In the second a very high temperature is required to initiate combustion, which, when commenced, approximates to an explosion, owing to part of the oil having been made gaseous becoming mixed with the compressed air, and so constituting an explosive mixture. The latter oils, therefore, may be either not properly consumed, or they may be burned with explosive violence.

Turning to the supply of oil, a map of the world, illustrating the various known sources of supply, was shown. As far as Australasian production is concerned, at present not much can be said, as all the oil that is being produced is by distillation from coal shale, of which, however, there appear to be huge supplies in New South Wales and Tasmania. Queensland may find natural oil; it, at any rate, has found natural gas at Roma. New Zealand has three fields which are in course of being proved. For some time to come, however, imported oil would have to be relied on in the bulk. The nearest heavily-producing fields are Borneo, Sumatra and Java. The writer of this paper was surprised to find on his arrival in this country so little use being made of the Diesel engine, and on making inquiries into the reasons was invariably informed, "Oh, the price of crude or residual oil is prohibitive." He has been to some trouble to get at the truth of the matter, and is now in the position of being able to say that at all the capitals of the Australian States crude or residual oil can be obtained at 80/- per ton of 2240 lbs. in large quantities. The only reason it is at that figure is because so little of it is used that steamer and tank charges pile on the cost. There are signs, however, that this price will very shortly come down. In England, where 98 per cent. of the oil is imported, the price of crude and residual oils stood at an average of 40/- per ton at port when the writer left six months ago. It should be said in passing that guarantees have been given by the most influential oil companies that as the consumption increases there will be a corresponding fall in the price so much so that, if a demand of 5000 tons could be guaranteed by any consumer or combination of consumers, the price would fall to about 65/- per ton to them. Still, even this price is higher than it ought to be, considering the proximity of Australia to the big oil-producing centres. It should also be said that to a large extent the Commonwealth Government does not help the question by imposing a duty on crude or residual oils of 5/- per ton, apart from the irksome regulation it imposes with regard to denaturing of the oil. A further anomaly appears in the tariff regulation, telling against internal combustion engines generally—i.e., the fact that the high speed, or, rather, quick revolution, types have to pay the same duty as the slower moving speed types; whereas in steam engines the fast moving types and steam turbines for direct coupling to dynamos are exempt. This is still more curious when it is remembered that there is far more chance of such steam engines being manufactured here than of large gas and oil engines. The question of fuel cost per ton has been somewhat elaborated, as it has necessarily a most important bearing on the final cost of the power developed.

COMPARISONS OF CAPITAL AND OPERATING COSTS FOR STEAM AND GAS VERSUS OIL PLANTS.

The most important items to be considered in ascertaining the total cost per b.h.p. hour or k.w. hour developed are:—

Fuel Consumptions
Load Factors
Fuel Costs
Labour Costs
Capital Costs
Maintenance and Depreciation Charges

The other factors which assist one in deciding on the type of plant to be adopted are reliability and simplicity. With regard to both of the last items, one is undoubtedly correct in stating them in the following order of merit, assuming that real high-class machinery be employed:—Diesel oil engines; steam plant; gasplant, with suction pressure type producers, primarily because with the Diesel engine there is only the one unit, therefore requiring the least attention and maintenance; and, secondly, because with a single unit it is far easier to obtain exact information as to how the plant is performing—i.e., there are not so many chances of minor defects arising, which only the keenest of observers are capable of locating, before they develop into serious trouble.

The following figures of costs are based on high-grade plants throughout:—

		Home prices.
(a)	Steam Plant—	
	(1) Machinery, per k.w. installed	£16 0 0
	(2) Buildings and foundations, per k.w.	8 5 0
	Total cost per k.w.	£24 5 0
(b)	Gas Plant—	
	(1) Machinery, per k.w. installed	£17 5 0
	(2) Buildings and foundations	6 0 0
	Total cost per k.w.	£23 5 0
(c)	Oil Plant—	
	(1) Machinery, per k.w. installed	£19 5 0
	(2) Buildings and foundations	5 5 0
	Total cost per k.w.	£24 10 0

In all the above the generating sets are of the direct-coupled high-speed type, and are based on actual figures of station cost at home, and are for large stations. For a recent case which the author had to consider here for a load of about 300 k.w. and no standby plant allowed for:—

(a)	Steam Plant—	
	(1) Machinery	£20 5 0
	(2) Buildings and foundations, chimneys, etc.	10 0 0
	Total	£30 5 0
(b)	Gas Plant—	
	(1) Machinery	£28 0 0
	(2) Buildings and foundations	7 1 0
	Total	£35 1 0
(c)	Oil Plant—	
	(1) Machinery	£24 0 0
	(2) Buildings and foundations	6 5 0
	Total	£30 5 0

From the above "Home" prices it would seem that difference in capital outlay is very slight. The Australian figures, however, appear directly opposite, in that gas is the most expensive. The amount allowed for building may appear high, but the figures are for brick and stone buildings. Land values are omitted in all cases.

Fuel Consumption and Thermodynamic Efficiency and Influence of Load Factor:—

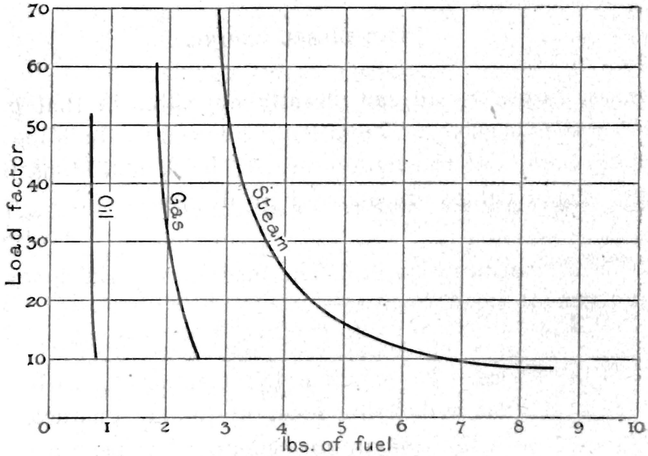
(a) Steam—To obtain a fair comparison with oil, a plant embodying most up-to-date characteristics to attain maximum economy has been assumed, i.e.:—Engines, compound condensing; boilers, water tube, with superheaters and stokers, economisers, etc.; boiler pressure, 150 lbs. per sq. inch; superheat, 100 deg. F.; vacuum, 25 ins.; steam consumption at full load, including auxiliaries, 20.5 lbs. per k.w.h.; coal, 13,000 units; water, evaporated per lb. of coal, 8 lbs.

(b) Gas—Engine, vertical single-acting tandem; producer, pressure; coal, 13,000 b.th.u. per lb.

(c) Oil—Engine, vertical single-acting 4-cycle; oil, 18,500 b.th.u. per lb.

The fuel consumptions on Fig. 9 are worked out on the basis of —(1) consumption per effective k.w.h. output; (2) consumption covering standby losses; and to these totals is added a certain percentage to cover inefficient handling, loss in efficiency in the plant due to fouling of tubes and pipes, etc.

From the fuel consumption shown on Fig. 10 are derived the following:—



Total Fuel Consumption per Kilowatt-hour Generated.

Fig. 9.

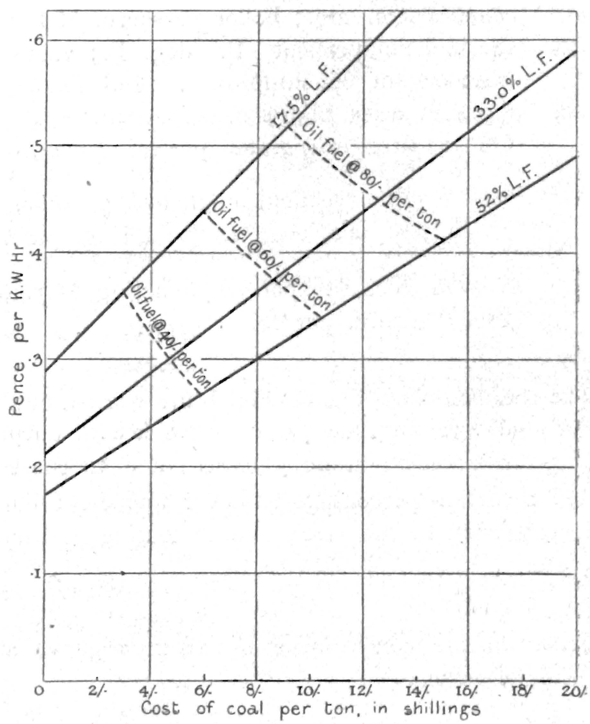


Fig. 10.—Steam Plant. Works Cost—pence per kilowatt-hour Generated.

OVERALL THERMO-DYNAMIC EFFICIENCIES.

Load Factor. Per Cent.		Steam Plant. Per Cent.		Gas Plant. Per Cent.		Oil Plant. Per Cent.
17.5	..	5.60	..	11.7	..	25.7
33.[illegible]	..	7.30	..	13.3	..	27.3
52.0	..	8.70	..	14.5	..	27.8

These results show that even with a high-grade and very efficient steam plant the comparative thermo-dynamic efficiencies are approximately as follows:—

Oil engine	100 per cent.
Gas engine	46 to 52 per cent.
Steam engine	22 to 30 per cent.

The figures here given compare extremely closely with actual figures obtained over a large number of supply stations at home, as do all the following tables and curves of running costs, which are taken from papers by A. H. Pfeiffer and Messrs. Andrews and Partis, which were actually compiled from running costs.

The superiority of the oil engine is very marked, and is due, firstly, to the thermo-dynamic efficiency, and, secondly, to the complete absence of stand-by losses. Fig. No, 10 shows curves illustrating lbs. of fuel consumed per k.w. generated under the various load factors. The following table closely approximates actual figures:—

Load Factor.		Steam Engine.		Gas Engine.		Oil Engine.
175 per cent.	..	lbs. 4.67	..	2.251	..	.717
33 per cent.	..	lbs. 3.55	..	1.979	..	.577
52 per cent.	..	lbs. 3.08	..	1.820	..	.66

The total works cost may be taken as follows for the same load factors as above:—

TABLE 3.

Total works cost per effective unit generated, maximum load, 1600k.w.

Load Factor.		Steam.		Gas.		Oil.	
		Pence per Unit Generated.		Pence per Unit Generated.		Pence per Unit Generated.	
		At 15s. per Ton.		At 25s. per Ton.		At 60s. per Ton.	
	Fuel		0.376		0.300		0.230
17.5 per cent.—							
	Oil, waste, water and stores	0.04		0.045		0.042	
	Salaries and wages	0.16		0.150		0.100	
	Maintenance and repairs ..	0.09		0.090		0.054	
			0.290		0.285		0.206
	Total		0.666		0.585		0.436
33 per cent.—							
	Fuel		0.286		0.265		0.218
	Oil, waste, water and stores	0.035		0.040		0.036	
	Salaries and wages	0.110		0.110		0.070	
	Maintenance and repairs ..	0.070		0.070		0.050	
			0.215		0.220		0.156
	Total		0.501		0.485		0.374
52 per cent.—							
	Fuel		0.247		0.243		0.212
	Oil, waste, water and stores	0.030		0.035		0.030	
	Salaries and wages	0.085		0.080		0.054	
	Maintenance and repairs ..	0.060		0.060		0.042	
			0.175		0.175		0.126
	Total		0.422		0.418		0.338

The curves given on Figs. Nos. 10 and 11 are figures of steam and gas plants given in the previous table plotted as curves of total works cost in pence per k.w. hour generated at the various factors. The dotted curves cutting these are what may be termed "parity curves" for Diesel engine plant—i.e., they represent the equivalent price that could be paid for oil fuel to obtain the same results. These, I believe, were originally calculated. Practical experience, however, points to their being too conservatively rated—i.e., they should be placed materially higher up the scale. In the experience obtained in the supply stations works

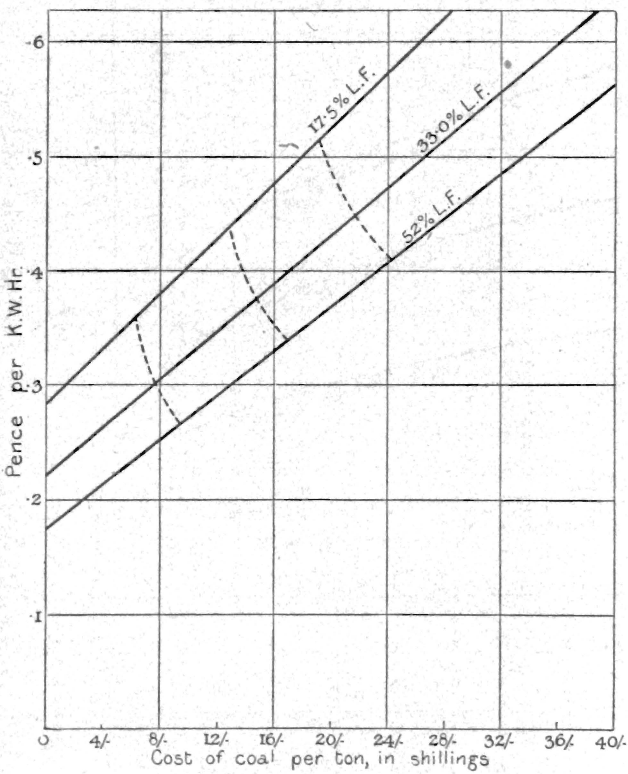


Fig. 11.—Gas Plant. Pence per kilowatt-hour Generated.

run by the firm to which the author is attached and others in which he has been interested the equivalent price has varied from 8-10 times the coal value. A more simple and useful method of showing the comparative prices which can be paid for oil over coal is as shown in Figs. Nos. 12 and 13, where various oil cost curves show the price that may be paid as against coal for the various load factors, as against both steam and gas plants. In confirmation of these figures being attained at home under cheap coal and labour, the following actual works costs are of interest:—

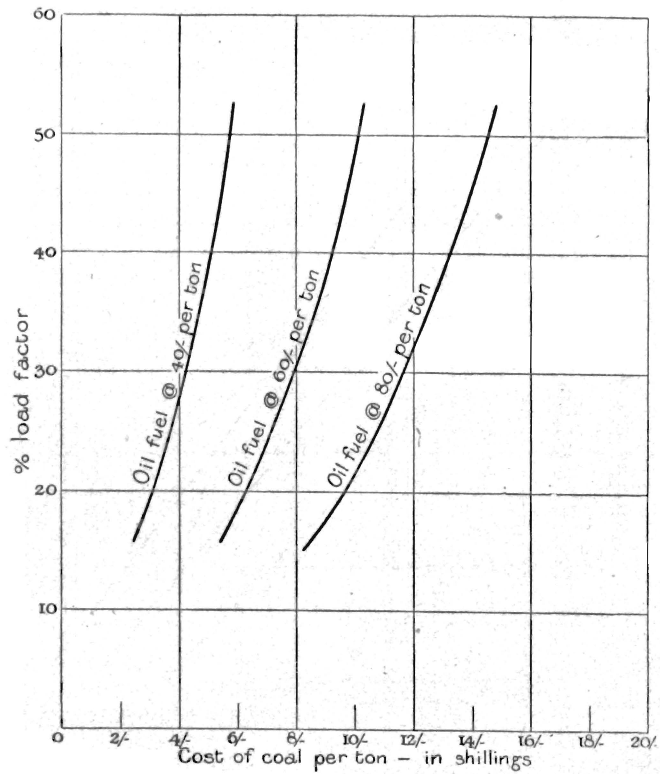


Fig. 12.—Steam versus Oil. Parity Curves.

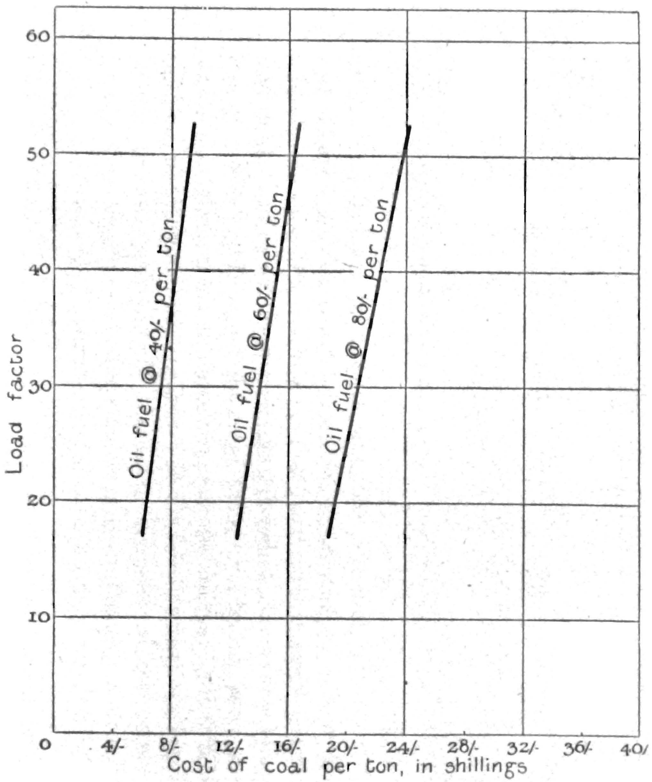


Fig. 13.—Gas versus Oil. Parity Curves.

WAKEFIELD AND DISTRICT LIGHT RAILWAY POWER COSTS.

Financial Year ended 31st December, 1908.

2 Units each 220 k.w.

HOWDEN'S STEAM ENGINES.

	£	s.	d.	Av. per U. Gen.
Salaries and Wages	£1637	4	6	.158
Fuel	1704	4	2	.164
Water	—			—
Oil and Waste	128	6	6	.012
Miscellaneous Supplies	15	3	9	.001
Repairs to Steam Plant	320	19	11	.031
Repairs to Elec. Plant	76	7	6	.007
Repairs to Ducts, Feeder Cables, etc.	1	15	10	.000
Repairs to Power and Sub-station Buildings	110	13	2	.011
	£3994	15	4	.384

Units generated, 2,495,516.

DIESEL OIL ENGINES.

	£	s.	d.
Salaries and Wages	£491	14	3
Fuel	725	5	7
Water	7	7	4
Oil and Waste	41	17	3
Miscellaneous Supplies	3	15	10
Repairs to Plant (Engines)	14	3	1
Repairs to Power Sub-station Buildings	0	18	1
	£1285	1	5

Units generated, 695,290. Load factor, 18.6.

N.B.—It should be noted that during the above period coal was at the rate of 5/3 per ton of 21 cwts., and, owing to local conditions, the rate for fuel oil was, from January to March, 69/6, and March to December, 61/10 per ton.

Belle Isle, Wakefield, 30/3/'10.

DAIMLER MOTOR CO. (1904), LTD., COVENTRY. DIESEL ENGINE PLANT.

Four Months' Generating Costs, Oct. 1, 1909, to Jan. 31, 1910.

B.T.U.'s generated, 592,250.

Works Costs—		
Fuel (at average of 55/- ton)	0.2051d.	per b.t.u.
Lubricating Oil, Waste, Stores, etc.	0.0231d.	,,
Wages	0.0546d.	,,
Maintenance	0.0214d.	,,
	0.3042d.	
Capital Charges—		
Interest and depreciation, 10 per cent. per annum on capital cost	0.1061d.	,,
Total cost per unit generated	0.4103d.	,,

LEATHERHEAD AND DISTRICT ELECTRIC SUPPLY CO. LTD.

Leatherhead Diesel Engine Plant Generating Costs.

Fuel (at average cost of 44/- per ton	0.190 pence
And total works costs	0.352 pence

Mr. Milton, Electrical Engieer, Maidenhead, in reporting to his council, stated that, notwithstanding the increase in output of 18,000 units, the cost of fuel for that quarter is less by £71 than the cost for the corresponding quarter of last year, the Diesel engine being the cause of the saving.

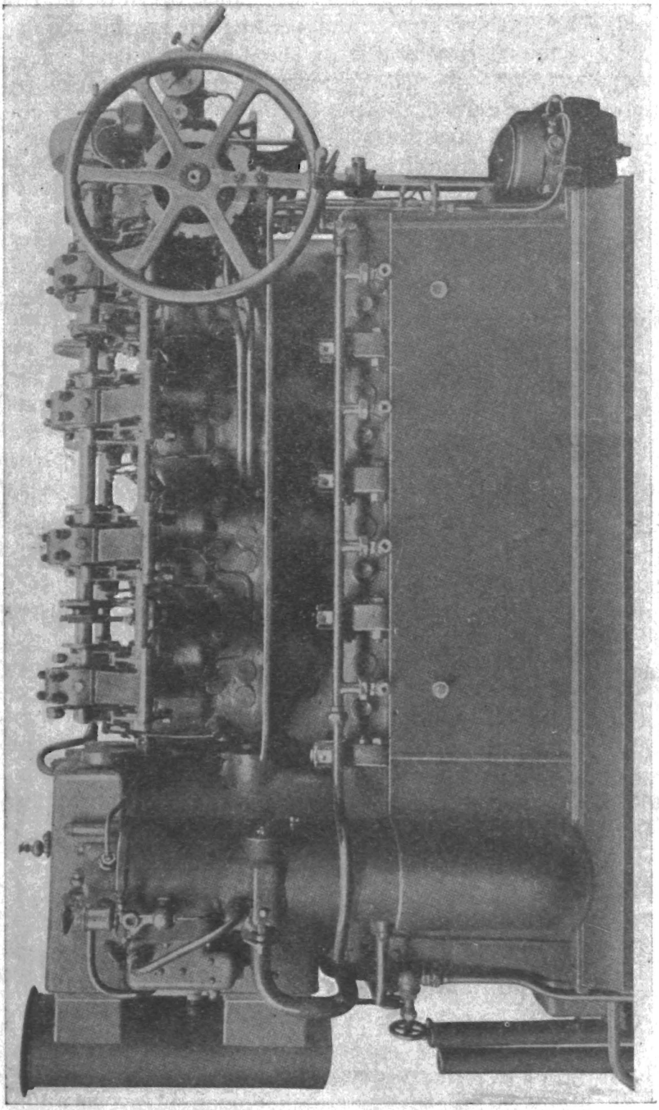
The report contains the following comparison between the Diesel oil engine and the steam plant:—

Total units generated in one week	11,311
Fuel costs	£18 15 0
Of these 6,518 units were generated by the Diesel oil engine, costing	5 11 0
Whilst 4,798 units were generated by the steam engine, costing	13 4 0

The saving on fuel for that week, as against the corresponding week of last year, was £6/10/-, although there was an increase of 2000 in units generated. The committee and council consider this very satisfactory.

OTHER APPLICATIONS.

One of the most interesting of these is the use of the Diesel engine in sub-stations as boosters and equalisers, and to cope with the peak load. This matter was very clearly



100 B.H.P. Diesel Reversible Marine Engine.

dealt with by Mr. Pfeiffer in his paper before the I.E.E., London, 1909, from a purely abstract point of view, and it is actually being carried out and confirmed by the results achieved by one of the largest of the London electric supply companies, who started by using them purely for balancer and booster drives. Now they have so extended the system that no less than 8000 h.p. is supplied by the Diesel, and the steam station, with its 3000 k.w. steam units, remains as originally put down.

OTHER IMPORTANT DEVELOPMENTS.

The most important application of all is probably the use of these engines for marine services as the main prime mover. The strides that are being made in this direction are very little understood. Few people are aware of the fact that upwards of 50 vessels, all exceeding 1500 tons capacity, are so engined, belonging to one firm—viz., Messrs. Noble Bros., who recognised the possibilities of the engine five years ago. The system adopted by them is as follows:—

The engine is direct coupled to a continuous current generator, the shaft being extended on to driving side of a magnetic clutch. Beyond the magnetic clutch and on the propeller shaft is mounted the armature of a direct current motor, the modus operandi being as follows:—

(1) All starting and slow speeds up to 50 per cent. of the vessel's speed being obtained by the engine driving the generator which supplies the motor, the clutch being dead, the engine running at top speed.

(2) All speeds about 50 per cent. are obtained by governing the engine, the clutch now being used, making engine fast to the propeller. The current for energising the clutch is supplied by the dynamo, and the motor is dead.

(3) Reversing obtained electrically, as in (1).

This system has many disadvantages. The weight is extremely high, owing to the engine speed being brought down to meet the propeller. Electrical troubles are frequent, due to reversing, as might be expected with continuous current unless done very slowly. However, it is still operating in these vessels, and the owners state that the showing quite warrants the continued use despite the disadvantages. Besides these, advices tell of over 60 ships having been either launched, put into operation, or on the slips, to be engined with Diesels. As far as the author has been able to ascertain, these are all direct drive equipments. Since writing the above the author ascertains that one vessel is being built on the Clyde to be Diesel electric on the Henry Moore system of electric transmission. Marine engineers at home and on the Continent are, it seems, from the paper read by Mr. Milton before the Spring Conference of the Naval Architects Institute, chiefly worrying themselves with purely mechanical improvements in applying the direct Diesel drive. The largest of these vessels is a tramp for the North German Lloyd, in which the engines are to develop 1500 h.p. each. These are being built on the patent system of the Augsburg Nurnheim Co., and will have three cranks, six cylinders—i.e., there are two cylinders in tandem on the one crank. The engines are to reverse by compressed air, which is stored in tanks and supplied by an independent engine. The compressed air is also used for all the auxiliary services. Perhaps the most interesting boat afloat is the oil tank vessel "Vulcanus," belonging to the Dutch East Indian Oil Co. She is fitted with 2-500 h.p. Diesels which have some novel points. The cylinders are vertical, and the engine resembles an ordinary quick revolution steam engine in appearance. The novel features are in the piston design. These are short pistons, water cooled, fitted with ordinary Ramsbottom rings, having a hollow piston rod, which is not water cooled, but passes the trombone pipes for water circulation through to the piston. The piston-rod terminates in a crosshead, and a connecting rod is used as in ordinary marine practice. They seem to operate well, and the fuel consumption is extremely low:—

Full load, 0.37 lbs. per b.h.p. hour
¾ load, 0.429 lbs. per b.h.p. hour
½ load, 0.495 lbs. per b.h.p. hour
¼ load, 0.77 lbs. per b.h.p. hour

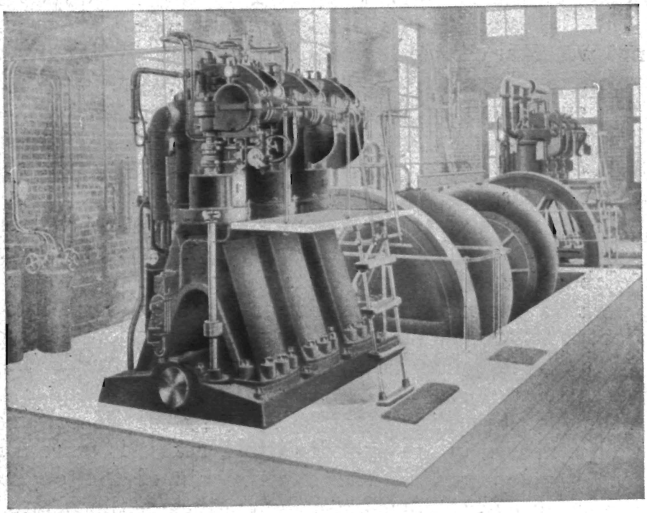
Mr. Milton, the Chief Engineer of Lloyd's, in his paper, throws an interesting ray of light on the possibilities in this connection. It is usually claimed that the oil consumption per brake horse power per hour is 0.4 lb. when the engine is working at full power, and when working at somewhat lower powers the rate of consumption is not much increased.

If one assumes that in a modern steam engine the consumption of coal is 1.25 lbs. per i.h.p. per hour, this corresponds to about 1.47 lbs. per b.h.p., so that the weight of fuel to be carried for the same voyage in a vessel fitted with Diesel engines would be only 28 per cent. of that of the coal necessary with ordinary steam engines. Mr. Milton is a mechanical engineer, and perhaps naturally looks at the question from a direct coupled point of view. The author, who has spent a good deal of time on this subject in conjunction with Mr. W. P. Durtnall, of London, is, however, of the opinion that the best, handiest, and in the end most economical method that can be used will be that of multiple high speed units, using electrical transmission of the polyphase alternating current type, the variable periodicity necessary for operating squirrel cage motors being obtained by means of a special combination of synchronous and non-synchronous generators. The details of the system have frequently been published, notably before the Institution of Marine Engineers, 1908 to 1909, and the Institution of Naval Architects' Spring Meeting, London, 1910. This was chiefly in connection with the turbo-electric application, but it was in 1908 pointed out that the Diesel engine must eventually become the prime mover, even if marine engineers resort to high superheat in conjunction with reciprocating cum-turbine drive, etc.

The day of the Diesel will only be deferred. I state this despite the knowledge that prophecy is a most dangerous business.

Another most interesting development is that of the Diesel electric locomotive, re which the author hopes to be in the position to give the Association some figures taken from the actual drawbar pull diagrams and running logs, which we hope to be able to take early next year.

The future possibility of obtaining improvements in thermo-dynamic efficiencies is not by any means hopeless. This might be in two ways:—(1) Utilisation of the exhaust gases for generating steam which could be utilised in a turbine; (2) utilisation of the exhaust gases direct in a low pressure gas turbine or rotary engine. Both of these have been proposed. The author had the pleasure of being connected with a test of a small gas turbine supplied, as mentioned, with exhaust gases. The result in the small way attempted was very gratifying, resulting in bringing the overall thermo-dynamic efficiency up to 38 per cent. The other method, however, will perhaps be the best for attaining large powers, as the condensers required for the gas turbines present some formidable difficulties, and the air pump losses will be undoubtedly heavy. In conclusion, the author wishes to thank those gentlemen whose papers have already been mentioned as supplying much of the groundwork of the paper, and also the Diesel Engine Co., London, and our President for his assistance, and regrets that the exigencies of a somewhat strenuous business life did not allow of more original matter being put before the members.



Two Diesel Engines of 120 B.H.P., each direct coupled to centrifugal pumps at the Dunedin (N.Z.) Drainage and Sewerage Board's Power House.