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Modern Developments in British and Continental Oil Engine Practice.

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READ

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CHAIRMAN: MR. JOHN LANG, R.N.R. (MEMBER OF COUNCIL).

IN presenting a paper on the above subject, the author feels that the marine engineer cannot much longer afford to neglect the advantages to be derived from the use of the internal combustion engine, in one form or other, for powers where 1,000 to 2,000 h.p. will not be greatly exceeded, but the general trend of opinion seems to be that whilst the subject is a very fine one for papers and discussions, the adoption of the new form of prime mover had best be left to their successors. However, the interests of all parties have been aroused and, that being the case, the problem is likely to receive in the future continually increasing attention.

It may be of interest, before proceeding with the paper, to call attention to the very excellent pioneer work done by Messrs. Priestman who, with " Eteves " patents, made the first successful oil engine for stationary work and who, moreover, were the first, or almost the first, to adapt the oil engine for marine propulsion. Many features of the Priestman engine were doubtless in advance of the times, such as the spray maker introducing the oil into the vaporizer, the electric ignition and compressed air for starting. It is to be regretted that they have now ceased to manufacture oil engines. In a paper of this description it is not proposed to deal with engines using petroleum spirit as these do not come within the marine engineer's proper sphere and are not of general interest, and it is obvious that the conditions of economy and safety for engines in use on every day shipboard, put them out of discussion. The merits of the heavy oil engine are very great and in this paper it is proposed to call attention to various makers of engines using " Crude," " Residuum " or " Intermediate " oils. The term " Crude " or " Residuum " oil is apt to be misleading as various shale oils (such as Scotch products) of widely different quality are occasionally referred to under this indefinite name. The products of the Texan, Borneo, Russian, Galician, Mexican oil fields are of a different character, due to the fact that they are natural products whereas the Scotch oils are only produced by distillation.

The majority of oil engines will give excellent results on Scotch crude and semi-refined oils if designed for crude fuel, but to assume that the same holds good on the residuum would be a bold assertion. There are among the group of residuums, oils that may be used as fuel for an oil engine, but could not be recommended for continuous runs as their constituents of tars, bitumen, sulphur, etc., are very much opposed to satisfactory and economical working. There are, however, still a reasonably large number of residuums which adapt themselves to oil engine running. The marine oil engine has many recommendations to commend it to the marine engineer. It is infinitely less complex than the steam engine with accessories, boilers, condensers, pumps, etc., occupies less than half the space of the same and effects great saving also of fuel space. It goes without saying that it will need no funnel in the ordinary sense of the word. At the same time, however, it is as well to remember that the exhaust products will have to be discharged at some point, and therefore some provision will have to be made, and both smoke and smell are encountered in the best types of oil engines. It occurred to the author that marine engineers generally may have a desire to have some definite information as to the various components of so-called crude oil; chemical composition, etc., and he has therefore given particulars herewith from that excellent work *Petroleum and its Products* by Sir Boverton Redwood.

"When heated, crude petroleum gives off condensible vapours. Here are examples of the volatilization of the various strata forming the crude.

"1st Stage.—Benzine, Gasolene, etc, which are yielded at up to 300° F.

"2nd Stage.—Paraffin, Kerosene, at temperatures up to 500° F.

"3rd Stage.—The products of mineral lubricating oils.

"Real crude oil varies in spec. grav. from 800 to 950 (American and Russian crudes)."

All crude oils have a proportion of asphalt in them and in many cases the Baku oils yield a residuum of 40 to 60 per cent. There is also a large variety in the yield of paraffin or kerosene from various crudes, some containing as high as 70 per cent. others being as low as 8 to 9 per cent. An oil containing 60 to 70 per cent. of paraffin would doubtless gladden the heart of any heavy oil engine builder who desired to operate his oil engine with it. The flash point varies between 25 to 70° Cent. (=77 to 158° F.) with different oils. The following gives some idea of the component parts of crude petroleum :—

"Bitumen, Tar, Coke, Sulphur, Paraffin, Vaseline, Sulphurated Hydrogen, Carbon, Bi-Sulphide of Carbon, Arsenic, Phosphorus, Calciums, Oxides. In some samples of Baku oil as high as 24 per cent. tar has been found."

It may be assumed that if the adoption of the oil engine for marine propulsion becomes general and boats replenish their oil tanks at various depôts through the world, there will be a great dissimilarity of performance by the engines from time to time as an engine doing well on Borneo, Mexican or American oil or similar crudes would only do passing well on, say, certain Baku or Galician fuels. It is to be hoped, however, that a universal standard may be arrived at in this matter.

I give on page 56 a suggestion.

FUEL OIL STANDARD.

1. Fuel oil.	Colour, black.	Spec. grav.	930–940.	
2. ,,	,, brownish black.	,,	900–920.	Admiralty standard. Flash not to exceed 200° F.
3. ,,	,, brownish black.	,,	875–880.	
4. Gas oil.	,, Red.	,,	850–860.	
5. No. 1 Paraffin.	,, pale straw.	,,	815–835.	
6. White ,,	,, white.	,,	800–810.	

The B.T.U of residuum of crude oils varies between 18–21,000.
Number 4 is semi-refined oil.
Numbers 5 and 6 are refined oils.

Few of the obtainable fuel oils are bona-fide crudes and it will be at this point distinctly understood that the majority of such have been treated in the stills, i.e. had the volatile and other products distilled from them. Genuine crude oil has, the author believes, been used in a few cases, but apart from using the raw product, which frequently contains sulphur and which is very detrimental to an oil engine, it is quite obvious that in commercial practice it would be exceedingly risky to use, as in this state its naphtha and benzine components once in contact with air become dangerous as an explosive, and it is to be assumed that no owner of a ship would even consider carrying such fuel.

The following table may be of interest as showing the great increase in the production of Petroleum from various countries.

THE WORLD'S PRODUCTION OF PETROLEUM. FROM THE "PETROLEUM REVIEW," MARCH 12, 1910.

Producing Country.	1909. Tons.	1908. Tons.	1907. Tons.
America	25,000,000	25,700,000	22,400,000
Russia	7,900,000	7,500,000	7,680,000
Dutch Indies	3,000,000	2,500,000	2,000,000
Galicia	2,150,000	1,750,000	1,170,000
Roumania	1,300,000	1,150,000	880,000
India	780,000	600,000	550,000
Other Countries	550,000	450,000	450,000
Total	40,680,000	37,650,000	35,130,000

The advantages of an oil engine for marine work over the steam engine are many and the author does not propose to traverse over ground in this direction beyond the following points:—

(1) Space occupied only 60 per cent. in comparison with steam.

(2) "Stand by" losses nil. Steam 15–20 per cent. of fuel consumption.

(3) Water required for cooling, half of that required for condensing purposes.

(4) Minimum of labour and time in replenishing fuel.

(5) Practical elimination of firemen and trimmers.

(6) Considerably reduced fuel space, giving,

(7) Increased cargo space.

(8) Weight of machinery much less than steam.

Having enumerated the advantages of oil engines it will be as well to also review some of the disadvantages.

(1) Are dependent upon compressed air to effect reversing (Bolinder's excepted) and starting.

(2) Will require an extra good bed or sole plate on shipboard, the vibration being in excess of steam.

(3) Are fairly high revolution engines.

(4) Failure of compressed air supply would entail inability to start or reverse.

(5) Disadvantage of a clutch in engines directly reversible.

(6) Engines are generally not so easy to handle at low speeds as steam.

Objection 1 is not now a serious factor. No. 2 is a matter for the ship-builders. No 3 propeller speeds not so high as the turbine. No. 4, this is referred to later in the paper. No. 5 is also dealt with in another portion of the paper. No. 6, this disadvantage is now rapidly disappearing as the new multi-cylinder engines are exceedingly flexible and can be reduced to less than one-third of their maximum speed when required.

Notwithstanding the advantages to be derived from electro-transmission it would appear that in moderate power installations, no ship-builder or shipowner is seriously inclined to consider such system on whole power lines (owing to the heavy cost of installation), but where this class of transmission is desired for reversing purposes, slow speeds, etc., it would appear that the Mirrilees proposed system has much in its favour but, even under such circumstances, the reversing engine is bound to become paramount in the long run. Before proceeding further it is advisable to classify the various types of engines, and accordingly the author has tabulated the following :—

Engine.	Cycle.	Size.	Fuel.
*Diesel, Sulzer and M.A.N.	Otto and Two-cycle	100 to 2,000	Heavy residuum
*Blackstone . . .	Otto . . .	70 „ 20	„ „
Bolinders . . .	Two-cycle .	50 „ 400	Semi-refined oil
*Griffin	Otto . . .	50 „ 150	Heavy residuum
*Diesel, M.B. & D. .	Otto . . .	50 „ 300	„ „

* These engines also work with Scotch shale oil, gas oils, solar oils, semi-refined and refined paraffin and, in some cases, with gas tar oils.

For commercial purposes generally and for the review of these motors before the Institute it is not considered desirable to refer to any engine whose power is less than 50 b.h.p. The Beardmore engine has also been omitted, it being the subject of a special paper to the Institute, some year or two back.[1] It is also totally impossible to deal, in a paper of this description, with more than a limited number of engines and such as shall prove of the most interest and whose principles are likely to appeal to marine engineers and to provoke dicussion.

Diesel Engine.—The Diesel engine is a unique motor and, as a marine prime mover, will certainly take some ousting from its premier position. As far as can be ascertained it is the practical pioneer of engines using residuum fuels, although it must be distinctly understood that even this engine will not operate on any or all residuums. The cycle of operations in the cylinder of a Diesel engine may be described as follows :—

(1) Outstroke of the piston on which pure air is drawn into the cylinder only.
(2) Return stroke of piston compressing air.
(3) End of compression and injection of fuel oil finely sprayed into the cylinder which is immediately followed by slow burning or expansion work being done on the piston.
(4) Return of the piston at end of expansion stroke and discharge of exhaust gases.

[1] See Vol. xviii. F. M. Timpson, Proceedings Institute of Marine Engineers.

The temperature of the compression may vary between 110°F to 1,200°F. Its principle of high compression and injection of fuel prior to immediate spontaneous burning is very satisfactory and under all normal conditions it is a very reliable engine and eminently adapted for marine work. The Diesel engine is built in England by Messrs. Mirrilees, Bickerton & Day, Stockport, Willans & Robinson, Rugby, and it is probably of interest to note that Messrs. Mirrilees, Watson & Co. built the first Diesel in this country at their Glasgow works in 1897. Abroad the Diesel engine is built by Maschinenfabrik Augsburg-Nurnberg A.G. at their various works in Germany. In Switzerland the builders are Messrs Sulzer Brothers of Winterthur, and also The Swiss Locomotive Works for certain sizes, under licence to Messrs Sulzer Brothers. In Italy by Franco Tosi Legnano. In Denmark by Bourmeister and Wain, Shipbuilding Works. In France by Augustine Normand. In Belgium by Carels Frères, Ghent. In Holland it is also now being constructed by Nederlandsche Fabriek van Werktuigen en Spoorweg-Materieel. This firm, by the way, have been the builders of the engine for the O. S. Vulcanus, and the American builders are the American Diesel Engine Co. It will be thus seen that the vast potentialities of this motor have been appreciated by many of the world's greatest engine builders, who now build it. In thermal efficiency it is high and gives 1 b.h.p on a consumption of not exceeding ½lb. of fuel per hour, full load, and runs for long periods with little or no attention, and many examples have been afforded where these engines have run 1 to 2 months without stop. While possessing so many salient features it may here be as well to emphasize the fact that the Diesel engines are expansive motors, i.e. the maximum pressure is more gradually attained and doubtless much shock is eliminated thereby, as with other forms of internal combustion engines the maximum pressure is reached immediately after ignition, and moreover the explosion in the ordinary type of gas or oil engine is altogether of a more violent type and it is one essential detail which pertains to the Diesel system only enabling relatively slow expansions to be possible, conditions which are not obtainable in any other internal combustion engines. For instance, to carry the compression of an oil engine much beyond 70 to 80 lb. per sq. inch or of a gas engine beyond 200 lb. per sq. inch would, in the ordinary course of events entail pre-ignition of the charge at about ¾ to ⅞ of the compression stroke. High compressions on an oil engine give marked detonating explosions and would not be considered for one moment by a builder as sound practice and, in gas engines, although the practice of extra high compression has of late years been largely adopted, it is recognized that the life of the liner and piston of such engines are considerably shortened.

Apart from explosion pressures it is apparent that the extremely high explosion temperature consequent on high compression, while effecting greater efficiencies for the time being, has very serious disadvantages, and moreover the general practice of high compressions, which began to be prevalent some years ago and finally ended in a general scramble among the gas engine makers as to who would go the highest is anything but ideal; the author indeed considers it the reverse of ideal. To be brief, competition for business among makers is now so keen that, what was, say for comparison, an 11 b.h.p. engine ten years ago of moderate compression is now given a high compression and frequently rated at 14 to 15 b.h.p. the bore and stroke of the old and new engines being almost identical. Thus, it has become recognized by oil engine builders that, if results are to be obtained on a par with the Diesel, wide divergence is necessary from established practice. In one detail alone the Diesel system scores heavily, viz. that of total absence of ignition apparatus, for, whether ignition be by so-called automatic system or by hot bulb, magneto, or other methods, extra attention is required if they are to be kept in first-class order. Moreover, with the Diesel system of injecting or spraying the fuel oil, most excellent combustion is obtained with the minimum of deposit. In the majority of oil engines on other systems considerably heavier deposits take place during the vaporization or combustion of the charge, entailing much more frequent openings up and removal of the same. Diesel engines, however, do not run at their best at very low speeds, being somewhat inclined to foul, neither is it advisable to run them with low water jacket temperatures, but neither of these conditions need be serious factors. That this engine is expensive to build must be of necessity as none but the finest workmanship and materials can be used and, moreover, it must be extremely solid in its structure. It will be understood that the manufacture of the Sulzer Diesel marine engines calls for the supervision of a special staff and it is obvious that the conditions are entirely dissimilar from those pertaining to stationary engines, as each engine of the marine type has to be specially designed and built for each individual ship, hence the initial stages in the construction of them are costly and slow. Messrs. Sulzer, whose name is famous as makers of the Sulzer steam engine are quite satisfied that the Sulzer steam engine with all its refinements superheating, condensing and Corliss type valves, able to give 1 i.h.p. on a consumption of steam between $10\frac{1}{2}$ and $11\frac{1}{2}$ lb. per hour, have no chance as to economy or efficiency when paralleled with the Sulzer Diesel engine. Herewith are some tables showing comparative cost of steam and oil engines.

TABLE "A."

STEAM ENGINE.

Fuel—Coal.	Labour.	Fuel.	Stand by Losses.
1,500 i.h.p. × $1\frac{1}{2}$ lb. per i.h.p. = 2,250 lb.	10 Firemen, Trimmers and 1 Donkeyman 1*s.* per day per man = 11*s.* per day for food. 7 days per week = £3 17*s.* Wages £1 week each = £11.	24 tons 2 cwt. per day at 14*s.* = £16 17*s.* 4*d.* = £118 1*s.* 4*d.* per week.	Assuming 20 days per annum, 5 tons per day = 100 tons = £70 per annum, say £1 7*s.* per week.
	£3 17 0 11 0 0 118 1 4 £132 18 4 sum total		

TABLE "B."

OIL ENGINE.

Fuel—Oil.	Labour.	Fuel.	Stand by Losses.
1,500 b.h.p. = 1,725 i.h.p. 1,500 × $\frac{1}{2}$ lb. = 750 lb. per hour	1 Donkeyman at £1 per week. Food 1*s.* per day = 7*s.* per week = £1 7*s.*	7 tons 16 cwt. per day at £2 per ton = say £15 15*s.* per day or £110 5*s.*	Nil.
	£110 5 0 1 7 0 £117 12 0		

Table "C."

Cargo Space Saving Compared. Oil *v.* Steam.

	Steam.	Oil.
4,000 ton vessel.	Nil.	40 per cent. on 4,000 tons = 1,600 tons, value say at £1 per ton per annum = £1,600.

Table "D."

Repairs to boilers as apart from engine repairs, scaling, new zincs, firebricks, per annum, £100.

Table "E."

Thermal Efficiencies Compared.

Steam, ordinary, as low as 6 per cent.; highest, including superheating, etc., etc., 15 per cent.
Hot air engine, from 7–10 per cent.
Oil engine, ordinary, 16–20 per cent.
Gas engine, 20–25 per cent.
Diesel System engines, 30–38 per cent.

The consumption of oil has in this, as in the case of these engines, been purposely estimated on the excessive side. But even on these figures it will be obvious that no ordinary tramp steamer with quadruple or triple engines has the slightest hope of putting up a fight on the score of running costs, and whilst by the adoption of steam turbines space might be reduced, no great reductions in running costs are to be obtained. It may, at this stage, be asked why the gas engine has not developed to the extent that the author and others anticipated it would. That the oil engine is more advanced for marine work is beyond question, but to state that the oil engine had developed as being the cheapest form of power would not be entirely in accordance with facts. No oil engine has the remotest chance of competing with a gas engine on bituminous producer gas. A good oil engine, however, can surpass a gas engine operating on anthracite or smaller powers. At this stage the following table may be of interest :—

1000 h.p. Bituminous Gas Plant, 24 hours per day, supplying gas for 1000 h.p. Gas Engine. Fuel consumption 10 tons 16 cwt. per day at 10*s.* per ton = £5 5*s.*

Oil Engines. 1000 h.p. ½ lb. per b.h.p. per hour = 500 lbs = 4 cwt. = 5 tons per day at £2 per ton = £10 per day.

Were anthracite or coke to be available in all parts of the world at reasonable prices some stubborn resistance would be offered by the cheaper gas power. It is astonishing that in England neither Messrs. Crossley Bros. nor the National Gas Engine Co. nor other large Gas Engine builders have made any definite attempt or are in a position to offer marine engines, oil or gas, of such power as are required for an ordinary going tramp vessel. The grand British total is largely summed up by Beardmore's experimental "Rattler," the Holzafel producer gas boat and a number of smaller installations.

The advent of the marine oil engine has been largely assisted on the Continent by an absence of coal such as Britain possesses, hence in England for stationary work with our abundance of cheap fuel and for powers of not less than 500 horse the oil engine can only compete under certain local conditions or for certain work or against an anthracite plant. For marine work, however, it is certain that the shipowner for some time to come will give his support to the oil engine, although the power costs are higher then would be the case of a gas engine and bituminous plant installed in a boat. But the increased cargo space which the oil engine permits would altogether predominate, as will be seen from the table "C," and would not appeal so strongly as in the case of land installations, and, in this case, would outweigh all other considerations. The question of the gas engine for marine may, however, be shelved for the time being but it is bound to again come to the front after the Oil engine has paved the way. In considering an installation of marine oil engines whilst the variety of plants is some disadvantage there is reason to believe that a 3,000 h.p. installation might be a compromise as say :—1,000 horse of steam for operating centre turbine, and $2 \times 1{,}000$ horse of oil engines port and starboard.

Excellent results have been obtained in land practice with oil and steam engines installed in power stations; moreover, there are waste heat exhaust products from the oil engines that might well be utilized for steam raising or superheating. There is every reason to believe that with a Wilson exhaust boiler the oil engine exhausts would provide steam equal to 15 per cent. of their output. Hence, 15 per cent. of 2,000 Horse$=$300 h.p.

With a steam-oil combination, however, there would be a loss of 25 per cent. cargo space compared with an oil installation alone, but the boiler space required would not be excessive and an extra advantage would be the use of the centre turbine for docking, very slow and reversing work. Auxiliary steam would not be available, of course, when the oil engines on the port and starboard positions were not running, but this would be supplied by an oil-fired main boiler. Under sea conditions the two oil engine sets would be running and also the turbine, a large proportion of steam being maintained by the oil-fired boiler assisted by the auxiliary boilers using exhaust gases from the oil engines.

Except under bad weather conditions the oil-fired boiler could be occasionally blown down even on a voyage, thus the steam unit could be maintained at highest efficiency, and even with the main steam boiler shut down it is probable that the turbine would be kept slowly going by the exhaust boiler steam only. Such a combination, however, is by no means essential to the installation of oil engines in a vessel, but it is obvious that the economical engineer would not view altogether with equanimity the deliberate waste of exhaust gas capable of giving him even 100 horse per hour. Moreover, provision must be made if these gases are not utilized for steam raising purposes to water-cool the exhaust pipes themselves, as uncooled pipes in an engine room from even 1,000 horse oil engine would be quite sufficient to make matters extremely uncomfortable for the engineers on watch.

Whilst every credit must be accorded to Dr. Diesel for the evolution of the Diesel engine and its principle, it must be borne in mind that although the inventor originally designed his motor for the combustion of coaldust, later search proved it to be impracticable and so far the Diesel system can only be utilized for liquid fuel, coal gas or producer gas being with all other forms of gas inapplicable. Slow combustion is attained in the Diesel engine apparently owing to the fact that with its system in addition to other things greater dilution of the combustible mixture with air is possible; consequently explosion is replaced by expansion or slow burning. As far as can be ascertained no form of igniter will ignite a charge of coal gas diluted by air to more than 1–14 to 1–15 parts, these latter figures being of course only experimental results. Producer gas, by means of its composition and low calorific value is certainly very sluggish in ignition and certainly could not have air dilution much beyond 1–4 to 1–5 parts (vide Dugald Clerk and William Robinson). Were it possible in gas engine practice to obtain ignition of considerably weaker mixtures doubtless much lighter explosions would be obtainable. But even then the slow combustion which is a characteristic feature in the Diesel engine would not be attained. At the same time it must not be forgotten that the latest type gas engine using producer gas and of the throttle governor type gives a much less violent explosion than the older types of gas engines, the explosions being graduated by the governor, which increases or decreases the volume of the mixture.

For many years oil engine builders endeavoured when using residuum fuel to vaporize it after the manner of ordinary petroleum engines; in fact this is still done in several engines. Their endeavours were successful as far as making vapour alone was concerned, but unfortunately, owing to variety in the temperature of the vaporizer, there were constant fluctuations between vaporization and cracking, and in the cracking process with the heavier distillates large quantities of deposit were left in the vaporizer cylinder ports, sufficient in the course of several days' running to interfere with satisfactory operation. It has now become recognized that for clean combustion, reduction of deposits, etc., vaporization of heavy fuel is better left alone, i.e. no attempt made to convert the fuel into vapour, but it is sprayed direct into the combustion chamber, the heavier globules of the fuel being broken up and subjected to combustion before they can fall out and leave deposits. Thus in a measure the spray so prominent a feature of the departed Priestman again makes its appearance although the modern application is of course different. Regarding vaporization it may be advisable to quote Professor Robinson's *Gas and Petroleum Engines regarding Cracking of Fuel Oil*:—

"When heated above their normal boiling points, the heavier hydrocarbons of the paraffin series are cracked or chemically split up, partly into lighter hydrocarbons of lower boiling points whilst marsh gas and hydrogen are set free and a slight carbon deposit formed with tarry deposits, etc. . . . heavy hydrocarbons are thus split up at temperatures above 400° F. In the oil engine a carbonaceous deposit may be produced by cracking the less volatile residue by the rapid fluctuation of temperature. Compression of the oil vapour checks evaporation and causes partial condensation, then the high temperature of inflammation instead of giving complete combustion, may result in the cracking of some oils and in the formation of residue which accumulates and in time forms the hard carbon deposits found in the combustion chambers of some engines. . . . On still further raising the temperature to a bright cherry red drops of oil are gasified or may only be partly converted into real oil gas and tarry products which are usually washed or scrubbed out in the process of oil-gas making (Mansfield Keith's, etc., systems) but cause trouble and stop the oil engine. It is necessary therefore to regulate the temperature of the vaporizer below this gas-making stage to prevent the formation of tar and deposit of carbon."

To Messrs. Priestman is due the first general employment of the water spray, i.e. addition of water vapour to the explosive mixture and which has again in recent years become prominent in certain quarters, almost being acclaimed as a great discovery. Hence, what oil engine builders are in many cases using on their latest oil engines, Priestmans adopted twenty years ago. Even Messrs. Priestmans would not, however, claim originality for it, water being first injected to a gas engine cylinder by Brown in 1823, although for a different purpose. On the merits or demerits of water spray it is not proposed to dwell, but where water spray is to be used it is certainly an advantage if the spray will be suitable for use in salt or sea water as, obviously, salt deposits on the piston or valves would tend to pre-ignition and other troubles which must be avoided in large oil engines. While certain ship builders and ship engine builders will naturally desire to build their own oil engines forthwith it is to be hoped that for a year or two they will decide to purchase standard models and gain experience before attempting to build an oil engine themselves. It is surprising how many entrants to the field of gas and oil engine building who, having wonderfully novel ideas and also strangely wonderful engines, have, after lengthy experiments and much expense, arrived at the end of their voyage of discovery, finding that they had reached that point of experience where the established builders left off fifteen or twenty years ago. Moreover, the profits on building oil engines will be found to be considerably below those obtainable on steam engines, and it would appear extremely desirable from this point alone to avoid journeys into the desert of exploration. The author has not in this paper traversed the elementary stages of oil engine operation as, in principle they are largely similar to those gas engines and oil engines which have been so frequently discussed at the meetings of this Institute, but has desired to make prominent the most vital innovations of the systems described so that at this juncture the cardinal points of the various systems may be reviewed by marine engineers.

Many questions have been raised as to the lubrication costs of the most approved engine but, under ordinary circumstances and provided a suitable lubricant is used, there will not be found great difference under this heading between oil engines and the marine steam engine, including auxiliaries in both cases. With reference to the auxiliaries this is generally a 20–30 or 50 h.p. small engine ; in the high powered units there are usually two auxiliary marine engines. These are employed to charge the various air reservoirs used for starting or reversing, and also (when compressed air is used) for operating the deck winches, otherwise the main engines have their own reservoirs which they charge themselves, for all the normal requirements of fuel injection and starting. The critic may here remark that, under certain conditions, if the auxiliary engine failed there might be difficulty in getting the main engines away or reversed. Admitted there might be such difficulty, but methinks the critic might be asked if, under certain conditions, his reversing engine employed on the present marine engine failed would not that also be awkward. The critic might reply that such a thing would be extremely remote; the author's reply *re* the auxiliary engine is ditto. An auxiliary engine is indispensable ; to rely entirely on the main engines keeping up air supply for all purposes cannot seriously be considered for marine work, and without these would be almost the equivalent of a steamer without the ballast or little donkey.

Much trouble was encountered in the early stages of marine oil engine building when many engines were reluctant to start on first admission of the compressed air and also through various faults in design. Moreover certain builds of the stationary type of engine were extremely troublesome to get away, when in the locality of humid or cold atmospheric conditions, but these occurrences are not a feature of the later production if properly handled. For instance, it would not be reasonable to expect that an engine will start with the main fuel valve choked up or with leaking valves. Now, as to the question of wear and tear this may probably be slightly higher than with steam, but as it is impossible to have steam engines without boilers, and as the latter put up the repair bill considerably, the oil engine is in the long run considerably under steam in repair costs. Accidents caused by burst air reservoirs are extremely rare, and it must be recognized that whether your motive power be steam, gas or oil, accidents in some form or other will occur and under all ordinary conditions there is far less risk of explosion than with steam engines and boilers. Generally the author's opinion is that the greatest success will attend the installation of oil engines in boats providing that ambitious schemes are not launched without mature experience, and at the onset moderate powers be used—say 1,000 to 1,500 h.p.—so that the units can be gradually increased in size as experience is gained by the marine engineer in running and sea going conditions. There are also many advantages to be gained by a trial of two small units instead of one large one, quite irrespective of the convenience in inspection, ease of replacing parts, overhauls, etc., than if in one unit. If desired, however, one large unit may be installed with good results, and where the expense of two propellers cannot be considered. In the building of gas and of oil engines, many engines have been evolved which, after trial in the test shops, have been relegated to the scrap heap, an expensive process but the only way if it is desired to send out a survival of the fittest, and new entrants into the field of marine oil engine building cannot expect to escape the same process in the initial stages. The Nurnberg and Sulzer engines are extremely well built, and it may be mentioned that the M.A.N. original engine is still at work and in excellent condition. The repair and upkeep of Diesel engines built by reputed makers have been much discussed, but there can be no doubt that they are superior in this respect to all other types of gas or oil engines. The point not to be overlooked in this connexion is that the wear upon the piston and cylinder, which occurs in gas or oil engines of the usual type, due to high temperatures, shock, unequal expansion, etc., is largely absent in the Diesel in which pressures are more or less constant.

The question of reversibility in the latest type of oil engines has been much discussed, and it will be easily understood that, as they are principally of the 2-cycle type, on the engine being brought to a standstill, or on slowing down, compressed air being admitted at the proper moment, duly determined by proper admission valves, the method of operation, engine piston working proceeds all the same irrespective of the direction of rotation, i.e. ahead or astern. The 2-cycle engine obviously has the advantage over the Otto or 4-cycle engine in the elimination of valves, and the value of this becomes particularly apparent in marine work. There is, however, no reason why the 2-

cycle principle should not be applied to a gas engine using producer gas, and the much discussed question of reversibility settled in this direction. The author, however, may say that while producer gas may be used on a 2-cycle engine he has every reason to believe that a new phase of difficulty will arise in connexion with such engines as it is not necessary to discuss in this paper Largely, however there is no novelty in the 2-cycle engine, but merely the exigencies of development in this direction have brought the more advanced method of using the cycle to a head. The practical pioneer of the 2-cycle engine was, without doubt, Day, the inventor of the engine which bears his name. Dugald Clerk says: "The Day engine has the peculiarity that it can run in either direction. This is possible because of the absence of timing valves or valve gear operated from the crank shaft."

In conclusion the author hopes that criticisms will be focussed on the main features of the engines dealt with so that the solid objection from marine engineers to the oil engine may be brought out; and objections there will be, but come as they may the survival of the fittest cannot be obscured. Assuming that the marine engineer has studied his engines and is prepared to devote that same skill and diligence which he devoted to the marine steam engine the troubles of operating marine oil engines will speedily adjust themselves. The human element is a factor in all engineering matters and it is apparent that if our engineers are not developed pro rata to the engines there must be an end of progress. While it cannot be expected that the veterans of steam propulsion will welcome the arrival of any form of internal combustion engine it is certain that the younger generation of marine engineers are ready to fall into line in the matter. An advantage also not to be overlooked is the rapidity with which a vessel can get under way. Except under special circumstances steam would not be raised in an ordinary boat from cold in less than 6 to 8 hours, whereas the oil engines can be easily started in less than half an hour. Another feature also with steam which has not been touched upon is that at dead slow to half speeds the fuel consumption goes up considerably and it is quite feasible to understand that during such an operation as docking the efficiency may be reduced from 25 to 40 per cent. While efficiencies and low fuel consumption can be maintained it would prove exceedingly interesting to have some authentic data on jobs not exceeding 1,500 h.p.

which would show that the fuel consumption was considerably under 1½ lbs. per i.h.p. ,the same to be spread over a period of say two years, trial trips not counted. In the matter of coaling also, where extreme rapidity is desired, it is more than human to expect that a marine engineer, in addition to his numerous other duties, can check every ounce of coal that is placed aboard, and owing to various conditions there is occasionally consider able leakage. In one case the author has in mind where the fuel has to be sent a considerable distance before reaching its ultimate destination, the loss is between 5 and 7 per cent. from this cause. Oil fuel on the other hand can be accurately measured.

In this paper it is not proposed to discuss the auxiliaries, etc., where another huge saving is to be accomplished. There is every reason to believe that cases of broken propeller shafts and damaged propellers will be greatly minimized with the installation of oil engines, as the latest type oil engines are fitted with a rapid acting governor so that racing is not allowed to any extent or is absent altogether. While the latest type of oil engine is fairly elastic it would not be claimed that it has the advantages of steam at extremely low speeds, but it could be hardly considered a very serious objection. As a comparative example of the class of steam engines an illustration of the latest Sulzer uniflow steam engine will be found and although these engines are capable of giving 1 i.h.p. on 10 to 11 lb. of steam per hour they have been found to be totally unable to compete with the oil engines of the same make. While the oil engine does not lay claim to have the great elasticity of the steam engine the author would remind critics that neither does the oil engine have the " elasticity " of fuel consumption on varying loads, in anything like the same proportion that is encountered with steam engines under similar circumstances. The consistency of the oil engine in fuel consumption is one of its marked features, and it is wellnigh impossible for any marine job to work to a fuel consumption having such small variations. Almost throughout the world liquid fuel oil is becoming now available, and such being the case the equivalent ½ lb. of the same gives the 1 b.h.p. When the oil engine is settled down to marine work the author is confident that differences of fifty, one hundred and two hundred tons variety in consumption on round trips will be a thing of the past, bad weather conditions reckoned upon. The following vessels are now under construction for oil engines :—

Bloom & Voss, Hamburg, 3 vessels having engines varying in power from 1,000 to 2,000 h.p. Engines by M.A.N.

6,000 ton vessel having 2 × 850 h.p. engines for the Hamburg South American Line.

6,000 ton vessel having Diesel engines by Carel Frères, Ghent.

2,000 h.p. set for a ship by Messrs. Barclay, Curle & Co., Whiteinch.

1,100 h.p. set of oil engines building by Messrs. Doxford & Sons, Sunderland.

The O.S. *Toiler* completing by Messrs. Swan, Hunter & Co., Newcastle.

2 × 400 h.p. engines (M.A.N.) now installing in 3,000 tons sailing vessel.

1 Dutch tug boat.

1 Russian tank steamer, 2 engines.

1 passenger tug, 200 h.p.

4 Small boats each having 2 × 250 H.P. Schneider Carels engines.

The following motors have also been supplied by Messrs. Sulzer.

4 × 100 h.p. 2 × 150 h.p. 1 × 400 H.P. 2 Motors each 400 h.p. (Italian Mail steamer *Romagna*) 4 × 300 h.p. 2 × 800 h.p. 2 × 1,000 h.p.

BLACKSTONE.—Messrs. Blackstone may now claim consideration, as their marine type engine has undoubtedly many salient features, and although they are not at the moment prepared to offer engines larger than 300 b.h.p. their motor is of the true residuum-burning type and as such is in the forefront among British oil engine builders for marine work. Based on a long experience in oil engine design and on many years' knowledge of stationary engine construction it is very probable that had the demand for the ordinary type Blackstone been less the marine type engine would have probably loomed up in greater evidence at the present moment. The designers, Messrs. Carter Brothers, are giving and have given many years' consideration to the marine oil engine and its possibilities. The Blackstone system may be called a compromise between the Diesel system and others, and whilst the fuel consumption is not so low as the Diesel or its efficiency so high it has the advantage of being a much cheaper engine in initial cost. Messrs. Blackstone have a number of these engines at work, and although in the early stages a number of difficulties were encountered they now produce an exceedingly economical marine motor, and there can be no doubt that, in the near future, more will be heard of this engine. The compression of the charge is comparatively low, viz. 150 lb. per sq. inch. The fuel is injected into the cylinder at or near the end of the compression stroke by air compressed to a pressure of about 400 lb. per sq. inch. A very high compression is necessary to raise air to a sufficiently high temperature to ignite crude oils, therefore, with a compression of only 150 lbs some additional means had to be provided to ignite the charge. Automatic ignition in which the charge is ignited by a substance kept incandescent by the combustion of the charges was tried, but the difficulty with this form of ignition was how to render the engine capable of running equally well either light or loaded. When running light the igniter would gradually lose its heat until it failed to fire, and when running fully loaded it would rapidly get too hot and cause the igniter to rapidly burn away. This difficulty has now been overcome by the employment of a dual spraying device consisting of a main jet adapted to deliver its charge into the combustion chamber, and an auxiliary one delivering a smaller charge into the bulb-shaped ignition lamp heated for starting, incandescence being afterwards maintained by combustion of the fuel. The ignition chamber communicates with the combustion chamber by means of a port, the flame from the ignition chamber impinging upon and igniting the main fuel spray. At each cycle the ignition bulb receives a supply of oil; the main spray, however, is controlled by the governor according to the speed of the engine. With a view of prolonging the initial pressure in the cylinder for a considerable portion of the stroke, it was found in the early experimental stages that this object could not be attained by injecting the whole of the fuel charge at the end of the compression stroke. To effect this purpose an oil reservoir is provided in conjunction with the main spraying valve into which the surplus oil from the igniter flows, and this chamber is so formed that it is not immediately emptied when the spraying valve is opened, a further supply of fuel being forced into the combustion chamber as the working stroke proceeds. In the marine engine reversibility is attained by means of sliding cams on the lay shaft which alternately operates the admission and exhaust valves, compressed air being the medium for the initial movement ahead or astern and as a matter of fact when reversing the fuel valves being closed, compressed air may be used to slow down the engine, i.e. admitted in opposition to the direction of rotation where an extremely rapid reversal is desired and under normal conditions without harmful effects.

BOLINDERS.—Messrs. Bolinders, the well-known engineers of Stockholm, have devoted considerable attention to the production of a reliable marine oil engine on the two-cycle principle. Although the makers specify their engine as suitable for crude oil this is apparently intended to refer to the intermediate oil, gas oils or heavy paraffins, as it appears to the author that the general design of the Bolinders vaporizer is not such as would lend itself to efficient vaporization of heavy residuums. Nevertheless the Bolinders has many recommendations, not the least of which is the direct reversing. The Bolinders operates on the following principle :—

The Bolinders Crude Oil Engine is of the modern two-cycle type, delivering a power impulse for each revolution of the flywheel. It has no valves, cams, gears or electric sparking device and the construction is such that all the parts work automatically and cannot be thrown out of adjustment. On the up stroke of the piston (A) a partial vacuum is created in the enclosed crank case (C) causing the necessary charge of air to rush in at the two opposite inlets (B). Near the end of the stroke, an oil-pump automatically injects the proper amount of oil through the nozzle (F) into the igniter ball (E). This latter has been previously heated to a dull red heat by a blow lamp, so that the hot walls of the same immediately convert the oil into vapour. The mixture of air and oil gas is then automatically fired, driving the piston downward during which the charge of air previously drawn into the crank case is compressed, and when the piston approaches the end of the down stroke, it uncovers the exhaust port (G), permitting the burnt charge to escape through the silencer, until its pressure reaches that of the atmosphere. Directly afterwards the transfer port (H) on the opposite side of the cylinder is uncovered by the piston, thereby allowing the charge of air compressed in the crank chamber to rush into the cylinder, where it is deflected upwards by the shape of the top of the piston and caused to fill the cylinder, thereby expelling the remainder of the burnt charge. Due to the two ports of the igniter ball (E)—this ball is being thoroughly cleaned of all deposit, by means of the fresh air permitted to rush through it, thus ensuring powerful ignitions.

The operations above described take place in the cylinder (D) and crank case (C) with every revolution.

Method of Reversing.—As ahead or astern is desired the propeller shaft is declutched. On throwing over the reversing lever the engine at once slows down and receives automatically from a separate pump a charge of oil followed by an explosion which gives a pre-ignition, i.e. the explosion occurs in opposition to the direction in which the piston is travelling. Almost immediately on this occurring the engine commences to revolve in the opposite direction and neither is it necessary to use compressed air in the operations. Recently one of the Bolinders boats completed a voyage from this country to South America and the following particulars may be of interest:—

Extract from Captain's Log, January 18, 1911. "We have arrived at Trinidad, but it has taken a long time depending upon the bad weather existing during the whole voyage. We left Havana on December 22, 7 o'clock morning, and arrived in the Port of Spain on the 14th instant, 5 o'clock afternoon. Thus the voyage had taken 23½ days. The distance was about 2,100 miles. This seems to be a long time for making 2,100 miles, but we had to work with high sea against us. Sometimes the sea was so rough that we could not move forward in many hours. Outside Haiti we had to ride out a gale, the sea grew to dimensions which had not been experienced in many a year. In two days we did not come more than forty miles forward. At last we were obliged to take the sea on the bow and tried to get abroad to South America. After a run of four days we had come where the sea was getting quieter, but now instead we got the stream against us, which sometimes had a speed of 1½ miles per hour. The engine worked excellently the whole time until the 22nd day when same began to slacken. The reason was that dirt had been concentrated in one of the suction pipes from the oil tank which caused the engine not to receive sufficient oil. The stream was here so strong that we could not stop and tried to come under the coast and berthed, whereafter the pipe was cleaned. After three hours the voyage was continued and we were then not more than 200 miles from Trinidad and twelve hours later we arrived in the Port of Spain. Consequently we had reached the destination port with both engine and boat in a very good condition, which must be called very successful after such bad weather, which had happened us.

"The Captain was very satisfied with the engine and was astonished at the even running of the engine, also in the largest breaking in waves contrary to a steam engine, which is considerably pitching when the screw comes above the water line. The boat will run between Port of Spain and the South American continent with loads of asphalt."

THE "GRIFFIN" PATENT LIQUID FUEL ENGINE.—Messrs. The Griffin Engine Co., have had many years' experience in the construction of oil engines for marine work and were among the early pioneers.

A distinctive feature of the Griffin engine is the system of vaporizing the fuel by such a vaporizer as shall utilize the best portion of the fuel whilst rejecting the tarry products, i.e. asphaltum or heavy asphaltum base which fall to the bottom of the vaporizer and may be easily removed. It is of course obvious that under such a system the economy of the engine will be somewhat reduced. However, as the consumption varies from $\frac{5}{8}$ to $\frac{3}{4}$ of a pint the b.h.p. at full load, this is not a very serious item. The Griffin engine will operate on the following oils: Motor Spirit, any brand of Kerosene, Benzine, Mineral, Naphtha, Alcohol, Liquid Fuel, Turpentine refuse, Tar Oil or Creosote, Crude Oil, Scotch Fuel Oil, Shale Oil, Texas Liquid Fuel Oil.

Messrs Palmers, Jarrow, are the licensees for engines built on the Griffin system and for marine purposes of over 100 h.p. The "Griffin" oil engine may always be recognized and differentiated from every other oil engine by the long bulky vaporizer, which is attached directly to the cylinders. This vaporizer is constructed with an outer jacket, which surrounds a second or inner annular chamber, which, in its turn, again encircles a central vaporizing chamber into which the oil is sprayed in a finely divided or pulverized state, and afterwards vaporized, the heat necessary for such vaporization being obtained from the hot exhaust gases, which pass directly from the cylinder into the annular chamber, and are afterwards discharged into the atmosphere. The heat of these exhaust gases, as they leave the cylinders (even at full load) never exceeds about 550°, this temperature, after expansion into the annular chamber, falling to about 450°, which temperature under no possible working conditions can be exceeded. It will thus be apparent that the heat of the central vaporizing chamber can never be sufficiently great to crack or decompose the pulverized oil which is sprayed into its interior to form the working charge. In other words, this pulverized oil is vaporized only and never gasified, i.e. the change is physical and not chemical, and thus the entire vaporized charge is recondensible into its original liquid state. The treatment to which the oil is subjected in the vaporizer is really that of "fractional distillation," the temperature of which is automatically regulated so that the lighter heating constituents of the oil only are vaporized, and thus separated from the tarry or asphaltum base and other impurities, which are precipitated in the vaporizer, the tar being automatically and continuously discharged during the working of the engine, while the incombustible ash, which adheres to the surface of the vaporizing chamber (while hot) in a semi-plastic state is easily removed by a wire brush (on the stoppage of the engine) in the form of fine friable powder. The operating conditions of the vaporizer are therefore such that even when employing crude oil a semi-refined distillate vapour, free from all tarry impurities, having a correspondingly high thermal efficiency, is utilized in the cylinders. One distinctive feature of the "Griffin" vaporizer is that it is open to the atmosphere, and operates under atmospheric pressure only. Its maximum working temperature (450°) is extremely low, while being subject to no internal pressure, absolute safety and entire freedom from the rapid deterioration (common to a highly heated closed retort) is secured. The introduction of their Patent Automatic Auxiliary Air Valve has greatly increased the thermal efficiency of the engine. It is fitted on a port in direct communication with the throttle valve, and admits the bulk of the air necessary for combustion without its passage through the vaporizing chamber. The density of the charge admitted to the cylinders is thus materially increased with a corresponding increase in thermal efficiency.

General Design and Arrangement of Mechanical Details. The "Griffin" Oil or Liquid Fuel Engine as now constructed is protected by four main patents besides others which are subsidiary. These patents cover : (1) A unique system of forming and governing the working charge in combination with exhaust heated vaporizer. (2) New Auxiliary Air Valve. (3) New Cata Thermic system of ignition. (4) Starting Gear. Starting is effected on engines of from 100 to 300 h.p. by means of the auxiliary starting engine.

MASCHINENFABRIK AUGSBURG-NURNBERG A. G. NURNBERG OIL ENGINES.—The M.A.N. are the oldest makers of the Diesel engine, having constructed the first engine in 1894, since which date they have turned out from their works some thousands of these engines. A feature of the Nurnberg engine as supplied for marine purposes is that fly wheels have been practically eliminated, and the author thinks that this will be appreciated by marine engineers, who have always had a great objection to such an adjunct on shipboard, naturally for various reasons. The Nurnberg oil engines are the sole product of the Maschinenfabrik Augsburg-Nurnberg A.G., Caxton House, Westminster, S.W., and the principal British licensees for these engines are Messrs. Babcock & Willcox, Oriel House, Farringdon Street, E.C. At the Nurnberg Works are built light-weight and heavy-weight single acting two-stroke engines in sizes from 110 to 2,000 b.h.p., working on the well-known "Diesel" principle (combustion under constant pressure). These engines are a distinct improvement upon the engines at present used for marine purposes. While the light-weight engines are suitable for propelling ships, boats, gun and torpedo boats, but especially submarines, the heavy-weight engines may be installed with advantage in cargo and passenger boats, as well as in tugs, either for sea or river navigation. The following are the chief advantages of the Nurnberg oil engines for marine purposes :—

They can be direct coupled to the propeller shafts, as they are directly reversible without the help of any intermediate gear or reversing clutch. The reversal is obtained by means of compressed air, which is used for the reversing of the valve gear and for the restarting of the engines. With the boat proceeding at full speed ahead, only a few seconds are required for reversing to full speed astern. The number of revolutions of the engine can be reduced to one-third, alterations of the boat's speed are, therefore, possible within wide limits.

As a general rule, the engines for the driving of propeller shafts are built either with six or eight cylinders. By this multi-cylinder arrangement, the turning moment of the engine is so uniform that the provision of a flywheel is rendered unnecessary. In case the output required is not more than 150 b.h.p., or if the floor space available is small, then the engines are built with four cylinders. These four-cylinder engines are likewise directly reversible. Starting and reversing the engine are done by working a single lever, which is also used to change the speed and output within wide limits. It is therefore impossible for the attendants to make any mistake. By providing all bearings and other parts subjected to pressure and friction with forced lubrication and by effective cooling, great reliability of the working of the engines is obtained and an uninterrupted run of same for a long time is ensured. When designing the engines, special consideration was given to facilitating the easy erection and dismantling of all parts. A space of about 6 to 16 in. (150–400 m.m.) (according to size of engine) above the highest point of the engine, is sufficient for complete dismantling and re-assembling in the boat itself. All working parts can be easily inspected and are very accessible, so that in case of a breakdown, they can be replaced in the shortest possible time.

Light-Weight Engines.—These engines are especially designed for Navy purposes, where engines of great lightness combined with absolute reliability are essential. By using only the most suitable material for these engines, this firm, succeeded in reducing the weight per b.h.p. of the larger engines to 35 lb. (16 kg.), and that of the smaller engines to about 40 lb. (18 kg.). This weight includes all auxiliary machinery and apparatus such as water and oil pumps, fuel pumps, air pumps, coolers and filters for air, oil and water, and the entire reversing apparatus with compressed-air receivers. As all working parts and bearing surfaces are of ample dimensions, and as forced lubrication is used throughout and the cooling is very efficient, satisfactory continuous running of the engine is ensured. They build six-cylinder engines of the following outputs :—

150 b.h.p.	at about	600	r.p.m.
200 ,,	,,	550	,,
300, 400 and 500 b.h.p.	,,	500	,,
600 b.h.p.	,,	450	,,
900 ,,	,,	420	,,
1,200 ,,	,,	400	,,
1,500 ,,	,,	330	,,
2,000 ,,	,,	300	,,

The above types may also be built in eight-cylinder arrangement if the available space requires this. If, for instance, a six-cylinder engine of 900 b.h.p. cannot be installed owing to the available room not being high enough, then an eight-cylinder engine of the 600 b.h.p. type can be provided. These engines may also be built with 4 cylinders and will still be reversible ; then, however, a small flywheel is necessary.

Heavy-Weight Engines.—These engines have a weight of about 88 lb. (40 kg.) per b.h.p., their chief advantages over the light-weight engines being lower fuel consumption, lower price, and lower speed. They are also very strongly built and are especially suitable for continuous working.

They build six-cylinder oil engines of this heavy-weight type of the following outputs :—

150–175 b.h.p.	at about	350–400	r.p.m.
300–330 ,,	,,	300–330	,,
600–650 ,,	,,	300	,,
1,000 ,,	,,	250	,,
1,200 ,,	,,	230	,,
1,500 ,,	,,	200	,,
2,000 ,,	,,	185	,,

For smaller engines, the fuel consumption per b.h.p. amounts to about 0·496 lb. (225 grammes) and for the larger to about 0·44 lb. (200 grammes). The weight of 88 lb. (40 kg.) per b.h.p. as stated above for the heavy-weight oil engines includes all auxiliary machinery and aparatus, such as water and oil pumps, fuel pumps, air pumps, coolers and filters, as well as the compressed air-starting and injecting apparatus. The thrust block of the propeller shaft is also included in this weight. A new type of double acting marine engine is now in course of construction and it is expected that this model will prove itself entirely suitable for very large power outputs and such as are required by battleships and merchant vessels. Up till January 15, 1911, they had delivered or on order for marine purposes two-cycle Nurnberg oil engines as follows :—

1. Single acting, heavy weight type	4,180	b.h.p.
2. Single acting, light weight type	13,400	,,
3. Double acting	11,000	,,
	28,580	

Mirrilees, Bickerton & Day.—The author recently had an opportunity of inspecting the works of this firm, and when it is remembered that they originally made a Diesel engine as far back as 1897 and were one of the first licensees under Diesel it will be apparent that in the building of these engines much experience has been acquired by them. Messrs. Mirrilees, Bickerton & Day prefer to conserve their efforts to the production of a standardized model and so far, with one exception, they have not devoted their energies to the production of a marine model. This by no means implies that they will not build a marine type engine, in fact they are prepared to consider such propositions where their standard models can be utilized for the work. It will be easily understood, however, that as the new Mirrilees Diesel Company only commenced operations at the end of 1907 they have hardly had time to devote more than a limited amount of study to marine work as, owing to the number of engines on order for stationary work, almost the whole of their efforts have been turned in the direction of production of these models. As far, however, as marine work is concerned, Messrs The Mirrilees Company had the distinction of supplying among others the famous H.M.S. *Dreadnought* and twelve other of the largest battleships. They have also constructed for the Admiralty a 120 b.h.p. engine for the propulsion of an Admiralty pinnace. This engine, however, was not of the reversing type and obtained the reverse movement by means of a clutch and reversing gear. The Mirrilees system of electrical propulsion is exceedingly interesting. On the crankshaft of the engine is fixed a dynamo of about one-fifth of the power of the engine. On the propeller shaft a reversing motor of similar power is fixed, the two shafts being connected by a clutch. As variations of speed between half and full speed ahead are obtained direct from the engine the electrical apparatus has only to deal with low speeds and reversing. When running slower than half speed or running astern the positive clutch connecting the propeller shaft to the engine crank shaft is liberated. This scheme gives full efficiency when going at any speed ahead over half speed and gives full control for reversing and at slow speeds. The cycle of operations in the Mirrilees Diesel is identical with the stationary type Diesels hitherto described. The engines supplied for ship lighting work have been very satisfactory and have been of the high speed type completely enclosed and with forced lubrication. In general practice these engines have proved themselves most reliable and particularly useful, enabling the ships to completely shut down their boiler plant when in harbour and without interfering with the supply of electricity for light or power purposes. The fuel oil used in the engines in these cases is the same that is used for firing the boilers and the relative prices for coal and oil are such that they have proved a great saving. Messrs. The Mirrilees Company have perfected and improved many details in connexion with their engines from knowledge gained in the construction of them. Their production plant is fitted with the most modern machinery and it is anticipated in the near future that the output will be largely increased. Regarding the weight of the Mirrilees Diesel engine the following approximate figures may be of interest.

	B.H.P.	No. of Cylinders.	R.P.M.	Approx. Weight.
Slow speed Engines	100	2	250	17 tons
	200	4	250	25 ,,
	300	6	250	31 ,,
High speed Engines	100	4	300	7½ ,,
	200	4	400	15 ,,
	300	6	400	22 ,,

SULZER DIESEL.—The question of direct reversal in the Diesel engine was solved for the first time in a practical manner by Messrs. Sulzer Brothers in the year 1906 when they placed their direct reversible Sulzer Diesel marine engine on the market. In contradistinction to former internal combustion engines, in which, as already mentioned, reversal was obtained by means of intermediate mechanism, the Sulzer Diesel marine engine (Fig. 2) is directly reversible like a steam engine. The engine is rigidly connected to the screw shaft and runs in either direction. The engine is single acting, and works on the two-stroke principle, as follows:—On the upward stroke of the piston, as in the four-stroke cycle, the compression of the air in the cylinder is effected to such a degree that the heat produced is sufficient to ignite the fuel spontaneously on the introduction of the latter into the cylinder. During the downward stroke of the piston the fuel is admitted in the form of a spray and is gradually burnt as it enters the cylinder. On completion of the expansion large ports in the wall of the cylinder are uncovered by the piston, the scavenging air-valves in the cylinder cover are then opened and the expanded combustion gases expelled by means of the scavenging air-pump. The accompanying indicator diagram (Fig. 3) shows the method of working.

First Stroke. Compression and heating air (Curve 1-2) *Second Stroke* (Working stroke) Combustion (2-2^1) Expansion (2^1-3) Exhaust of combustion gases and introduction of pure air (3-1). The two-stroke engine differs from the four-stroke engine inasmuch as the latter requires two complete revolutions for one working stroke whereas in the two-stroke engine each revolution produces a working stroke. With cylinders of equal size, therefore, the two-stroke engine will give approximately double the power produced by a four-stroke engine, or, expressed differently, for any definite power required the two-stroke engine will be much the smaller. In addition to the saving in weight thus effected, there is also the economy in space which is of particular importance on board ship. In the latter case there is also the further consideration of space economized on account of the liquid fuel requiring less room for storage. The engine is usually made with four cylinders, which not only ensures a perfectly uniform turning moment but enables the engine to be started with certainty irrespective of the position of the crank. Besides the working cylinders the engine is supplied with an air-pump for the highly compressed air for starting, reversing and the injection of the fuel, and, further with a low pressure scavenging pump. Important accessories to the engine are the three steel vessels for the reception of the compressed air (for starting and injection purposes). The engine is of the enclosed type but the various parts, such as cranks, bearings, pistons, etc., are readily accessible by means of removable doors. The engine can be reversed in a few seconds. When starting, the hand-wheel, shown on the right of the engine in the illustration, is turned and admits compressed air into the cylinders. A further movement of the wheel puts the starting valve out of gear, at the same time opening the fuel valve, so that the engine starts working. In the reverse manner the engine is stopped and reversed. The starting valves and fuel-valves are operated by oscillating eccentric cams, the motion of which is determined by the motion of the reversing shaft according to the direction of the engine, whether running or at rest. All reversing operations are conducted from the hand-wheel referred to above, and may follow one another very rapidly, thanks to the simple and practical combination of the reversing mechanism.

General interest will be awakened by the results which have been obtained with a 150 horse power engine recently supplied to the Steamship Company in Zurich. The company in question having a steamer which was useless for regular service on account of its slow speed determined to have it fitted with a more powerful engine. The speed of this particular steamer was hardly $8\frac{3}{4}$ miles per hour, whereas the present time-table demanded a speed of $11\frac{1}{4}$ miles per hour at least.

The displacement remaining unaltered, this increase of about 30 per cent. in speed would have meant a $2\frac{1}{2}$ times increase in the output of the engine. The new plant was to fit into the space of the old one, and the weight was not to exceed the weight of the old plant; the working expenses also were to be cut down as much as possible. It was not difficult to foresee that the substitution of a new steam plant for the old one would not have answered the purpose with any degree of certainty—in fact, the only possible way of attaining it was by the introduction of a Diesel engine. Preliminary investigations of this plant soon offered abundant proof that the conditions laid down as regards both speed and economy would be fulfilled. The Diesel engine was fitted in the early part of 1909. The steamer has done regular daily service since the end of July, and the results of the trials have exceeded all expectations, inasmuch as a speed of over 12 miles per hour is obtainable while the cost of fuel has been reduced to one-fourth. It must, however, be taken into consideration that the engine which was replaced by a Diesel was made many years ago, although on the whole the comparison holds good for a new steam engine of modern construction. Compared with the old steam plant the output of the engine has been doubled. The amount of fuel carred is sufficient for the steamer to travel ten times the distance hitherto possible and this at an increased rate of speed, at the same time saving in weight of 35 per cent. has been obtained. The trial trips which were carried out by the Steamship Company took place on September 30, 1909. The trial course measured exactly 24 kilometres (14·9 miles). The fuel consumption was regulated by a decimal weighing apparatus and it may be mentioned that the measurement of fuel as compared with that of coal is almost mathematically exact. The fuel used was Galician petroleum, the present price of which in Zurich is about 48*s.* per ton. At a speed of $12\frac{1}{2}$ miles per hour the cost of fuel was $1\frac{1}{2}d.$ per mile, the cost of fuel per b.h.p. hour under similar conditions being 0·139*d.* The further working costs will also be considerably less than with the steam plant, as there is no boiler to maintain, and all expenses connected with cleaning, repairs and attention to same are therefore entirely obviated.

In addition to supplying the motive power, Diesel engines may also be used to advantage on board ship for lighting and pumping purposes. Such an engine is shown in Fig. 4 and is designated a high speed engine by Messrs. Sulzer Brothers. It works on the four-stroke cycle and in design is somewhat similar to the standard type of stationary engine. The engine, similar to the marine engine described above, is usually constructed with four cylinders, which ensures the perfect balance of the moving parts. In view of the high number of revolutions, the bearings and wearing parts are of exceptionally substantial design. The compactness which is a feature of all Diesel engines is specially notable in the height of this engine and is a decided advantage. For ship lighting or bilge pumping purposes, the Diesel engine can be coupled to a dynamo direct or centrifugal pump above the water line and this forms an independent unit, an advantage which it would be difficult to over-estimate in the engine room being flooded and the main plant put out of gear. A small auxiliary engine is provided for all sizes above 200 h.p. where the main engine is to be used for deep sea work, and for powers beyond 1,000 h.p. two auxiliaries are usually employed, so that under abnormal starting and reversing conditions an adequate supply of compressed air is available and Messrs. Sulzer consider their marine engine under these circumstances to be equal to 50 or more reversals per hour, without hitch.

The author regrets that he is unable to show the details of the latest valve mechanism for the reversing machine engine in print, but it must be borne in mind that engine builders must be somewhat reticent in certain matters of improvement. Messrs. Sulzer are prepared under guarantee to instal engines for marine work 1,000 to 2,000 h.p. in one unit that will give all reasonable results that a shipowner could desire. In the matter of reversing it may be mentioned that certain of the Sulzer engines on test in the Italian Navy were purposely swung over from full ahead to full astern with satisfactory results. Such a test speaks volumes in itself as to the capacity of these engines to meet emergency conditions, and a trial of such severity is very unfair to any engine. Messrs. Sulzers have now passed the experimental stage on a new model for large powers in which 500–700 horse per cylinder is attained.

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INSTITUTE OF MARINE ENGINEERS

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LECTURE ON "ELECTRIC DISTANCE THERMOMETERS"

BY MR. G. A. H. BINZ,

February 20, 1911.

CHAIRMAN: MR. A. COOKE (MEMBER).

VISIT TO THE GAS LIGHT AND COKE CO.'S WORKS AT BECKTON

Saturday, May 27, 1911.

RECEPTION AND CONCERT AT THE ROYAL BOTANIC SOCIETY'S GARDENS REGENT'S PARK, W.

On Friday, June 30, 1911.

VISIT TO THE BOW ELECTRIC GENERATING STATION

Saturday, July 15, 1911.

26TH ANNUAL CONGRESS OF THE ROYAL SANITARY INSTITUTE

Held at Belfast on July 24th to 29th, 1911.

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