visible.

14. No wood fittings or bearers are to be fitted in the stokehold spaces.

15. 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 of the boilers, smoke boxes, casings, etc.

16. Water service pipes and hoses are to be fitted so that the stokehold plates can at any time be flushed with sea water into the bilges.

17. If the oil fuel is sprayed by steam, means are to be provided to make up for the fresh water used for this purpose.

18. If the oil fuel is heated by a steam coil the condensed water should not be taken directly to the condensers, but should be led into a tank or an open funnel mouth and thence led to the hot well or feed tank.

APPENDIX XV.

DIAMETER OF SUCTION AND DELIVERY PIPES RECOMMENDED FOR VARIOUS QUANTITIES OF MEXICAN FUEL OIL.

Fuel Oil in Galls. per Hour.	Diameter in Inches of— Pump Suction.	Pump Delivery.
50	$2\frac{1}{2}$	$1\frac{1}{2}$
100	$2\frac{1}{2}$	$1\frac{1}{2}$
150	3	$1\frac{1}{2}$
200	3	2
250	$3\frac{1}{2}$	2
300	$3\frac{1}{2}$	$2\frac{1}{2}$
350	4	3

APPENDIX XVI.

VISCOSITY OF MEXICAN FUEL OIL AT VARIOUS TEMPERATURES.

Temperature.	Viscosity (Redwood No. 2).
32° F.	8,412 secs.
40° F.	5,096 ,,
50° F.	2,227 ,,
60° F.	1,285 ,,
70° F.	539 ,,
80° F.	335 ,,
90° F.	210 ,,
100° F.	145 ,,
110° F.	95 ,,

The readings on Redwood's No. 2 Viscometer compare with the readings on No. 1 Viscometer for the same sample of Mexican oil as follows:—

Temperature.	Viscosity. Redwood No. 1.	Redwood No. 2.
70° Fahr.	7,500	695
100° Fahr.	1,460	155

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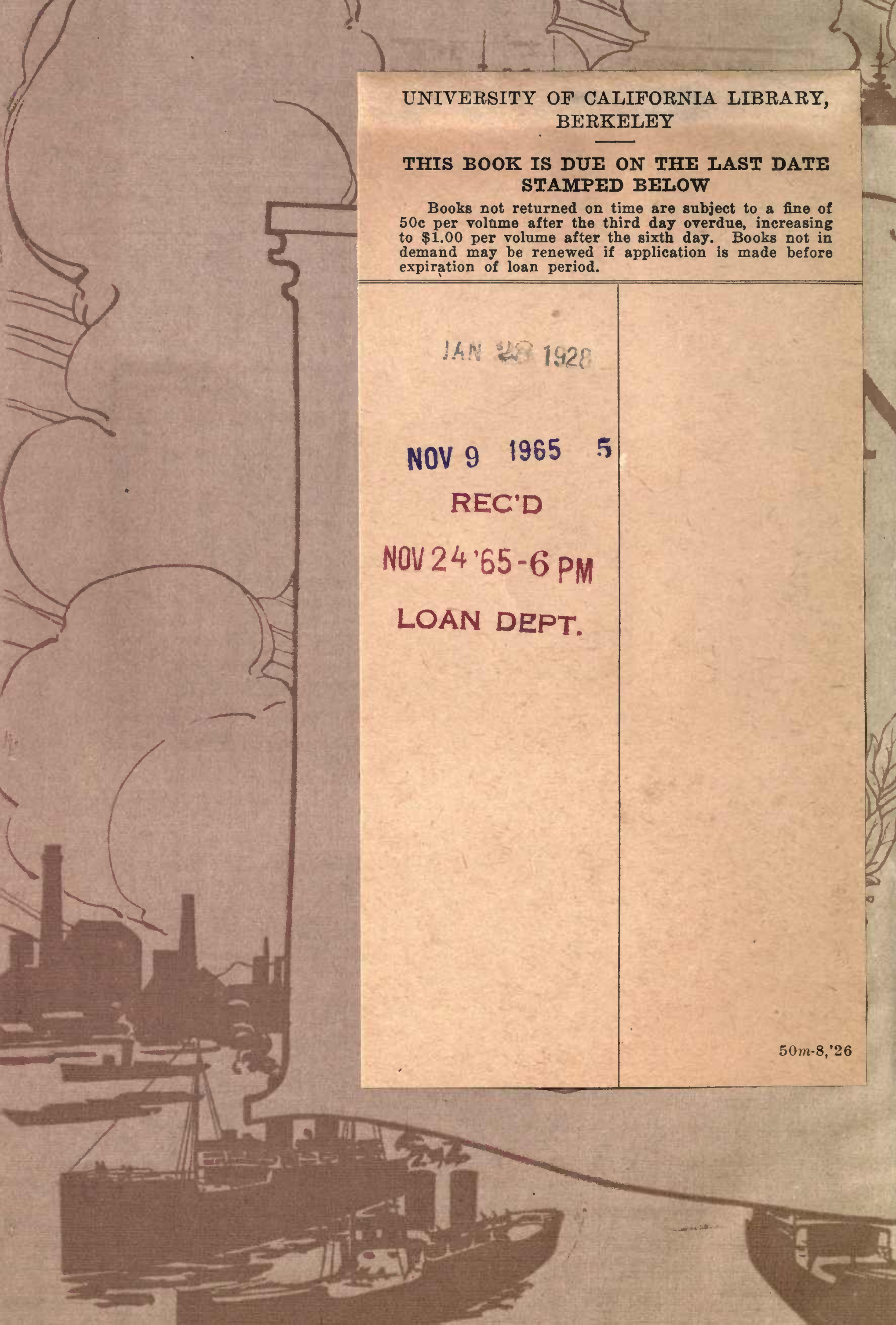

FUEL

f

STEAM

LOCOM

LAND BOILERS

INDUSTRIAL FURNACES

& OTHER USES