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Types of Large Marine Oil Engines.

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READ

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CHAIRMAN: MR. W. E. McCONNELL (Member of Council).

The marine heavy oil engine is now recognised as a practical proposition for the propulsion of sea-going vessels. A study of the shipbuilding returns for recent months clearly indicates that many shipowners have no longer any doubt as to the reliability of the marine oil engines, and are eager to benefit, by the low consumption of fuel oil and the saving in space, which accrues from the application of this prime mover to the propulsion of ships.

For large powers to say 6,000 S.H.P. and upwards, the geared turbine will undoubtedly remain in favour for a long time in certain quarters.

For lower powers down to say 500 S.H.P. the problem for the shipowner will soon be that of deciding what particular type of heavy oil engine to install.

Certain types of oil engines have reached what we might term the "standardised" state, by reason of the gradual perfection of design brought about by the experience gained of the running of the engines over periods of time extending to almost ten years in some instances.

Other types which have been recently adopted, have still to stand the test of time, and may from the Marine Engineers' point of view, be said to be in the experimental state.

In this paper it will be found that the author deals with one of the latter types, namely, the Scott-Still engine, in more detail than with other types, and that he inclines to refer the knowledge he has acquired of other heavy oil engines to the Scott-Still engine for the following reasons. Firstly: the Scott-Still engine is the latest development in marine propulsion, and embodies certain novel features with which it is assumed the members of this Institution will be less familiar than with the details of the older types of Diesel engines. Secondly: the author has had the special privilege of having charge of the construction and operation during extensive shop trials of an experimental marine Scott-Still engine unit, developing 400 B.H.P. in one cylinder. The first of these trials took place in May, 1920. Since then an important series of tests have been carried out, extending up to the date of this paper, under varied running conditions, from which important data have been obtained.

It is fairly certain that the marine oil engine will gradually work towards a very limited number of forms, and have the same similarity of design as have all the present day reciprocating steam engines. As engineers, we are fortunate to have lived in the days of transition in marine oil engine design and application.

Assuming then, that the development of the marine oil engine will for a considerable time be left to designs of the reciprocating type, it might prove helpful to summarise the essential features of such types under the following headings:—

A. Operating cycles and fuel economy.
B. Cylinder charging and exhausting.
C. Combustion of the fuel.
D. Cooling.
E. Framing.
F. Valve gear and manœuvring gear.

OPERATING CYCLES.

The oil engine is one variation of the general type known as internal combustion engines. The internal combustion engine is the most direct method of converting the heat energy of the fuel into work. The fundamental function of the engine is to provide an envelope in which to carry out the combustion of the fuel in the presence of the requisite quantity of oxygen.

Again the energy liberated from the fuel must be available in such a manner as to perform useful work.

The convenient method of attaining these two features of the internal combustion engine is to provide a cylinder in which a piston moves, and by its attachment to the usual slipper, connecting rod and crank, to obtain the necessary rotary motion for the turning of the ship's screw.

It is found that using air as the medium in which the heat units of the fuel are liberated, certain limitations of efficiency arise.

Having obtained complete combustion of the fuel in air, an amount of work equivalent to the heat units of the fuel burned cannot be obtained for several reasons, viz.:—

(*a*) Incompleteness of the temperature reduction of the products of combustion.

(*b*) Cooling of the products by the heat radiated to, and conducted away by the envelope itself.

(*c*) Mechanical losses.

Fig. 1 shows the extent of these losses on a diagram of the usual pressure-volume kind. Such a diagram as enclosed by J.K.L.M is a practical impossibility if assumed to represent

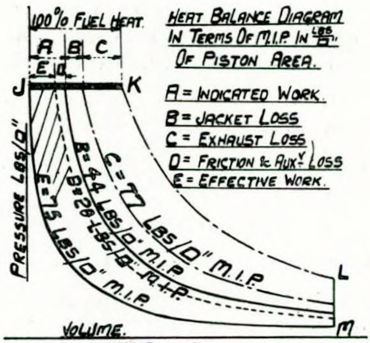


FIG. 1

100% combustion efficiency, but it is drawn to show the magnitude of the losses in terms of mean effective pressure in pounds per square inch of piston area.

It is found by experiment that the extent of the losses varies with the size and piston speed of the engine. The work obtained direct from the combustion products to the piston rod, does not vary so much as the division of the losses between cooling and exhaust.

The greatest gain in overall efficiency may be looked for in the recovery of some portion of the losses B and C, as against possible perfections of the process of combustion itself, which at the present state of knowledge, appear to have reached a somewhat flat portion of a combustion efficiency curve.

The operation of an internal combustion engine involves four distinct processes as follows:—

(*a*) Enclosure of a charge of fresh air.

(*b*) Complete combustion of the fuel in the air.

(*c*) Reduction of the temperature of the products of combustion by re-action with the moving piston.

(*d*) Discharge of the products of combustion.

It is here sufficient to state that the cycle of operations may be arranged to occupy two strokes or four strokes of piston movement, which will be referred to subsequently as two-cycle and four-cycle engines respectively.

It is found that the efficiency of the heat cycle is improved if the air charge is compressed to a fairly high pressure and temperature before combustion.

The compression pressure varies from 300 to 500 lbs. per square inch, depending on certain other circumstances, such as the degree of spontaneity of combustion desired.

The process of combustion and the charging and exhausting of the cylinder lend themselves to variation.

The process of combustion may be arranged to occur by any one of the following ways:—

(1) Combustion at constant pressure.

(2) Combustion at constant volume.

(3) Combustion at constant volume followed by a further combustion of oil at constant pressure. This method is now termed "mixed" or dual combustion.

The first method, combustion at constant pressure, is that on which all Diesel engines operate. Compression is carried up to about 500 lbs. per square inch. Oil is injected about the top dead centre and is controlled in such a manner as to give a combustion line which is practically at a uniform pressure of 500 lbs. per square inch. Cut off occurs at about 30 degs. to 40 degs. past top dead centre, and the gases expand in the cylinder until discharged at the bottom centre.

The theoretic efficiency of this cycle is about 54 to 55%, depending on the compression ratio and cut off ratio.

The following makers of engines have adopted this process:—Burmeister, Cammell Laird, Fiat, Sulzer, Werkspoor, N. B. Diesel. All these makers, as will be seen later, employ the same method of injecting the oil into the cylinder.

Constant volume combustion is not attempted as standard practice, although this method sometimes arises accidentally.

All the oil is injected at or near the top dead centre, so that the pressure rises suddenly in the cylinder. Expansion begins right from the top dead centre. For the usual compression pressure of say 500 lbs. per square inch, the maximum pressure will be considerably higher, depending on the amount of oil injected. The theoretical efficiency is in the vicinity of 59%.

The mixed combustion process has now a certain number of adherents.

In this process, a small part of the fuel charge is injected early enough to give a rise of pressure of from 100 to 200 lbs. per square inch above the compression pressure. A further part of the fuel charge is injected, such that constant pressure combustion results.

This is quite a stable process and has been adopted by such firms as Doxford, Vickers, and Scotts' in their marine oil engines.

The theoretical efficiency again depends on the compression ratio, cut off, etc., and works out about 54 to 56%.

Fig. 2 shows a typical full power card for an engine working on this process. The compression pressure is 300 lbs. per square inch and the maximum pressure 550 lbs. per square inch.

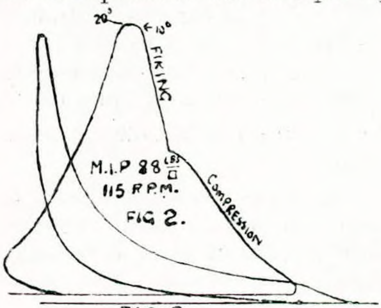


FIG. 2

The sudden rise of pressure from A to B on the PV diagram might be expected to give a certain amount of shock to the piston rod, etc. Alongside is shown a diagram which is out of phase with the crank, the top dead centre position being about the middle of the diagram. The rise from A to B is now seen to take almost 10 degs. to accomplish, and gives a slope which is not very different from that which would arise from a diagram with a compression pressure equal to the maximum pressure of Fig. 2.

The charging and exhausting of the cylinder will be dealt with in detail later; it is sufficient to note that it is regarding this part of the cycle that the fundamental difference of the two-cycle and four-cycle engine turns, and it is in the efficiency of this operation that any difference in economy of the rival cycles results.

Fig. 3 shows, to a fairly open pressure scale, the exhausting and charging process for a two and four-cycle engine.

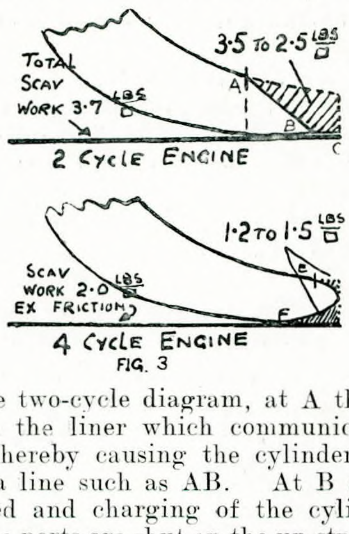


FIG. 3

Looking at the two-cycle diagram, at A the piston has uncovered ports in the liner which communicate with the atmosphere, and thereby causing the cylinder pressure to fall suddenly along a line such as AB. At B scavenge ports or valves are opened and charging of the cylinder takes place until the scavenge ports are shut on the up stroke.

The loss of M.I.P. which takes place here is about 3·5 to 2·5 lbs. per square inch.

The four-cycle diagram shows the exhaust valve opening later than the two-cycle ports, and the pressure falls along the full line E.F., resulting in a loss of M.I.P. of about 1·2 to 1·50 lbs. per square inch.

The four-cycle engine cylinder acts as its own charging pump, and the thickness of the atmospheric line represents to scale the work absorbed in this portion of the cycle, and may be assessed at about 2·0 lbs. per square inch, excluding the friction of the parts.

In the two-cycle engine, the charging air is supplied to the main cylinder from a separate source, and work has been done on it. If any of the air escapes, or loses pressure, so that when the scavenge portion of the cycle is completed, all the air pumped is not enclosed in the cylinder, then the amount lost is at the expense of more oil to be burned in the cylinder.

The ratio of the scavenge pump volume to cylinder volume is about 1·40, and the pressure should be low, say 1·5 lbs. per square inch. Referring this to the main cylinder area, the equivalent pressure would be 2·10 lbs. per square inch.

Allowing mechanical pumping efficiency as 65%, the equivalent pressure would be 3·20 lbs. per square inch.

In Fig. 3 the scavenge work is assumed to absorb 3·70 lbs. per square inch.

The losses in an oil engine are:—

(*a*) Air compressor losses.

(*b*) Scavenge or pumping losses.

(*c*) Friction (main cylinder line only) losses.

(*d*) Losses from incompleteness of expansion.

The following is suggested as a reasonable comparison of the two cycles:—

	Two Cycle.	Four Cycle.
Mean indicated pressure (complete expansion) ...	95 lbs./sq. in.	95 lbs./sq. in.
Air Compressor	9	9
Scavenge or pumping	3·7	2·0
Main cylinder line friction and small auxiliaries	8·0	10·0
Incomplete expansion	3·0	1·2
Mean brake pressure	71·3	72·8

Assuming that the oil consumed per indicated horse power hour is the same, a slight gain is shown for the four-cycle engine, in the proportion of 100 to 98.

The foregoing notes show that the difference in fuel economy of the two rival cycles is very slight, and may very readily disappear.

The two-cycle engine, from the complicated nature of the charging process, did not reach the minimum consumption so readily as the four-cycle engine. For that reason, the two-cycle engine is still at a disadvantage, but this is being rapidly overcome.

Fig. 4. The following table shows the divergence of type in relation to three important features of an oil engine.

FIG. IV.

ESSENTIAL FEATURES OF TYPES OF OIL ENGINES.

PRINCIPLE OF LOAD TRANSFER TO CRANKSHAFT.		CYLINDER CHARGING.			FUEL ATOMISATION.		
		4 Cycle.	2 Cycle.			Solid Injection.	
Single Piston.	Opposed Piston.	Valves in Cyl. Cover.	Controlled Ports.	Single Port.	Air Injection.	Constant Pressure.	Intermittant Pressure.
	Cammell Laird			Cammell Laird	Cammell Laird		
	Doxford			Doxford		Doxford	
Burmeister, &c. Wain ...		Burmeister			Burmeister		
F.I.A.T. ...			F.I.A.T.		F.I.A.T.		
N.B. Diesel ...		N.B. Diesel			N.B. Diesel		
Sulzer ..			Sulzer		Sulzer		
Scott Still ...				Scott Still			Scott Still
Tosi		Tosi			Tosi.		
Vickers ...		Vickers				Vickers.	
Werkspoor ...		Werkspoor			Werkspoor		
Polar				Polar	Polar		

What one might call the British engines, show a preponderance as exponents of solid injection and in the adoption of the opposed piston engines.

So far we have only dealt with the cycle of events occurring within the cylinder. External to the cycle in the cylinder in most oil engines, power is not obtained and herein lies one of the principal features of the Still engine.

In the Still engine, as in all other oil engines, the products of combustion are discharged from the cylinder at a considerable temperature, 700 to 800 degs. F.

This hot gas is passed through a regenerative process, whereby the gas loses its heat to water and raises steam of an equivalent amount, at a pressure suitable to the conditions governing the use to which the steam is applied.

The heat which normally passes to the cold jacket water of the usual oil engine, is in the Still engine a further source of steam generation at the same pressure as that raised from the exhaust gas heat.

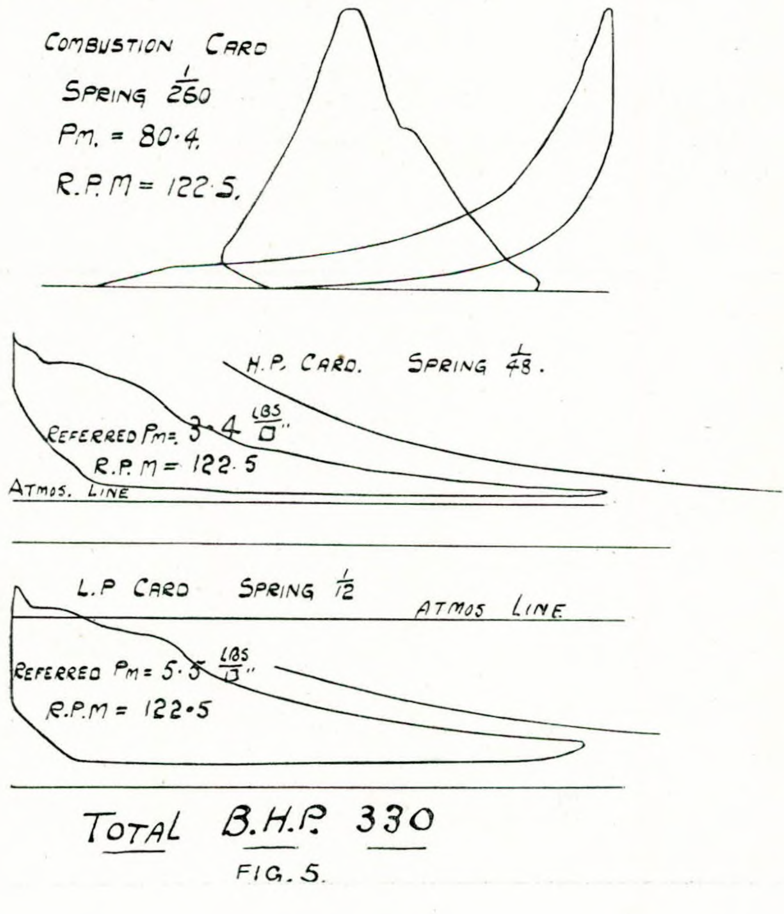


FIG. 5.

The steam pressure is roughly 120 to 150 lbs. per square inch with a corresponding temperature of 340 degs. F.

The Still engine is really cooled by the use of a "hot" jacket, the features of which will be referred to later.

The Still engine therefore turns into steam, heat which would otherwise be lost.

The steam is collected in a steam receiver and is returned to the engine and acts on the underside of the main oil engine piston.

The power obtained from the steam is approximately 10% of the oil side and is almost sufficient to overcome the friction losses of the engine, leaving the oil side free to perform useful work.

Fig. 5 shows a complete set of cards taken from the experimental single cylinder Still unit at Greenock.

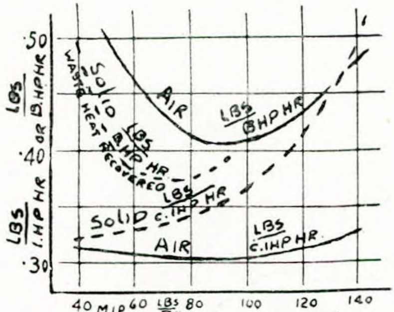
Fig. 6 shows a table of fuel consumption rates of several types of engines.

FIG. VI.

FUEL CONSUMPTION RATES.

TYPE.	FUEL CONSUMPTION IN LBS. /B.H.P. HR.					KIND OF OIL USED.	TOTAL M.I.P. AT FULL POWER LBS/□″	REFERENCE.
	Over Load.	Full.	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{4}$			
Burmeister ...		About ·40				Diesel Oil.		M.S. Sept., 1920
(Fullagar). Cammell Laird		·391				Anglo-American		M.S. June, 1921
Doxford ...		·441				Anglo-American SP. GR. ·902	105	M.S. Mar., 1921
F.I.A.T. ...		·42						M.S. Mar., 1921
N.B. Diesel ...		·42				Anglo-Persian ·90	102	M.S. May, 1921
Scott Still ...	·398	·375	·367	·394	·476	Shale Oil ·865 SP. GR.	91·2	Eng. Sept. 2, 1921
Sulzer ...		·418	·413	·425	·50	Gas Oil ·89 SP. GR.	103·5	M.S. Feb., 1921
Tosi	·411	·42					97·	M.S. Dec., 1921
Werkspoor ...								
Vickers ...		Under ·40						

Fig. 7 shows the fuel consumption curves in lbs. per I.H.P. hour and lbs. per B.H.P. hours plotted against M.I.P. varying according to the propeller law, for solid injection and air injection engines.



FUEL CONSUMPTION "SOLID & AIR" INJECTION

FIG. 7.

The Scott-Still engine has been run since on heavy fuel oils up to the usual boiler oil ·95 specific gravity.

An Anglo-American Diesel oil, the consumption is as good as given in the table for shale oil.

The overall economy of oil engines is influenced by the consumption of lubricating oil. The consumption of lubricating oil is very much in the keeping of the engineers in charge, and a very gradual, but not reckless cutting down of the oil should be employed.

Cylinder Charging and Exhausting.

The four-cycle engine piston acts as its own charging and exhaust pump. An inlet and exhaust valve are provided in the cylinder cover, operated by cams suitably timed to give the maximum charge weight of air in the cylinder.

It is probably possible to enclose 90% of air at normal temperature and pressure, allowing for the contraction of the residual exhaust and momentum effects of the gas columns.

The variety in the design of this portion of the four-cycle engine is not great, usually consisting only of variations in the operating mechanisms.

One four-cycle type of engine has, however, a distinct difference in principle.

Fig. 8 shows in diagrammatic form the arrangement adopted by Tosi. The valve in direct communication with the cylinder acts on one stroke as an exhaust valve, and on the next stroke as an inlet air valve. Beyond this valve is a semi-rotary selecting valve, which can connect the first valve at the cylinder with either the exhaust or inlet passage in the cover.

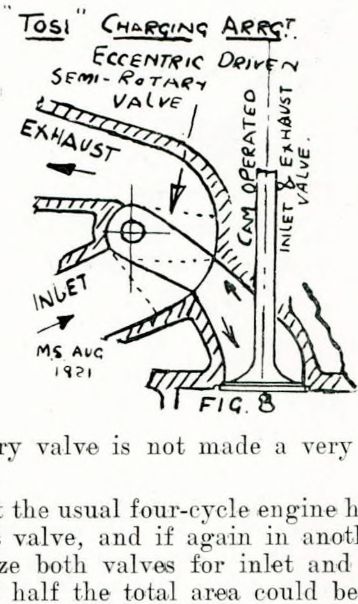


FIG. 8

The semi-rotary valve is not made a very close fit in its housing.

Assuming that the usual four-cycle engine has one inlet valve and one exhaust valve, and if again in another design it was possible to utilize both valves for inlet and exhaust alternatively, valves of half the total area could be fitted. This is where some of the gain of the Tosi arrangement is obtained. Further, the combined valve will be a cooler valve, because of its smaller size and because of the cooling effect of the charging air. The charging air is bound to pick up heat in this system on its way to the cylinder, and so reduce the charge weight somewhat, but the loss from this would be difficult to detect owing to the flatness of the fuel consumption curve for ordinary M.I.P.'s.

The introduction of the semi-rotary valve in the cylinder head of the Tosi engine adds to its complication, but as an offset to this, it is not placed directly over the cylinder end itself.

The charging of the two-cycle engine is a more interesting, and one might add, more difficult problem, and it is for this reason that the two-cycle engine has been slow in general adoption.

As already stated, the charging air is pumped at a pressure to the cylinder. This pressure should be as low as possible and ranges from 1 to 3 lbs. per sq. inch in slow speed engines. Regarding the most suitable pressure to use, it is found to be that which will pass the specified quantity of air through the scavenge ports. It is not fixed by the length of sweep of the air in the cylinder.

Assuming an engine of the opposed piston type, 18in. dia. × 48in. total stroke at 110 r.p.m., and a period available for scavenge of 70 degs. = ·10 secs. approx. For the air to move 4ft. 0in. in this time would require a velocity of 40ft. per second, which can be given by a few inches of water head.

The pressure is then dependent on the port and passage areas and these should be as large as possible.

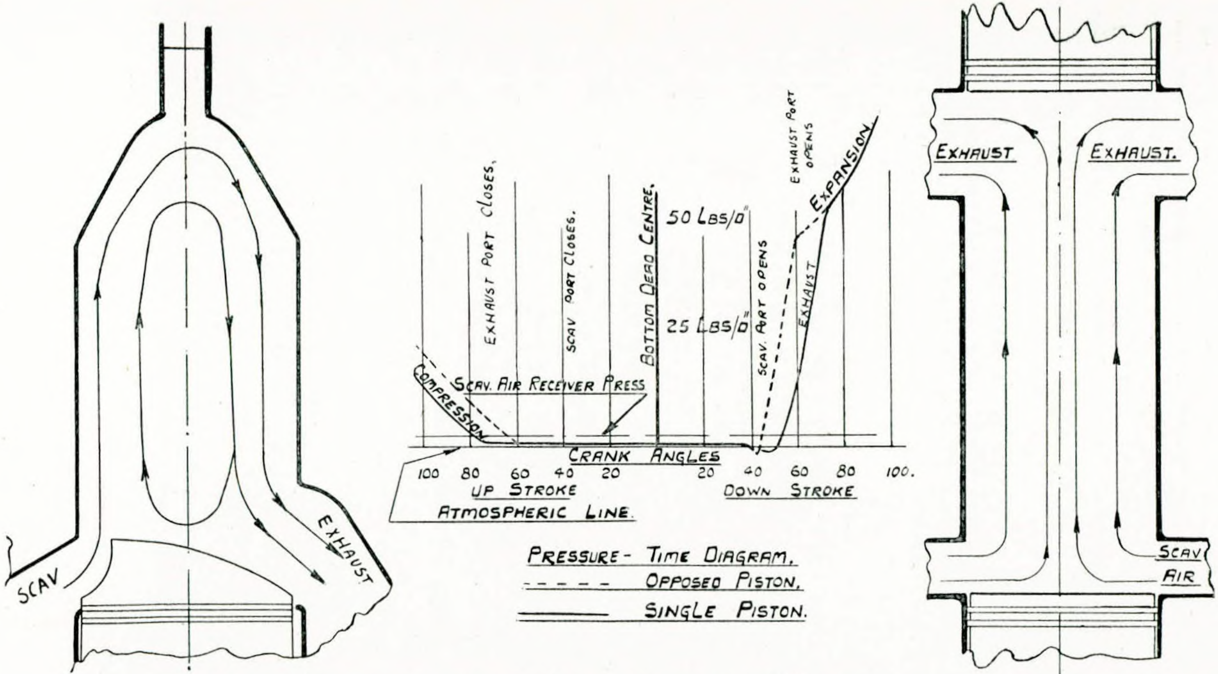
Fig. 9 shows in diagrammatic form the scavenge principle known as single port scavenge, as adopted in the Scott-Still, Cammell Laird, Fullagar, Doxford and Neptune Polar engines. The pressure time diagram is also shown. The exhaust port closing position determines the charge weight of air which will be enclosed. The time interval between the scavenge port closing and the exhaust port closing, allows air to escape from the cylinder, unless some other means is provided.

For the same cylinder swept volume, it is possible to enclose a greater charge weight in the opposed piston type, as shown by the dotted lines in the pressure time diagram.

The whole circumference of the cylinder at each end is available for the scavenge and exhaust ports. Large areas are readily obtained and therefore low scavenge pressures.

In the opposed piston type, clean sweeping of the cylinder is obtained, as shown by the direction arrows.

Single port scavenge without other devices is only justified on the score of simplicity, as a certain sacrifice of maximum M.I.P. necessarily follows its adoption. However, in the Scott-Still engine, the recovery of heat from the exhaust by the generation of steam, permits of simplicity of the oil engine being carried to an extent which would not be desirable in ordinary single piston oil engines.



SINGLE PISTON. SINGLE PORT SCAVENGE PROCESS. OPPOSED PISTON.

FIG. 9

Fig. 10 shows the charging arrangement now popularly called "supercharging," and the diagrams indicate the methods adopted by Sulzer and Fiat respectively, these being the two chief exponents of the system.

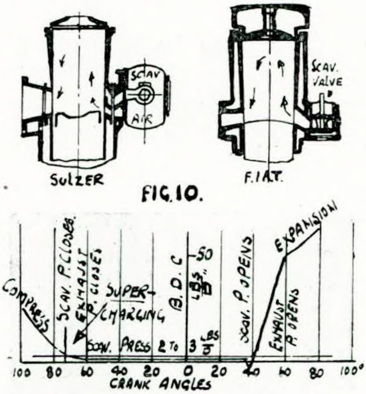


FIG. 10.

The excess of air with which it will be possible to charge the cylinder, will depend on the scavenge ratio and the timing of the charging ports.

As to how far scavenge efficiency can be improved by providing direction for the incoming air, is a matter of experiment. Scavenge efficiency can be obtained in two ways:—

(a) By the clean sweeping of the exhaust in front of the incoming air.

(b) By dilution of the residual exhaust gas with fresh air.

The first method is the desirable one, provided that the air passage shapes and areas are such, that the effect is obtained without serious increase in scavenge pressures.

The second method arises out of imperfections of (a), but may still give results which are good measured in terms of lbs./B.H.P. hour.

The pumping of the air may be carried out in two ways.

(1) By reciprocating pumps driven by the engine.

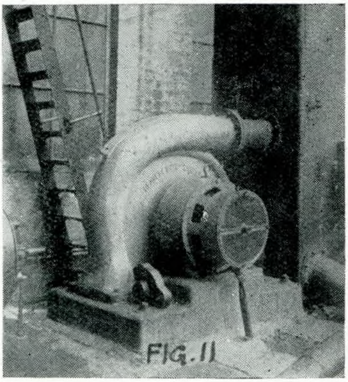
(2) By rotary blowers driven by an electric motor or other means.

The rotary blower is now enjoying a certain popularity.

The factors governing the choice of scavenge unit, are principally two, depending on the capacity required and the general type of engine room auxiliary fitted.

The turbo blower can be driven by a variable speed motor, so that the air can be reduced to suit the engine requirements, and also on occasions, the blower speed can be increased to give overload conditions for the engine, when an increase in scavenge ratio is very desirable.

Fig. 11 shows a Reavell turbo blower which runs at 3,000 to 4,000 revs. per minute, giving 1,000 to 2,000 ft. 3/min. and is used to give air for the Scott-Still single cylinder experimental unit. Very little trouble has been experienced with the running of this machine.



The machine of this type requires to run well below its surging point to give absolute satisfaction, *i.e.*, it should be designed for a pressure adequately above the pressure required for the engine.

Reciprocating scavenge pumps driven by the engine in either of the following ways is quite satisfactory :—

(1) Pumps driven by levers from the engine crosshead.

(2) Pumps driven at the forward end of the engine crankshaft.

(3) Pumps driven between groups of cylinders.

(4) Pumps driven in tandem with the main cylinder.

Each method has advantages and must be considered with reference to the general design of framing and ship conditions.

The Cammell Laird method of attaching the scavenge pump piston to the upper opposed piston is novel. The pump cylinder is rectangular. One wonders if the lubrication of the scavenge pump rings might not be excessive, as they would appear to be almost certain to receive more than would ordinarily be given them in another situation.

Two-cycle engines are said to reduce the number of valves on the engine. This is not quite true when one takes into account the number of valves fitted to the scavenge pump. These valves may be of automatic type, in the form of thin disc, or alternatively, positively driven piston valves may be fitted.

The automatic valve of a large total area, would seem to be the best solution of this problem, and in any case they are bound to have a much easier and happier life than the corresponding valves in the blast air compressor.

Combustion of the Fuel.

Two methods of injecting the fuel oil into the compressed air charge have definitely established themselves as suitable and reliable enough for marine engines.

The first and best known is the air injection system. In this system, fuel oil is pumped to a valve in the cylinder head by a pump which measures out the oil in relation to the power required.

At the correct moment this valve in the cylinder is lifted by a cam and the oil is blown into the cylinder by air at about twice the pressure within the cylinder, *i.e.*, about 1,000 lbs. per sq. inch. This air is provided by an air compressor which is almost invariably fitted at the extreme forward end of the crankshaft.

The second method is that called " solid " injection of which two variations are adopted.

In the first the oil is pumped up to pressures in the vicinity of 4,000 to 8,000 lbs. per sq. inch in the pipe joining the fuel valve. The fuel valve is lifted bv a cam in the usual fashion, the period of the valve being such, that with the requisite size of hole to obtain the proper degree of atomisation, the pressure can be maintained. This method is usually termed " constant pressure system."

The second variation under solid injection, is that in which the pressure is applied to the valve only at the firing point, and in this case the valve is lifted by the action of this fluid pressure upon the differential spindle of the fuel valve. The valve is not cam operated. This system will be referred to as, " intermittent " pressure system.

The following may be taken as the requirements which each system ought to satisfactorily fulfil.

(1) The consumption per B.H.P. hour low, *i.e.*, atomisation of the fuel satisfactory.

(2) Alteration of valve opening period to suit low loads.

(3) Prevention of oil entering the cylinder other than during combustion process.

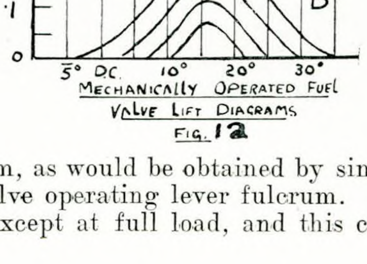
(4) Distribution of fuel to cylinders uniform.

(5) Ability to run at low M.I.P. and revolutions.

With regard to point 1, the solid injection systems will give consumptions measured in lbs. / B.H.P. hour as good and better than the air injection systems up to a M.I.P. of about 100 lbs. per square inch.

Fig. 7 already referred to, shows something of the nature of the comparison of these types. So far the consumption measured as lbs./I.H.P./hour for solid injection engines, is not so good as air injection, and obviously if it could be made as good, the consumption measured as lbs./B.H.P. hr. would be very much better and no question would then arise as to which method should be adopted.

Regarding point 2, Fig. 12 shows for cam operated valves, how the fuel valve lift diagram varies according to the method employed of effecting the change. Lift diagram A is the desirable one, as the initial injection of the fuel occurs at about the same position for all loads. Diagram B shows another variation in which the period is reduced symmetrically with the



MECHANICALLY OPERATED FUEL VALVE LIFT DIAGRAMS

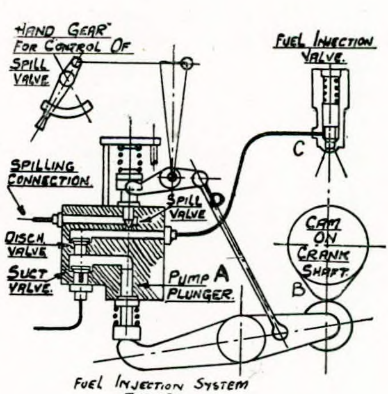
FIG. 12

middle of the cam, as would be obtained by simply altering the height of the valve operating lever fulcrum. The injection is definitely late, except at full load, and this cannot be said to be a satisfactory method of fulfilling point 2. J. L. Chaloner in the "Motor Ship," December, 1920, has gone into the question pretty fully.

In any case in order to accomplish a variation of valve period, such as A, a complication of the valve gear arises, although in some cases this motion has been obtained by the same movements as effect reversal of the valves.

The Still engine system of fuel injection lends itself to the fulfilment of point 2 in a particularly satisfactory manner.

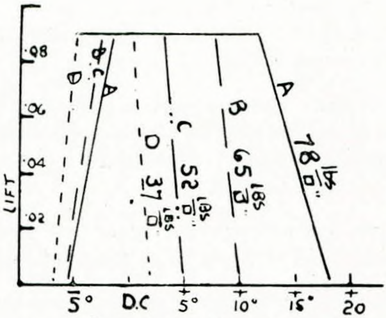
Fig. 13 shows in diagrammatic form, the complete injection system for the Still engine. The fuel pump plunger A, is operated by a cam B, keyed to the shaft at the requisite angle; a spring returns the plunger.



FUEL INJECTION SYSTEM
FIG. 13

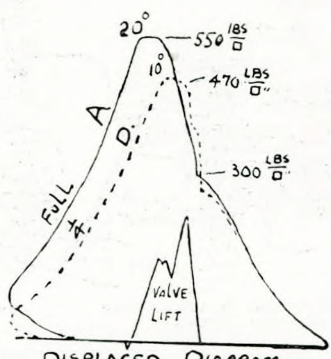
The plunger moving forward builds up a pressure in the fuel pipe to the valve in the cylinder. At a certain point on the travel of the pump the pressure is such as to overcome the spring loaded fuel jet C, and the valve opens suddenly and spraying commences. After a further movement of the pump plunger, and depending on the load, a spill valve D, situated in the high pressure pipe, is tripped open, the pressure falls suddenly and the fuel jet returns smartly to its seat.

Fig. 14 shows a set of fuel valve lift diagrams taken during a varying load trial, and shows how the period varies in the correct manner.



VALVE LIFT DIAGRAM
FIG. 14.

Fig. 15 shows the corresponding displaced power card for the extreme loads, together with a copy of the actual valve lift diagram obtained at full load.



DISPLACED DIAGRAM
FIG 15.

The variable period has undoubtedly been obtained in a very desirable manner, with a very simple arrangement. In this automatic type of fuel valve, the parts are so light, that it is possible to obtain shutting and opening speeds quite impracticable with cam operated valves, which have all relatively heavy parts to accelerate.

The prevention of oil getting into the cylinder except at the correct period, is a point which is fairly important. In the air injection, and constant pressure solid injection systems, any leakage at the valve face must find its way into the cylinder.

With the intermittent solid injection system used for the Still engine, this defect cannot arise, as the oil is only under pressure at the fuel valve during the period in which the valve should normally be open.

Regarding the distribution of the oil to the cylinders, two systems are in vogue.

(1) An individual pump to each cylinder, the pump measuring out the oil to the valve each stroke. This system is applied equally well to air injection and solid injection.

(2) Pumps delivering oil to a common system and subsequently distributed by throttling at a box or by arranging the fuel valve periods to give the desired effect.

The system as outlined in (1) cannot possibly give overload conditions to a cylinder without a change in the pump setting.

System (2) may, under certain circumstances, allow of excess of oil going to the cylinder.

The Still engine falls under System (1).

The ability of an oil engine to run on low M.I.P. at low speeds, depends on the temperature after compression being high enough and remaining high enough when injection commences. Air injection of the fuel causes misfiring at low speeds, due to the cooling effect of the injection air adding to that already affected by the cylinder surfaces. It may be safely stated that a solid injection engine will fire regularly at a lower speed than an air injection engine.

The Still engine in addition to this advantage of being of the solid injection type, is also hot jacketed. This still further facilitates regular running at low speeds.

For the proper atomisation, penetration and distribution of the fuel in the solid injection systems, high pressures have to be employed, varying from 5,000 lbs. per sq. inch to 9,000 lbs. per sq. inch.

This pressure sounds a bit high, but with the proper realisation of the requirements of the parts subjected to it, the system can be made extremely reliable.

Most parts are made from forged steel billets and special designs of pipe couplings must be used.

The Still engine has been run on all classes of fuel oil up to Mexican boiler oil, giving consumptions which vary practically with the calorific value.

Heating of the heavier oils is necessary to allow the oil to be handled by the pumps.

Cooling.

A very important side of the marine oil engine is that associated with the cooling of the liner, head or cover and piston crown, together with any parts, such as exhaust ports or valves, over which the hot gases career.

Ordinary oil engine practice for a long time past has been to cool the liner and head with salt water, and to cool the piston with fresh water or oil.

If fresh water were used throughout the jacket system of an engine, a higher outlet temperature could be obtained without danger from salting up or scaling, with a resulting gain in overall efficiency.

From descriptions published of new engines, one notes a tendency to introduce fresh water cooling for all purposes, and the author believes that this will ultimately become standard practice.

Oil cooling for the piston can only be justified on the argument that leakage is not harmful to the crankcase oil. This infers that given a satisfactory system of water cooling, from which leakage cannot arise to contaminate the oil, water cooling would be adopted. As to how far the present water cooling arrangements to the piston are unreliable, many of you will have some fixed notions.

In ordinary Diesel practice two methods of piston cooling are in use.

(1) Telescopic pipe method, in which a fixed pipe on the piston works into a fixed pipe in the engine framing, with or without glands, together with a third enclosing pipe to catch leakage.

(2) Link and lever method, by which the water is passed along a lever and picked off at the end by means of a flexible hose, or up the tubular elements of the link to the piston rod. The water goes up the centre of the rod and down again and away by means of the links and levers.

The telescopic pipe arrangement well and truly lined up, would appear to offer the readiest solution to this difficult problem.

The Still engine must be considered apart in relation to piston cooling. The method adopted for cooling is to direct the steam, which in any case is acting on the under side of the piston, over the surface of the piston. The actual arrangement whereby this is carried out, is to make the piston rod run into a fairly close fitting sleeve, and to drill holes up the rod to the top for a short distance there.

The incoming steam is thus made to impinge with high velocity on the centre of the piston crown. A large number of spiral ribs guide the steam outwards over the crown and down the side of the ring carrier portion of the piston barrel. The steam is thus considerably dried, and may even be superheated, with a resulting increase in steam efficiency.

The question of how best to effectively cool the liner, is one which requires more and more attention with increases in the cylinder dimensions.

That the usual practice of fitting a cast iron liner which will resist the bursting stresses and of allowing, to a certain extent, the temperature head in the liner to look after itself is not good enough in large cylinders is quite realised.

Methods have been recently adopted by several firms, whereby the liner is made comparatively thin, the necessary bursting strength being obtained by some form of re-enforcing.

Burmeister and Wain designs do not seem to have changed yet in this direction, as they still have the thick liner.

The Tosi engine has gone a step in the right direction of lowering the liner stresses, by getting more effective cooling of the liner. A form of stepped concentric channel is formed on the liner, by casting a shallow rib which is turned to a diameter to fit inside the jacket.

All the water supplied to the cylinder must pass along this channel with no doubt considerable velocity, and so giving more efficient cooling of the liner.

Provided the requisite fit is provided, the liner may be said to be reinforced by the jacket.

If salt water cooling is adopted, large inspection doors are provided in the jacket wall.

In the Still engine the cooling is obtained by means of the use of a "hot" jacket in which water is maintained at about 100 to 120 lbs. per square inch and 340 degs. F. Any heat which passes through the cylinder wall to the water, raises steam which is allowed to pass out at the top to a steam receiver. All the cylinders are connected up to a common system with common steam receiver.

The jackets circulate by convection, no pump being used to pass the water through the jackets. Fig. 16 shows a diagram of the liner and jacket construction.

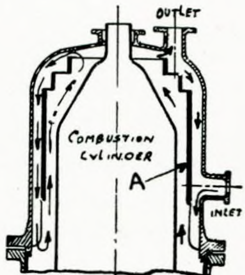


FIG. 16.

The convection currents indicated by the arrows, are materially assisted by the presence of the stiffening drum A, fitted over the radial ribs cast with the liner.

As compared with ordinary Diesel cooling practice, the advantages of the Still system may be stated briefly as—

(1) Heat to cooling medium raises useful steam.

(2) Hot jacket enables low compressions to be used.

(3) Very uniform temperatures for the whole cylinder liner.

(4) Natural reinforcement of the liner from the water pressure in the jacket.

(5) Thin liner gives low temperature stress.

As the cylinder jacket is under pressure similar to that in a boiler, this part is made of cast steel.

In the Still engine a large proportion of the steam raised is obtained by temperature reduction of the exhaust gases after leaving the cylinder.

The gases are passed through a regenerator, placed close to the cylinder, and of sufficient surface to reduce the gas temperature to such a point as to allow of uncooled exhaust piping being used thereafter.

Valve Gear.

The usual method of operating the valves of an oil engine, is to provide a shaft with cams, and to have an intermediary such as a push rod and lever, or lever only, between the cam and the valve.

Together with the operation of the valves in correct phase with the crank, there is the necessity to provide reversing mechanism for the astern running in marine engines.

These operations are made to take place in a variety of ways, and a detailed description of the mechanism is without the scope of this paper, and it will be sufficient to state that ahead and astern cams are provided, with means whereby the lever is put into contact with the desired cam. Three methods of effecting this selection of the cam are in use:—

(1) Sliding the cam or the camshaft as done by Burmeister and Wain, N. B. Diesel, etc.

(2) Moving the roller or engaging a second roller as done by Tosi, Sulzer and Scott-Still, etc.

(3) Shifting the lever fulcrum as done by Werkspoor.

All these methods require that the lever be lifted clear of the cam before shifting to the other cam.

The four-cycle engine is as easily reversed as the two-cycle provided that the number of cylinders on the engine is such as to give a starting position anywhere by having the starting cam profiles overlapping in phase. More than four cylinders are required for this.

The operation of the valves of the Scott-Still engine is carried out hydraulically throughout the whole engine. The operation of the fuel valve has already been described.

The valves for the steam engine are operated as follows:— Oil is pumped to a pressure of 400 lbs. per square inch by a special pump provided for valve operating. The oil is passed to a distributor driven at the engine speed at the crankshaft, through the usual spiral gears.

The distributor consists of a plug rotating in a fixed barrel, with ports arranged in such a fashion, that oil can be supplied to adjoining pipes and released again at an interval as required by the particular valves at the cylinder to which the pipes are led. At the cylinder, the pipe is connected to an operator attached to the valve to be operated. The operator is simply a plunger which the admission of oil under pressure moves upwards, and on the release of this pressure, the valve returns under the action of oil at 400 lbs. per square inch on a differential spindle in the operator, very much after the manner of the usual spring return for cam operated valves.

The action of the valve is absolutely consistent, and as can be seen from the steam cards shown in Fig. 5, clean opening and closing of the valve takes place.

The operating mechanism is all at the crankshaft.

Fig. 17 shows the distributor for the steam valves for the single cylinder unit. The handwheels A are for alteration to the cut off.

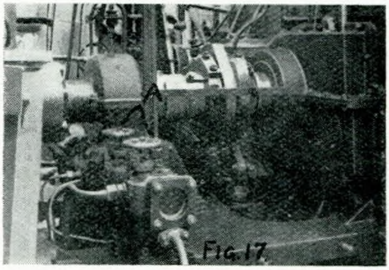
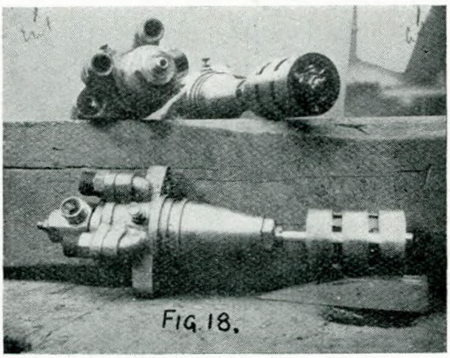


Fig. 18 shows the valve and valve operator which is contained within the steam cylinder cover.



In all Diesel engines, the starting and manœuvring of the engine is carried out by compressed air.

The air may be stored at 300 lbs. per square inch as done by Burmeister and Wain, or at the maximum pressure of 1,000 lbs. per square inch, as adopted by most other makers.

The capacity of the reservoirs fitted enables a limited number of reversals to be carried out, probably about 20. Extensive manœuvring with little time between, would entail the starting up of the auxiliary air compressor.

Any difficulty of starting the usual Diesel engine arises only when quite cold, and one notes that several makers are now fitting steam heating connections to the jackets, to make this operation surer. When hot, the engine fires very often too readily, and very high pressures may result with rash handling. It is probable that the crankshaft suffers more in manœuvring, than in the prolonged running at sea.

The fact that the starting air valve on the cylinder is idle during the steady running of the engines, which may extend into weeks in the case of marine engines, causes a little uncertainty of action when suddenly called into use.

That this is no bogey, the author knows from experience, and one notices the tendency in ordinary Diesel practice to fit a protecting valve for the starting air valve, together with lubricators for the internal parts of the valve.

Again the author does not propose to enlarge on the details of starting and manœuvring except in the case of the Still engine.

The Still engine is peculiarly fortunate with its manœuvring arrangements, in that a familiar working medium, steam, is used.

As the undersides of all the main pistons are steam engines, the engine is self-starting in the usual steam engine sense.

The steam valves being always in use are not likely to give trouble on manœuvring.

There is no necessity to hurry the starting process in the Still engine, as due to the hot engine, firing is a very certain operation.

When one considers the question of flexibility, the Still engine again shows up in a favourable light.

The engine has the usual flexibility of a solid injection oil engine, with the additional advantage of having a hot jacket for the cylinder. As it is possible to run the engine on steam alone, very low revolutions could be obtained.

It is possible to run the Scott-Still engine at M.I.P.'s of up to 40 lbs. per square inch without cooling the piston, so that if the steam pressure requires raising up fairly quickly, by shutting off the steam to the engine, the steam receiver pressure will come up very quickly, without separate firing, the engine waste heat being sufficient to do this.

Fig. 19 shows a photograph of the starting and manœuvring gear. A is the steam stop valve, B is the fuel pump hand control, but which may be engaged with a servo motor controlled by the governor, having speed regulations by the handwheel D. E is the cylinder drains.

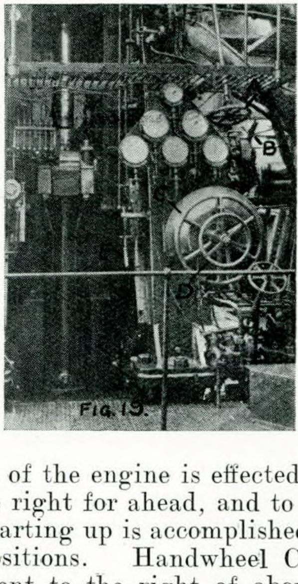


FIG. 19.

Complete control of the engine is effected by a movement of handwheel C to the right for ahead, and to the left for astern. In each direction starting up is accomplished by turning C into three successive positions. Handwheel C is shown in stop position; a movement to the right of about 20° sets all the valves ahead. A further movement of 20° allows steam to the engine, with a cut off of nearly 100%; when the engine has accomplished a revolution or two, the wheel C is turned to its extreme position and the fuel oil is automatically cut in, at the same time the steam cut off has been reduced to normal. Reversing is effected by the same sequence to the left.

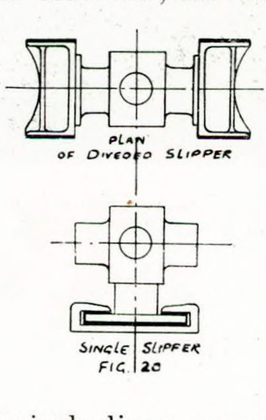
Engine Structure.

In single piston engines the fixed portions from the cylinder cover down to the bedplate, have to stand the main combustion load, and it should be the object of the design to take the load as directly as possible to the bedplate. If saving of weight was the only consideration, then the adoption of through bolts from the cylinder head to the bedplate, would be the one solution. However, the question of rigidity of the structure, makes the employment of some form of strong crankcase construction desirable. On examination of the engine structure in most types of single piston engines, one notices a similarity in design, which goes to bear out the statement that ultimately a very limited number of designs will survive.

A. columns over the main bearing either joined to the next as one casting, or separate, with facings provided so that the closing in doors may be oil tight, is the general practice.

Associated with the design of the crankcase is that of the engine crosshead, in so far as providing guide plates for the slippers is concerned.

Fig. 20 shows the two designs of slipper arrangements generally adopted. The divided slipper arrangement as adopted by F.I.A.T., Sulzer and Scott-Still, has advantages of access to



the crankcase over the single slipper arrangement. The through bolts taking the load from the cylinder head to the bedplate may alternatively be taken to the top of the A columns, and then *via* the columns to the bedplate. The latter is the method adopted in the Scott-Still engine.

As far as possible, absolute freedom of expansion should be provided in the cylinder of an oil engine.

Fig. 21 shows a photograph of the Scott-Still single unit engine. The steam cylinder is supported on a flange at the middle of its length, and is free to expand up and down.

The combustion cylinder is supported on the short cast iron standards seen at the top of the column, and is quite separate from the steam cylinder, except by concentric location. The combustion cylinder is free to expand through a gland in the cylinder jacket at the top, and has absolutely no axial or circumferential restraint.

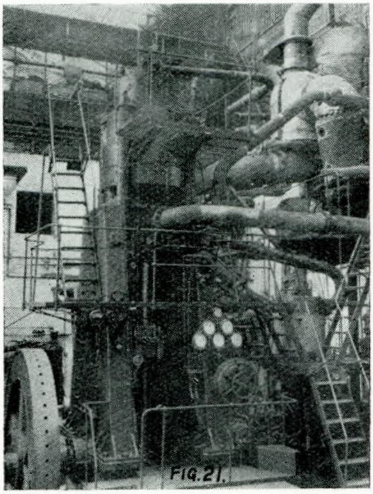


FIG. 21.

The steam load is taken direct to the column from the cylinder, and the combustion load *via* the through bolts from the cast steel jacket to the columns.

In the opposed piston type of engine, the framing does not take any substantial part of the combustion load. At the same time, the question of rigidity must be considered, especially as certain thrust surfaces must be provided at the top piston, at a distance from the crankshaft which might give rise to awkward movement.

The dynamic balance of the engine is reputed to be perfect.

The Cammell Laird Fullagar engine represents a very neat form of opposed piston engines. By attaching the upper piston of one line to the lower piston of the adjacent line, a reduction of the cranks of from 6 to 2 is obtained in a two line engine. Additional guide surface is required to look after the thrust of the cross tie rods.

This combination of cylinders and pistons has made the opposed piston type of engine a very promising one for large powers. The low piston speed and revolutions obtained in these engines should appeal to every marine engineer.

CONCLUSION.

As is obvious from the wide nature of the subject chosen for this paper, only very brief references to certain features of design were permissible, and much has been left out on which a discussion would be extremely valuable.

Such matters as lubrication and ship arrangements have not been referred to.

No reference has been made to the double acting Diesel engine, although it is well known that several firms have experimental units in hand.

If the author has appeared to bestow undue attention on the Scott-Still engine, he would crave your indulgence. You will gather from the introductory remarks that he has lived in a Scott-Still atmosphere for some years back, and will appreciate perhaps what that means. At the same time, so far as in him lies, he has endeavoured to deal impartially with the consideration raised in respect of all the types of oil engines referred to. In conclusion he trusts that the paper will assist the members of this Institute towards a clearer idea of the essential and distinguishing features of the leading types of marine oil engines.

The CHAIRMAN: I think you will agree that we have had a very interesting paper. I will not take up any time because we have passed a resolution at our Council meeting that these meetings should terminate by 8.30. If there appears to be a good deal more to add at 8.30, an adjourned discussion can be arranged for. I would like to say that the outstanding feature of Mr. Hutchison's paper is its fairness. We have had the four-cycle man rampant, and we have had the two-cycle man rampant, but to-night we have had an extremely reasonable exposition by Mr. Hutchison. It deals with a very interesting phase of this subject, the Scott-Still engine. I have only one question to raise—in one of the photographs a part of the apparatus was referred to by Mr. Hutchison as a regenerator. Actually it is a Cochran boiler, but it is not clear to me whether it is a boiler as such in which fuel is burnt or whether the exhaust gases only are used in it. I would also refer to Sir Dugald Clerk's remarks concerning this engine, in which he stated that the logical outcome of the Still idea would be the use of the exhaust heat, and the heat of the jacket, in a turbine engine. I would like Mr. Hutchison to say a few words on Sir Dugald Clerk's proposal to use the jacket water in a boiler to make steam for a low pressure turbine. I now leave the discussion to you; I feel I ought to assure Mr. Hutchison that any lack of comment will not be due to lack of interest, but rather to the fact that the engine is a new type, and owing to the advance copies of the paper not having been read by many present.

Mr. W. McLaren: I would like to ask what is the weight of the Scott-Still engine as compared with a Diesel engine of the same power, also a reciprocating steam engine, and a steam turbine, geared or ungeared. No doubt the principle of the Still engine is right, but the photographs have shown that there are many complications, which would be a serious drawback in the case of a set of marine engines. Those who have been able to read "The Engineer" of last week will have seen an interesting article on the Still engine, and Mr. A. Rennie recently read a paper on the subject to the Institution of Engineers and Shipbuilders, Glasgow. We are thankful as marine engineers to have Mr. Hutchison here this evening. As the Chairman has remarked, we have had both the four-cycle and the two-cycle engine dealt with in former papers, and we have been glad to learn to-night something of what is being done in other directions. It is a definite step forward, when, as in the Scott-Still engine, it is found possible to save a portion of the power which is otherwise lost in the waste heat from the fuel. I have much pleasure in thanking the Author for coming here and giving us this paper.

Mr. F. O. Beckett: I would like to supplement the remarks of Mr. McLaren by noting that Messrs. Alfred Holt and Co. are displaying much enterprise and have taken the lead, as far as this engine is concerned, by placing an order for an installation on the Scott-Still system in a vessel of 400 ft. length, 52 ft. beam, and 2,500 B.H.P. This is the first order for a motor-ship with this class of machinery. I understand that the guaranteed fuel consumption will be ·375 lbs. per B.H.P., with solid fuel injection. There is much to be said for Messrs. Holt's enterprise. They have been very progressive in the past. There is one point on which Mr. Hutchison touched, the method of injecting the scavenging air, in connection with which I am inclined to think the designers have not altogether allowed for one factor affecting marine work. Where you have air varying in density in different parts of the world, due to tropical temperatures, etc., it seems that difficulties may arise. Diagram No. 13, with the constant lead, I think it was termed, reminds me very much of Stevenson's link gear and Allen's link gear. Some of us present will remember the hard driving required with these link gears, and I notice the conditions here are somewhat similar. I notice the Scott-Still engine has a cast-iron liner; I suggest it is necessary to be very careful with such a liner if the super heat is more than 100° F., having in mind Professor Carpenter's experiments which proved that cast iron grows under such conditions. Also you may find pitting occur; I have had experince of this due to the scouring action of the gases. With reference to the Cochran boiler, I should like more information regarding the procedure under starting conditions—is the boiler fired at the outset, and the steam generated afterwards by the exhaust gases? Another point of importance to marine engineers—can the space required by this type of engine be kept within the limits of the ordinary engine room space of a ship, in view of the enlarged cylinders, crank cases, etc.? In conclusion, I should also like to compliment Mr. Hutchison on the agreeable manner in which his paper has been presented to us.

Mr. A. F. Evans (Surveyor of Machinery, Royal National Lifeboat Institution): May I ask whether with the Still system, owing to the higher cylinder jacket temperature, a greater M.E.P. is obtainable. This point is very interesting to me, as although I am not at the moment directly concerned with the Diesel engine, I did take a considerable interest, and was in a way, connected with some of the early work in connection with Marine Diesels.

Because of this it is somewhat disappointing to me to find that the M.E.P. of the Diesel has not increased in the same ratio as the increase that has been obtained with the petrol engine, and as a heat engine, I am afraid that the Diesel has allowed the Petrol engine to get ahead.

It would also be interesting to know the weight of this engine, my requirements I may add would be met by an engine of say two hundred H.P. weighing about fifty pounds per horse power.

I am glad to note that in the Still Engine, blast air has been dispensed with, this is a point that I laboured in the early days, but at that time one could not get makers to realise that high pressures were necessary. Three or four thousand pounds were considered sufficient, and even five hundred pounds in the case of the large Semi Diesels, and I tried in vain to get designers to try a much higher pressure. I understand that present practice goes up to ten thousand pounds, and I should be glad if the author could let me know if experience has shown that there is any limit, above which no benefit is derived from any further increase.

With regard to the Still Fuel pumping system, it contains a very excellent feature in eliminating any possible pressure on the fuel valve till that pressure is actually required. I cannot help thinking however that this system is far from ideal. I should like to see the differential valve abolished and the fuel pumped direct into the cylinder by a pump that attains the full fluid pressure at once, sustains it during the fuel injection period and allows the pressure to immediately fall to zero. Such a pump can be produced I am sure.

A previous speaker made reference to the steam boiler used with the Still Engine, which reminds me of the return of the *Selandia* from her first voyage.

The chief engineer was being questioned by a marine engineer as to the faults and troubles they had found, and in reply to the query as to which item gave the most trouble during the trip he replied, " The steam boiler we use for heating the ship—it will have to be replaced."

The CHAIRMAN: Before I call upon Mr. Hutchison, for I feel sure he would like a little time to enlarge upon the points raised, I will only observe that the makers of the Scott-Still engine claim a very low consumption. I presume that the figures quoted are laboratory figures, and we have learned from experience that laboratory results require modification under practical working conditions. The figures are allowed to be a little flattering; I cannot help noticing that they are all about ·42 or below. In the log books the figure averages ·44. I suggest there is a considerable margin between the laboratory figures and those obtained from practical running. Without further enlarging on this, I think the remaining time will be best spent in hearing Mr. Hutchison explain the points raised.

Mr. D. R. HUTCHISON: The function of the regenerator is to take the heat out of the exhaust gases. In the case of the experimental unit, a Cochran boiler is used, but for marine purposes it is proposed to use a Yarrow type boiler as a steam collector and final regenerator. A small tubular regenerator is placed close to each cylinder. With regard to Sir Dugald Clerk's proposal as to the use of low pressure steam, it is convenient to use the under side of the main oil piston as a steam cylinder and a reasonable steam consumption will be obtained in multi-cylinder engine using high pressure steam of about 120 lbs. per square inch.

If at any time the Still engine is made double acting on the oil side then the steam would be used in a separate engine. Regarding the question as to whether the steam should be used at a low pressure, that would mean low temperature in the cylinder jacket resulting in lower combustion efficiency and probably higher compression pressure. Regarding the point raised that the figures obtained from the Scott-Still engine are laboratory figures; the tests of the single cylinder engine were made over long periods and under ordinary conditions. On the steam side, as can be seen from the saturation line shown on the H.P. card in Fig. 5, the diagram factor is poor.

It is anticipated that in a ship where the H.P. cylinder would be the under side of one of the main oil pistons the diagram factor would be 80%, and the fuel consumption would go down to about ·36 lbs. per B.H.P. hour in consequence. Capt. H. Riall Sankey's report on this engine published in "Engineering" of the 10th February refers to this matter. Diagram A shows the function of the regenerator or boiler. It is fixed at such a height that the water level in the boiler is higher than the cylinder jackets. The exhaust gas temperature is reduced from 700° F. to 180° F. As regards the method of raising steam; an oil burner is provided in the boiler for raising steam from cold. The burner is shut off when the engine is on load on fuel.

The question of weight has been raised. In Mr. Rennie's paper comparative figures are given, if we take an example—reciprocating steam engines and Still engines of 1,300 H.P., the weight of steam reciprocating machinery is 338 tons, as against 315 tons for the Still engine installation. The weight in lbs. per B.H.P. is about 210.

Mr. Beckett enquiries about the effect of temperature of the scavenge air under tropical conditions. As in the case of aero engines at high altitudes there is reduction of oxygen supplied to the cylinder each stroke, reducing the power capacity of the engine and increasing the fuel consumption for a given power. In the Still engine less radiation would then take place from the jackets, etc., giving a slight increase in steam.

Regarding the question of growth of the cast iron, the iron used for the cylinder has been subjected to growth tests in our works laboratory. The results indicate that the iron used does not grow to any serious extent.

Regarding the space occupied by Still engine machinery, on the average it is about 10 to 20% less than for reciprocating steam engines or turbine installations.

A question raised by Mr. Evans is how high the mean indicated pressure may be raised. This is not easy to answer directly.

In the experimental Scott-Still engine the fuel consumption is a minimum at about 75 to 80 lbs. per square inch as shown in

Fig. 7. Under sea conditions it is desirable to have a wide margin of power to cope with emergencies, and it is not wise to rate marine engines too highly.

The effect of the hot jacket on the mean indicated pressure should enable a higher M.I.P. to be carried due to increased combustion efficiency. A loss may occur due to reduced charge weight. In any case any gain in maximum M.I.P. will not be very great. The maximum M.I.P. depends on the complete combustion of all the air and oil passing through the engine.

Regarding the question of fuel injection pressure; very little gain results from pressures over 6,000 lbs. per square inch, although this depends on the proportions of the spray cap and combustion chamber shape.

The CHAIRMAN: What temperature do you carry in the jackets?

Mr. HUTCHISON: About 340° F.

The CHAIRMAN: Will that affect the liners in the larger engines? What is the largest liner you have tried?

Mr. HUTCHISON: So far, 22 in. diameter. By reinforcing, a very thin wall can be used and a high jacket temperature used.

The CHAIRMAN: Have you any pressure in the jackets?

Mr. HUTCHISON: Yes, 120 lbs. per square inch.

The CHAIRMAN: That seems a good idea, as it reinforces the liner.

Mr. HUTCHISON: I think I have answered the principal questions in the discussion. I shall be very pleased to answer any others which may be sent in later.

Mr. J. CARNAGHAN: I should like to propose a vote of thanks to Mr. Hutchison. I am specially interested in this engine because it is being made in the place where I served my apprenticeship. When I called there recently I found that all the old steam men were now Still engine enthusiasts. It is noteworthy that practically all Messrs. Scott's employees are enthusiasts on the Still engine, and there must be a great deal in it, as all these men should really be engaged on the steam engine. I would like to endorse the Chairman's remarks, that this has been one of the most fairly written papers we have had.

Mr. F. O. BECKETT: I have much pleasure in seconding this vote of thanks. I should like to include Messrs. McLaren and Whiteside, for operating the lantern.

The CHAIRMAN: I have pleasure in informing you that Mr. Acland, who is associated with the Still engine, is present and we should like him to come to the later continuation of this subject, on March 14th. I would like to associate myself particularly with all the foregoing remarks regarding the impartial treatment which Mr. Hutchison has given to this subject; it has stimulated a curiosity with regard to the novel principle proposed in the Still engine.

Mr. HUTCHISON: I am very glad the paper has been so well received, and am very pleased to have had the honour of coming down to give it to you. I would like to add my thanks to the lantern operators for the admirable way in which the views have been shown.

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The Still System of Internal Combustion Engine for Marine Purposes.

BY F. LEIGH MARTINEAU.

READ

Tuesday, March 14, *at* 6.30 *p.m.*

CHAIRMAN: MR. R. S. KENNEDY (Member of Council).

Recently a paper was read before the Institute which dealt with some points of the Still System as applied by Messrs. Scott's Shipbuilding and Engineering Company, of Greenock.

The Author has, in consequence, amended his original draft and eliminated those points where overlapping occurred, and has also tried to make this paper more general and less specific, that is so as to apply to the Still System generally and not to one particular rendering thereof.

In the course of conversations, the Author has found that there exists in the minds of some people an erroneous impression on the system dealt with in this paper. It is imagined that it is necessary for an engine, if it is to operate on the Still System, to be of a particular type; this, however, is not the case, for any type of internal combustion engine can, by the modification of a few details in certain vital parts, be made to operate upon the Still System, and by this change improve its results by at least twenty per cent.

For instance, many here present have no doubt at some time or another been closely in contact with some particular make of Diesel engine. The modification of the designs of such an engine could enable it to be built upon the Still System whilst at the same time it could retain almost all of its original characteristics, such for example as compression pressure, system of valve operation and system of fuel injection, etc. It would then, if made of the same size give at least 20% more power with the same fuel consumption or it could be of smaller size, and use less fuel but yet develop the same power.

Whether such a change would be advisable in its entirety is a matter for consideration, as one of the advantages possessed by the Still System is that it enables an engine to be built in which certainty of ignition of its fuel is obtained with a lower compression pressure than is normal, and yet on its combustion cycle, an indicated thermal efficiency can be obtained with this reduced compression presssure, as high as is available from a normal cylinder with a higher compression pressure, this effect being due to the lower heat loss through the cylinder walls in the Still System.

Considered from a commercial and running point of view, it is contended that under these circumstances it is often advisable to make engines operating on the Still System with a lower compression pressure than is normally required, and not to aim at obtaining the greatest possible efficiency, but rather to have in view an engine with the lowest upkeep cost.

Even under the conditions suggested

(1) Certainty of starting is maintained.

(2) A high combustion thermal efficiency is obtained.

(3) A lighter scantling can be adopted, as the maximum pressure which can be accidentally developed within the cylinder depends upon the compression pressure.

It may be as well here to briefly state the general features of the Still System, in order that it may be quite clear to those who are not yet acquainted with it.

Its essential features are

(1) A combustion cylinder in which a piston operates.

(2) A water jacket surrounding this cylinder maintained by the heat wasted which passes through the cylinder walls at a temperature equivalent to a certain steam pressure.

(3) A regenerator in circuit with the jacket and through which the combustion exhaust gases are passed to give up their heat to the contained water.

(4) Steam is generated therefore both by the heat wasted through cylinder walls and that contained in exhaust gases.

(5) Such steam is supplied to the cylinder by suitable valves, and operates upon the under side of the combustion piston.

(6) It will be seen that an engine upon the system is double-acting and a combined combustion and steam engine partaking of the characteristics of each.

As has been already stated, the heat losses to the cylinder walls are less than in a normal engine, this is because the temperature of the cooling water within the jacket is that due to the steam pressure adopted, *i.e.*, at 150 lbs. per sq. in. 366° F.

The effect of these smaller losses, causes the indicator card to show a gain in area on its expansion which is higher at the time of release than in a normal card. The result is a higher mean effective pressure for a given fuel consumption, and a slight increase in the percentage of the fuel heat turned into work on the piston.

Besides this, the temperature of the exhaust gases at the time of release is higher, and steam is more easily raised in the regenerator, *i.e.*, from a smaller surface, than would normally be the case.

The quantity of heat, small though it is, which does pass from the combustion cylinder to the jacket water is very valuable as it raises steam at 100% efficiency there being no loss, except that due to outside radiation, which obviously has only to be deducted from the steam after it has been formed by the heat transmitted.

When steam is raised in a normal boiler the actual efficiency is greatly reduced by air leaks into the furnace and even through the grate, and considerable difficulty is experienced in maintaining a high efficiency.

The exhaust gases passing through the steam generator attached to a Still System engine however, do not suffer from this trouble, except only in the case of a two-stroke engine which is over scavenged, and as they pass at high velocity over the boiler surfaces they can the more readily give up their heat to such surfaces. The result is that the efficiency of steam raising is high in the exhaust gas generator.

These two facts together result in the combined steam raising efficiency of both the jackets and generator being very high, much higher than is possible in a normal boiler, and as a consequence the maximum quantity of steam is available from otherwise wasted heat.

Having obtained steam as an extra profit without having to consume additional fuel, it is obvious that it should be utilised in the most economical manner.

The whole combustion engine, cylinder and pistons are already provided and the arranging of a lower cylinder cover, piston rod, gland and steam valve make the use of the steam in the main engine easy, without any disturbance and difficulty on the combustion cycle, and with the addition of the minimum number of moving parts and therefore of their unavoidable frictional resistances.

The question then arises, is such a method, whilst evidently economical from the point of view of construction, as economical as is possible from the point of view of economy in the use of the steam?

The answer is that it is inconceivable to find any system by which the steam could be used more economically.

It is evident that the combustion piston is the hottest part of the engine, and as this is also used as the steam piston the steam will receive heat during expansion from it, and therefore pass to exhaust at a slight superheat, whilst the heat it receives is given up from the hot piston which in turn keeps at a workable temperature.

Because of this fact it is possible but not desirable to expand the steam right down in a single cylinder without condensation losses.

Summing up it will be seen that the fact of using both a combustion cycle and a steam cycle to work in the same cylinder causes an inter action between them which is to the advantage of both.

A combustion cylinder of necessity has to be kept cool to allow of mechanical operation whilst a steam cylinder is better kept hotter than the steam, to produce economical results; the Still combination of the two is therefore absolutely logical.

Up to this point only the scientific or thermal considerations have been dealt with; what are the mechanical effects and the changes in mechanical parts necessary to allow of the use of a system which can produce such results?

The one point about the Still System which renders it attractive to the Author is the simplicity which can be obtained thereby.

The main mechanical change, namely, the fitting of a cover, gland and valve on the lower end of the cylinder has been mentioned.

There is no difficulty about this, and the arrangement is actually used in one make of two-stroke Diesel engine to allow of air starting on the lower side of the piston, after which the air swept out of the lower part of the cylinder is used to augment the scavenge supply.

There are other essential points and these are the cylinder liner, cover and piston.

Owing to the high temperature of the cooling water, say 350° F., it is essential that the difference of temperature between the water and the inner wall of the liner should be small, otherwise the inner surface temperature will be such as to render lubrication difficult. There is only one method by which this temperature difference can be made small if cast iron is the material to be used in the manufacture of the liner, and that is by making its walls thin. Obviously a thin cast iron liner cannot withstand the bursting stress due to the compression and combustion pressures within the cylinder.

This, Mr. Still has overcome by making the liners with outside longitudinal ribs, on the ends of which a mild steel hoop is pushed, this hoop then takes the bursting stress and the liner is only called upon to bear its longitudinal load and heat stresses.

Longitudinal ribs at practically constant temperature throughout are in the best condition for taking the longitudinal load, and the small temperature differences which exist between any two parts, about 50° F. of necessity, point to the fact that the stresses produced in the liner by temperature are negligible.

This arrangement of cylinder overcomes all difficulties of heat stresses, and being maintained at a uniform temperature from end to end by the jacket, it remains truly parallel and this reduces the friction of the piston rings, as they do not have to breathe in passing from end to end of the bore.

(Incidentally this form of cylinder overcomes many difficulties of the normal Diesel Engine).

The piston, to enable it to part with its heat to the steam easily, is also ribbed on its under side and the steam at entry is projected on to these ribs and in this manner it becomes heated as much as possible, whilst at the same time the piston is maintained at a reasonable working temperature.

One of the questions which is often asked is how much steam is produced by the Still engine. This question, unfortunately, cannot be answered directly, as the amount of steam is dependant upon the quantity of heat wasted by the combustion cycle. This quantity varies with the load, with the type of engine, and the cycle upon which it operates, and in this respect the Author would like to emphasise that the initial advantage of the Still System is that there is a direct gain in efficiency on its combustion side, or, in other words, less heat is wasted and therefore less heat is available for generating steam than in a normal engine operating under similar conditions. It may be stated, however, that the quantity of steam generated in a complete power plant operating on the Still System at full load is somewhere between 15% and 30% of the power generated on the combustion side.

With any type of engine, however, it will be found that as the load is reduced, the quantity of steam available also decreases, until at a very light load, there is just sufficient heat available for maintaining a constant pressure in the steam generator without any steam being used. Under such conditions, however, there is no difficulty in maintaining the pistons at a reasonable temperature, for the amount of heat liberated by the combustion process is not sufficient at such a low load to cause them to overheat.

The steam which is produced, however, is used in the engine to the maximum advantage and under conditions superior to those existing in a steam engine, as has been pointed out in a previous paragraph. The following diagram Fig. 1 shows the effect of the change-over of an average Diesel engine to operate on the Still System. The upper half of the diagram gives the heat flow of the Diesel engine pure and simple; the effect of the Still System upon it is shown by the lower half of the diagram.

It will be seen from this that whereas the Diesel can only convert 31% of the heat value of the fuel used into useful work from the crankshaft, the change-over to the Still System increases this to 40%. This brings up another point about which great doubt seems to exist, as it is often suggested to the Author that such an arrangement must mean complication.

In this paper the marine installation of engines on the Still System is alone being considered, and the Author ventures to

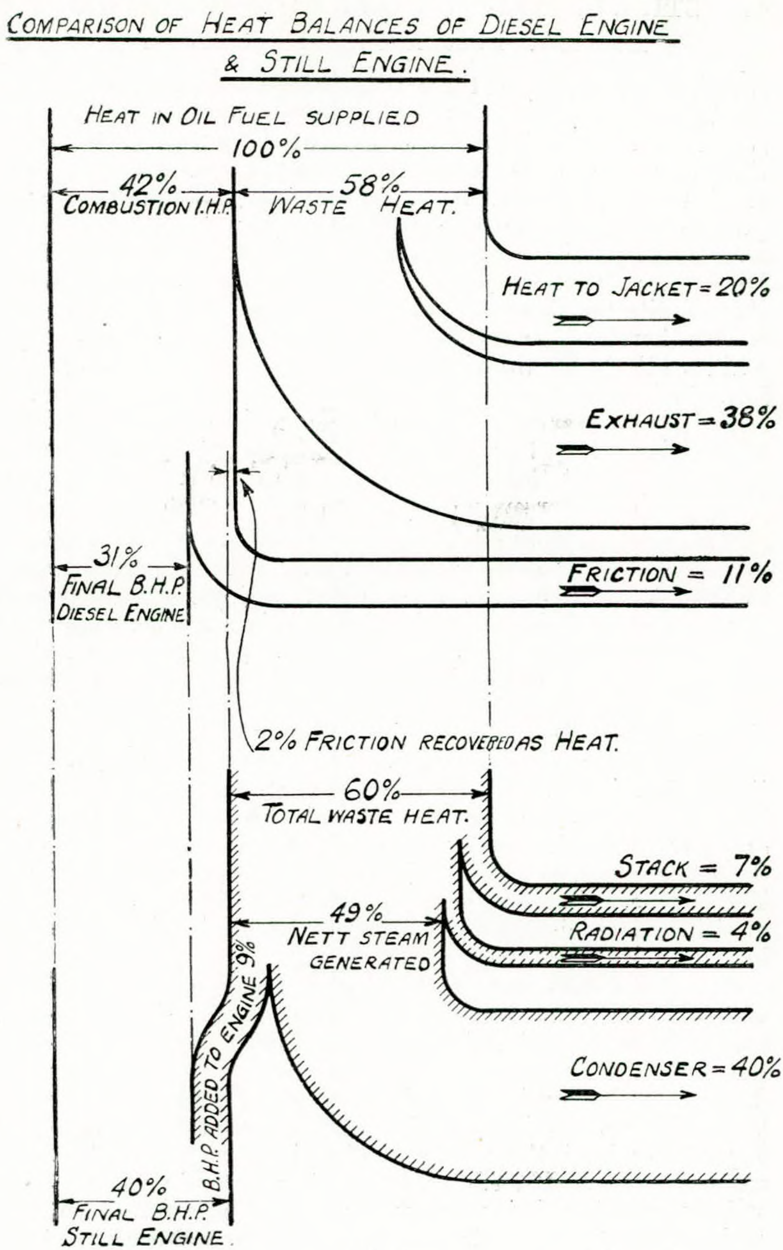
COMPARISON OF HEAT BALANCES OF DIESEL ENGINE & STILL ENGINE.
HEAT IN OIL FUEL SUPPLIED
100%
42%
COMBUSTION I.H.P.
58%
WASTE HEAT.
HEAT TO JACKET = 20%
EXHAUST = 38%
31%
FINAL B.H.P. DIESEL ENGINE
FRICTION = 11%
2% FRICTION RECOVERED AS HEAT.
60%
TOTAL WASTE HEAT.
STACK = 7%
49%
NETT STEAM GENERATED
RADIATION = 4%
B.H.P. ADDED TO ENGINE 9%
CONDENSER = 40%
40%
FINAL B.H.P.
STILL ENGINE.

Fig. 1.

say that if a survey of those Diesel ships which are already at sea is made it will be found that the greater percentage have steam boilers also included as part of the outfit. Obviously these boilers do not use sea water, therefore fresh water has to be carried in large quantities, or alternatively evaporators must be provided and care taken that all steam used is condensed; this entails the provision of condensers. The later installations of Diesels are also making use of fresh water for cooling purposes; this entails the use of a cooler for this water and circulating pumps therefor. It will be seen therefore that a Diesel engine, besides all the auxiliaries necessary for its functioning, will have to have a water cooler, an exhaust silencer (also water cooled), air reservoirs for starting air, a boiler and all the auxiliaries connected therewith; in other words, a duplicate set of plant without the advantage of such duplicate set of plant being available for main propulsion.

Now we come to the Still System. This is given in diagrammatic form with all its auxiliaries Fig. 2. These auxiliaries are those to which, if I may say so, as Marine Engineers we have all been accustomed since our birth, that is in a marine sense, and we know that their care has become a matter of second nature with us and we are so well acquainted with them and they have stood the tests of time so long that they can all be put down as thoroughly reliable and simple, and it will be seen from the diagram that there is no duplication, that there are fewer auxiliaries than is the case with a Diesel engine outfit, and yet they have the added advantage that at a pinch they can be made use of for the operation of the main engine. The fact is, the Still System renders an internal combustion engine a dual system. The engineer therefore has two strings to his bow, the failure of either of which will not necessarily get him into trouble with his executive officers.

One of the worst difficulties from an operating point of view which is being experienced with internal combustion engines at sea at the present time is that due to the presence of water in the fuel oil. This matter is of great moment for the increased demand for fuel oil is not likely to cause the quality to improve, but rather to deteriorate and the presence of water in the oil has of late been the means of stopping two or three Diesel engines at sea. If such an engine has water in its fuel pipe and ceases to fire, it is necessary to re-start on air. If water is still present she will refuse to start and every attempt made at re-starting will only cause a reduction in the cylinder temperature, and this entails an increasing difficulty of starting, and it must be remembered in this respect that it is impossible to inject fuel during the starting period. There is thus no ready means of overcoming the difficulty which has arisen.

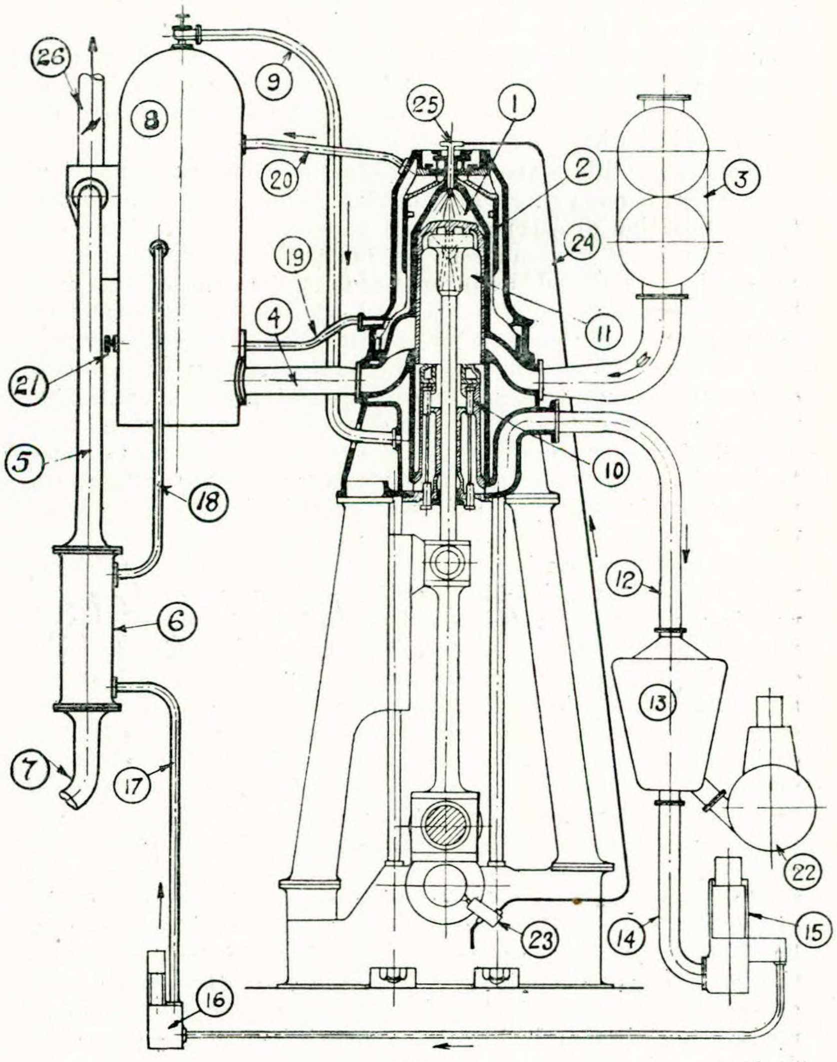

Fig. 2.

The engineer in charge of a Still System engine under such circumstances can be quite happy, for by drawing on his steam reserve and, if necessary, firing up under his boiler; he can wind his engine round under steam with his fuel injection continuing to function until the water has been eliminated from the system and the engine picks up again, and he can be particularly happy because the engine will still keep up at its high temperature, steam being his old and tried friend which is at hand and which he is using instead of attempting to start with a refrigerating medium.

Looking at this matter from a purely commercial point of view, there is one thing which is quite certain and that is, that the installation of a certain shaft horse-power of engines in a ship of the Still System engine will not be more expensive than the equivalent Diesel, as in operation, the saving of fuel will be somewhere between 10% and 20%, the capitalisation of such saving spread over the number of years that a ship is in service, will be found to amount to a very large proportion of the cost of the installation, and under such circumstances it is contended that it is of greater benefit to the shipowner. It should also be a benefit to the engineer who has to run it, because of its greater familiarity, and this brings the Author to one other point which is of great moment with the trend of shipping at the present time.

To-day we are passing through a period of trade stagnation when freights are difficult to obtain, and therefore prices are running low, and everything which will tend to economy should be studied with the utmost care, whether it be economy in first cost, economy in upkeep, economy in running costs. Here again the Still System is of benefit, as not only can its fuel consumption be smaller for a given duty, but the supply of lubricating oil required will be less, and this, as many of you here present know, has been one of the great troubles of many ships fitted with internal combustion engines, and further, as the members of this Institution will appreciate, there are thousands of sea-going engineers with certificates who have been trained in steam and who know steam inside out, all its failings, all its difficulties and its idiosyncracies, for every one there is who has been trained to a sufficient knowledge of internal combustion engines as they exist to-day for the advantageous running of these at sea, and if the number of such ships augments rapidly the difficulty with personnel will increase rather than decrease.

Were such ships engined with Diesel engines on the Still System this difficulty would almost disappear, as the trouble is usually that of auxiliaries and not main engine, and the Author reiterates that such auxiliaries with the Still System are those of the steam engine and not those of the internal combustion engine, and in this respect he thinks that it will be found easier for those at sea, as they will only have to augment their knowledge from the point at which they have arrived on taking charge, instead of having to change their views and begin a new education.

In conclusion, the Author would like to draw attention to the remarks of Mr. Harold E. Yarrow, C.B.E., in his presidential address before the Institution of Engineers and Shipbuilders in Scotland, delivered on the 18th October, 1921. In this he pointed out that the enormous sums spent in research both at the N.P.L. Tank at Teddington and the tanks at private yards on the subject of ships' forms had been remunerative, for the result had been that it was possible to reduce the fuel consumption by 5% which made a difference between "profit and loss"; if 5% of fuel consumption can make this difference in this case, surely the 10% to 20% benefit in fuel consumption obtained with the Still System engine is well worth having.

The CHAIRMAN: I am sure we have listened with great interest to Mr. Martineau, Engineer to the Still Engine Company, who is therefore quite on his own ground. It is very interesting to the steam engineer to hear that the time we have spent over those saturated steam tables is not going to be altogether wasted. There is just one point which struck me—I was discussing the question of the balancing of crank-shafts with Professor Wells. There have been several cases of failure due to fractures resulting from wrong balancing, though the causes have been somewhat obscure—the fracture has often occurred in the web. I was wondering if the fact that in the Still engine you have a mean effective pressure nearer the two extremes than in normal Diesel engines will affect this question of balancing. I do not know whether Mr. Martineau can tell us anything about that?

There is another question I would like to ask—in the drawing office we had a sort of figure giving the "steaming weight" of machinery for the ordinary slow running triple engine, namely, five h.p. per ton, when the boilers were full, condenser full, and water in all the pipes. I should like to know what the "steaming weight" of the Still engine would be.

Mr. F. M. Timpson: I should like to ask one question—does this engine require the use of all fresh water? If you do not use distilled water you are likely to get a great deal of scale. A novel feature of this engine is that the cylinder walls are exposed alternately to oil and steam; has this any effect? As regards the stresses on the crankshaft, it is possible that they might be abnormal. I believe that has been one of the troubles of the Diesel engine, and has been responsible for the adoption of the opposed piston type.

Mr. H. A. D. Acland (Still Engine Company): It is rather invidious to call upon me to join in the discussion, particularly as a number of my friends are in the room and know that I am connected with the Still Engine Company, and I cannot therefore "throw stones" at the lecturer. There is one point of additional interest, regarding the question of oil possibly contaminating the water and thereby getting into the boilers. It is a very serious and awkward bugbear which all steam engineers have had to deal with. The Still engine will suffer from the same if arrangements are not made to prevent it. The quantity of oil used in the Still engine is very greatly reduced as compared with the normal Diesel engine, but it is more than would be used in a steam engine. All possible steps are taken to prevent the oil getting past the rings to the steam side; special oil scraper rings are used, and a filter, in series with the feed pump, acts as an additional safeguard. A further cure may be of interest—I have never seen it adopted elsewhere—in the engine shown in the photograph a small circulating pump is coupled with its suction just below the surface of the water, in the steam drum of the boiler and re-delivers the water through a second filter to the bottom of the boiler. The pump is thereby balanced as regards pressure, and the only work done is that due to friction resistance of the filter. After fourteen days and nights continuous run on that engine the feed pump filter was opened up and found to be fairly dirty. The continuous scumming process had prevented any excessive accumulation of sediment, and Lloyd's inspectors reported that the boiler was in perfect condition and that the filter was good for another fourteen days' running without changing the filtering medium. That was possibly better than any steam job could be. These two means, I think, may be taken to dispose of the risk of lubricating oil getting into the boilers. There is one other point of interest where the Still engine differs from the Diesel or any other internal combustion engine; in a normal engine the main and connecting rod bearings are always subject to a downward load; the direction of thrust on the main bearings throughout combustion and expansion is downwards. In the Still engine the load is reversed by the steam admission at the bottom of the stroke; the load on the bearings is thus made negative, giving the lubricating oil a chance to enter the bearings and ensure efficient lubrication.

Mr. J. H. Graves: There is just one small point not quite clear to me. Could Mr. Martineau give a clear idea of the system adopted to prevent water entering the combustion chamber?

Mr. E. A. Evans: The question of relationship is one which has always given me a certain amount of trouble in the past. When monstrosities occur in families, one is always anxious to know whether the hereditary source responsible is on the side of the father or the mother. I am wondering whether I should find any diamonds in the crank-case of a Diesel engine! Mr. Martineau says that diamonds are very much akin to coke; it is true there is a similarity, but I think it is very much like the monstrosity in the animal kingdom. It rather leads one to suppose that the carbon is very abrasive. I do not think Mr. Martineau intends to convey that idea, but it was suggested to my mind. In the Diesel engine it is true that the carbon does contaminate the oil in the crank-case. As those present may know, I am not an engineer, but my connection with Diesel and other oil engines enables me to observe that designers are taking care to separate the crank-case from the cylinder glands, and the risk is thereby being eliminated. In the few papers which I have had the privilege of hearing, mention has been made of the suitable oil to be used. I wish the authors would not pass over this point lightly by referring to just "a suitable oil for the job." Mr. Acland has suggested that lubrication is a very important item, and I think a little more guidance should be placed in our hands. Mr. Martineau and Mr. Acland have had experience of the troubles incidental to lubrication, and I think their experience should be at our disposal. It is not clear from what has been said this evening what type of oil is being used. Fortunately I have had the opportunity of seeing the engine referred to at Greenock. The question of the vaporising of the oil with the steam had not been brought to my notice, though I had suspected it. I hope that Mr. Martineau when replying, will give us some particulars of his experience on this point. I think the trouble could be eliminated very easily.

Mr. W. McLaren: We are much indebted to the Author. It is a very satisfactory feature of this new combined engine that it makes use of the waste heat, not for making hot water for use on board, but for generating steam for power purposes. I see from the trials that the ratio of horse-power obtained on the steam and oil sides respectively is 1 : 8, actually 41 h.p. from the steam and 340 h.p. from the oil engine, the actual rate of evaporation being only 800 pounds of water per hour. The Cochran boiler I see has a capability of evaporating 2,000 pounds of water per hour. It leads one to ask how is the heat actually obtained going to be augmented. It appears to me that difficulties will arise when considering the design of a large engine with say quadruple cylinders. There is a point regarding the diagrams shown, namely the arrangement of the steam connection right in the crown of the boiler jacket, which appears to me likely to cause trouble due to priming. I am pleased to note that there is a header in between the engine and the boiler. There is a question as to oil getting through from the steam side, but I think that can be easily eradicated. I have had experience of somewhat similar conditions in a steam engine working at 150 lbs. pressure, over a period of some years. By a suitable arrangement of headers the oil passing over was precipitated and drawn off continuously, so that there was no question whatever of oil getting into the boiler. It says much for the designers of the Still engine that they are apparently taking every precaution to prevent trouble from this source. I hope the Still engine will be a great success, as it deserves to be.

Mr. Jamieson: I should like to have heard some comments by exponents of the Diesel engine. Let us get a clear perspective of the subject in hand. The Diesel engine does not require internal water to make it a successful unit. In the Still engine it has been necessary to modify the liner; that form of liner will be the subject of much experiment before the engine is right. With regard to what the Author has called the "waste heat," I think it should be called "wasted heat." The question of the utilisation of exhaust heat is by no means new, but it is new to the Diesel engine world. In gas engines the heat available from the exhaust is 50 to 80 per cent. higher than that of the Diesel engine.

It is an accepted dictum among large builders of Diesel engines that the combination of steam and oil is not a perfect combination, because there is a tendency to get the weaknesses of both types with the advantages of neither, and that compromise is not possible. History teaches that you cannot compromise without great danger and considerable expense. So far as the internal cooling of a large engine goes, if we can already run the greater part of six months without a stop, and with a piston diameter of 40ins., I think the case for the necessity of internal cooling rather falls to the ground. I do not say that it is not desirable in stationary work, but in marine practice; you must have auxiliaries, and these are preferably electrically-driven. It is a complicated job, even in a small unit of 400 h.p. Mr. Martineau proposes to utilise steam for manœuvring when the engine gives out, but I do not think this will be either practicable or economically desirable. With regard to the Author's claim that a saving of 20 per cent. in fuel will be possible, speaking as one who has had fourteen years' experience I cannot quite agree with the figure arrived at, and I doubt very much whether a saving of even 10 per cent. will be effected.

Mr. Shackleton: This subject is very interesting to me, and I have previously studied very carefully the figures given in Mr. Hutchison's recent paper. It appears to me that a lot of oil must have been used in the burners on the job, but no figures were given; could Mr. Martineau give those figures? I made certain assumptions, namely, ·28 specific heat of gas, 30 lbs. of air used per pound of oil in the engine. We get some of the very efficient Diesel engines to-day working at a temperature of 700°F. I cannot imagine any steam being raised at such a low temperature as that. Even in an economiser a very usual temperature is 800°F. I am not sceptical, and I see many advantages in the Still engine, but with regard to the suggestion which has been made that this engine, being provided with a boiler, can run when there is anything wrong with the engine on the oil side, I cannot imagine the boiler, which has only about 300 sq. ft. heating surface, being capable of driving the engine. I should be particularly interested if Mr. Martineau could tell us how much oil was used in the experimental engine. I have enjoyed the lecture, and wish to express my appreciation.

Mr. G. J. Wells: The paper to-night is a most interesting one. The action of the heat engine depends upon the temperature difference of the expanding medium at the beginning and end of the cycle. Many years ago it was noticed that the lowest temperature for successful working was 120°F. In Cotterill's book on the steam engine there are accounts of experiments which were made to obtain some of the work which was being wasted due to the heat left in the exhaust gases. These experiments did not succeed because the cost was much greater than the gain. Other attempts were made from time to time, until the advent of the internal combustion engine, which has greatly widened the field. Economies may now be effected which were not possible with the old type steam engine, because we are dealing with much higher temperatures in the engine cylinder. In the Still engine we see a good attempt to make use of the higher range of temperatures. Certain little details in the paper ought, I think, to be corrected. There is undoubtedly a great future for an engine of this type. The commercial test will be the important one. I see a statement made to the effect that steam is generated in the jacket at 100% efficiency. If we can do that we are approaching the ideal of perpetual motion! The temperature of the gases would be about 2,000°F., and the amount of heat recoverable in useful steam cannot be more than 7/8ths of this. At any rate there is a very considerable loss because to get 100% efficiency you must supply the heat to the hot body at the same temperature. The next point I would like to criticise is the diagram in which are shown together comparative engine and boiler efficiencies. Some 10 or 15 years ago tests were made with an engine of 8/15 h.p., and the results showed a consumption of 14 to 15 pounds of steam per horse-power hour; by means of superheating the steam the figures were reduced to 9 to 10 pounds. This shows that, in considering the sheet of diagrams, before one can draw any useful conclusions, one should separate each portion of the plant; for example, the boiler efficiency is often confused with the efficiency of the combustion. If you force the rate of combustion, incomplete combustion will ensue. A paper read by Mr. Lawford-Fry before the Institution of Civil Engineers, giving the results of a number of very careful experiments, showed that 70% was the mean boiler efficiency recorded. The rate of evaporation varied from 40 to 140 lbs. per square foot of grate area per hour. The overall efficiency of the plant was 47 to 48%, and the absolute quantity of heat utilised was in the neighbourhood of 70%. It is a well-known fact that you can get different efficiencies by different stoking, and in the diagram shown by Mr. Martineau you can recognise in two or three types of installation, totally different conditions as regards the engines and boilers. I do not think it is possible to draw satisfactory conclusions from such comparisons. With reference to the lecturer's remarks concerning the unequal expansion at the two ends of the cylinder liner in a normal Diesel engine, which he claims is eliminated in the Still engine, I think this point is rather exaggerated. The temperature differences he quoted, namely 200° at the top to 70° at the bottom of the liner, cannot be right. Even if it were so, this range of temperature over a metal liner is of little or no importance, as experiments carried out in 1900 by Mr. Hudson, of Messrs. Hick, Hargreaves & Co., and others later in 1910, by Professor Dalby have proved. The real difficulty occurs where you have a gas on one side of a place at a very high temperature, and on the other, water at a very much lower temperature. In the experiments by Mr. Hudson and Professor Dalby the records showed a temperature of 2,000° in the flue tube which fell to about 40° on the steam side of the boiler. If you have water in a pan and try to boil it, you cannot burn the pan; there must be a very cool film between the gas and the plate. The law of nature must be observed, and therefore I think the lecturer's reference to a temperature difference of 200° to 70° must be a figure of speech.

I agree with Mr. Timpson that there may be trouble due to deposit or sediment as found in ordinary gas engines.

In another diagram shown on the screen I noticed that the mean pressures run up to 140 lbs. per sq. inch—that seems to me rather high.

A previous speaker has questioned the amount of steam that should be produced from the exhaust gases. There is an answer to that on the chart at the end of the paper. The amount of heat wasted is 58%. It should be possible to make good use of that and obtain 10 to 12% increased efficiency. The claim made in respect of the experimental engine is a gain of 9 h.p. The chart I have mentioned should show some light on this question.

In the foregoing remarks I have criticised freely, and I have given some reasons for my criticism, but the subject is a very interesting one. Experiments are now being carried out by Mr. Still's company which are being followed with keen interest by engineers generally, and I think the number present here this evening shows the interest taken by the Marine Engineer especially. All of us will be extremely pleased to see Mr. Martineau here again later, and to hear the history of the Still engine's progress. I wish it every success.

Mr. W. McLaren: Before the Chairman calls on Mr. Martineau to reply, I was hoping that someone would raise the question as to the effect of the new system on the engineroom personnel. The point will arise: how are the steam and oil certificates going to be dealt with, and who is going to be in control. The steam engineer is a little offended because he has not been given an oil certificate in return for his services to his country during the war.

The Chairman: Mr. McLaren's remarks are very much to the point. A remark in the paper brought it to my mind, that it would be simpler to deal with the Still engine because of the similarity in general design to the steam engine, particularly as the auxiliaries are those of the steam engine. I do not think we need fear any difficulty regarding the steam engineer's capacity for adapting himself to the new conditions. I think the engineer to-day can deal with almost anything; his training is so comprehensive. In my younger days we thought we were great swells, those of us who could boast of being able to use the differential and integral calculus, whereas to-day we find boys of 16 and 17 using the calculus as a matter of course.

I will now ask Mr. Martineau to reply to the points which have been raised.

Mr. F. L. Martineau: The Chairman in making the opening remarks dealt with the question of the vibration of a crank shaft. The question of torsional vibration is really a very complex subject, and it is dependent primarily upon the impulses given to the shaft and the natural period of vibration of the shaft itself. If the impulses happen to synchronise with that vibration, it means "good-bye" to the crank shaft! The only things to do to destroy the synchronism are to design the shaft with a period which cannot synchronise or have the shaft out of balance to give a variable periodicity.

As regards the Chairman's query regarding the horse-power per ton, there can be so many types of engines built on this system, and they can be run at such a large range of speeds, that it is hardly possible to arrive at such a figure as the Chairman desired. The Still Engine Company built a test cylinder which ran at 360 revs. per minute and developed 300 shaft horse-power;

the total weight of plant in the engineroom worked out at 39 lbs. per horse-power, or 57 h.p. per ton. On the other extreme you may get only 7 h.p. per ton. For normal marine work the figure would range from 7 to 14 h.p. per ton.

Mr. Timpson raised the question of distilled water for the jackets. Of course it is desirable to use fresh water, and to use it over and over again. The question of scale formation was one which the engineers connected with the Still Engine Company feared might give trouble in the liners, but it was found that, although water of a high degree of hardness was being used, there was no scaling in the passages between the ribs of the cylinder liner because the rate of circulation of the water is so great that the sediment, if any, is carried over to the steam drum. The other point raised by Mr. Timpson, as to the influence on the cylinder wall of the combustion at one time and the steam at another, experience shows that as the result of thousands of hours running, the surface of the cylinders becomes a glass-hard surface, like the surface of a mirror, and no trouble whatever has occurred on this score.

Mr. Graves asked whether there is trouble from water entering the combustion chamber. Considering that the products of combustion are largely water, the question does not arise.

I quite agree with Mr. Evans that those who are versed in the subject of lubrication, should keep closely in touch with developments on the engineering side. In our research laboratory at Chiswick, we have found that the best is one of the lubricants which contains graphite. I shall be very glad to talk the matter over with Mr. Evans.

Mr. McLaren raised the question of the size of the boiler used by Messrs. Scott in the installation at Greenock. This boiler is much too large for the particular cylinder, but it was their intention to add another two cylinders later. In that way the same boiler would have been suitable for the three cylinders. As regards Mr. McLaren's question of priming, the release of steam occurs at the normal water surface of the Cochran boiler, and as the quantity of steam released is well within the capacity of the boiler, it is evident that trouble should not accrue from this cause. If it did, the Cochran boiler would not have the name it has for being a reasonably good boiler.

Mr. Jamieson mentioned that the Still cylinder liner will require considerable experiment before it can be right. Perhaps it may be of interest for him to know that some twenty cylinders of varying sizes up to 22in. diameter have been built, and run many thousands of hours since the year 1912 and none of them have so far failed or caused trouble even at extraordinary overloads. Mr. Jamieson also remarks that the use of exhaust gas from gas engines to raise steam is well known; so it is, but the waste heat to the jacket is not used, and if the one is worth obtaining, why not the other?

It is sad to learn from Mr. Jamieson that the builders of large Diesel engines have an "accepted dictum" that the combination of steam and oil tends to produce the weaknesses of both. As a matter of fact, it eliminates the difficulties of both from the mechanical and theoretical point of view and does what all designers of heat engines desire, namely, it increases the temperature range of the cycle. Mr. Jamieson also considers that compromise in engineering is dangerous: is not the whole of engineering design a question of compromise between various ideals to obtain the best commercial results?

Regarding Mr. Jamieson's remarks on internal cooling, I do not know whether he is under a misapprehension. Surely steam, if it can be used for cooling a piston, is better than water, because water puts up the weight of the reciprocating parts, which means a heavier crank shaft and a heavier engine all over. Another trouble is, that it is necessary to convey water to the piston for cooling, this entails considerable complication and running joints which are often the cause of much trouble, due to water hammer.

With regard to the other point, where Mr. Jamieson referred to existing engines with 40 in. pistons running perfectly, the question is—at what mean effective pressure are they working? We desire to run at 120 lbs. M.E.P., whereas the engines mentioned are working at 50 to 60 lbs.

Mr. Jamieson also thinks that the gain in consumption will not be 10%. Is it not preferable to believe what has been found by actual test and experience by such men as Captain H. Riall Sankey, C.B., C.B.E., rather than what Mr. Jamieson, who has never run a Still system engine, thinks.

The next point was raised by Mr. Shackleton as to how much oil the auxiliary burner was using when the engine was running. The reply is that the burner was not in use. As regards the temperature of the exhaust gases, which is about 800° F., there is no difficulty in reducing the temperature from 800° to 50° above the steam temperature, and that is what is actually done.

Mr. Wells spoke about the range of temperature, and the method suggested by Professor Cotterill for obtaining more useful work therefrom. The same method exactly is being used by the General Electric Company in the U.S.A., who are using mercury in a boiler, the vapour of which is employed in a turbine and afterwards condensed in a steam boiler, the steam from which operates other turbines. In this manner the upper limit of temperature is increased and the overall efficiency of the plant raised to about 25%. In the case of the Still system a bigger range of temperature is being used than has ever been done before, namely, from 2,000°F. to the lowest temperature of the exhaust gases, roughly 200°F. This whole range of temperature is used and is the reason for the high efficiency obtained.

Mr. Wells considers that the proportion of total heat transmitted to the jacket, water from the cylinder cannot raise steam at 100%, as this heat can be measured by the amount of steam generated, it is evidently correct. Mr. Wells has even then not reached perpetual motion, as after all, it is only some 10% of the total heat and cannot give up its energy without loss.

I was not quite certain as to what was Mr. Wells' point regarding the diagram on the sheet. It was intended to show that a bad stoker can often spoil the efficiency of an engine. In the Still engine you cannot have bad firing, because the engine does the firing for you. With regard to the varying temperatures in the cylinder liner, there is in a Diesel engine considerable difference in temperature—the top end of the cylinder is in contact with the flame for a greater period than the bottom, and the rate of heat flow is greater at the top. The temperature of the metal of the cylinders is controlled really by the difference in temperature of the two sides—between the temperature of combustion on the one side and the temperature of the water on the other, and there is less difference with the Still system. As regards the high M.E.P. given in one of the diagrams, that diagram was taken from an engine on trials and the maximum M.E.P. used was 163 lbs. per square inch, and was merely for the purpose of research work.

In conclusion, Gentlemen, I thank you very much indeed for your attention.

Mr. HEASLEY: I think you will all agree that we have had a most interesting paper on a subject which appeals to us all. I am associated with Messrs. Alfred Holt and Co., and I came here to hear something more about this new engine, which my firm are taking up in connection with one of our new vessels. I have great pleasure in proposing a hearty vote of thanks to Mr. Martineau for his lecture.

Mr. WATSON: I have much pleasure in seconding this vote of thanks.

Mr. MARTINEAU: I am quite certain of one thing—that my talk to you to-night has not given more pleasure to you than it has to me, and I shall be very pleased to come again, as one of your members has very kindly suggested, if you so desire.

The CHAIRMAN: Before closing, our thanks are due to Messrs. Redman and Whiteside for so ably assisting with the lantern.

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ILLUSTRATED LECTURE. LADIES' NIGHT.

"On the Trail in Mexico."

By C. WILLIAMSON MILNE.

Tuesday, March 7, 1922.

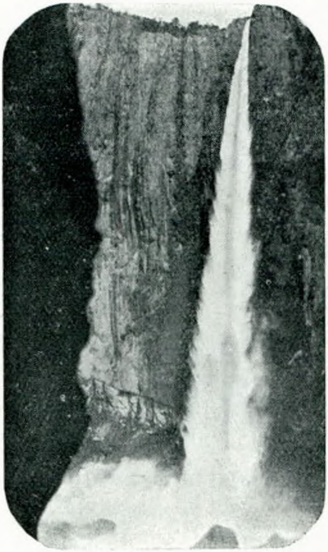
CHAIRMAN: J. R. RUTHVEN (Member).

WE were indebted to Mr. C. Williamson Milne for his courtesy in sparing time to give us the benefit of his observations in Mexico, with illustrations from his camera, resulting in a pleasant evening to all present. A view of the map gave indication of the route taken to reach Mexico and of the comparative areas of Britain and the lands beyond. The area of Mexico was stated to be 767,090 square miles; the frontier on the United States of America 1,993 miles; population 15,000,000, consisting of 2,862,000 whites, 6,477,000 mixed race, and 5,724,000 Indians. The two chief ranges of mountains are: on the east Sierra Madre Oriental, and on the west Sierra Madre Occidental —a continuation of the Rocky Mountains. The chief peaks being Popocatapetl, an extinct volcano, and Oxtaccihuatl, each about 18,000 ft., Orizaba 18,225 ft., Colima 12,750 ft.—the only active volcano in the North American continent. The rivers are not navigable for any distance for large vessels, but serve the important work of irrigation. The Rio Grande rises in Colorada with a stretch of 1,500 miles; Rio Lerma in Toluca,

1.—Cathedral and Plaza—City of Chihuahua.

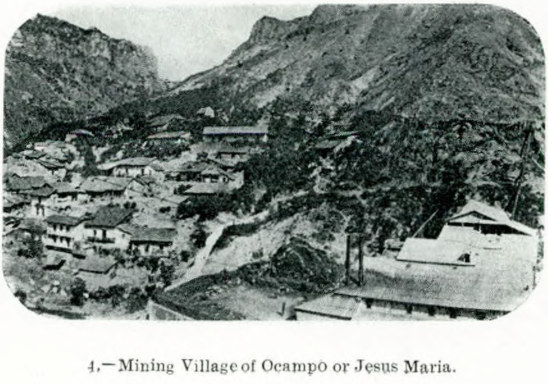
2.—Mr. Milne in travelling rig.

passes through Lake Chapala to San Blas, then over the falls of Inanacathan, 540 miles; Panuco, on which Tampico is situated; Rio Balsas, 426 miles; Papalcapam, the chief tribu-



3.—Falls of Basasiaschie—height 950 ft.—State of Chihuahua.

tary, is the Rio Tinto, the most remarkable river in Mexico, in some places the depth is 500 ft. and the average 60ft., but vessels cannot go up the Papalcapan, which is rapid and shallow.

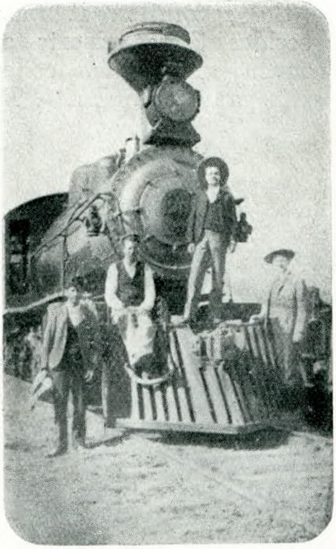


4.—Mining Village of Ocampo or Jesus Maria.

The ports on the Atlantic coast are Veracruz, Tampico, Puerto Mexico, Progreso, Tuxpan, Frontera; and on the Pacific, Salina Cruz, Acapulco, Manzanillo, Mazatlan, and Guamas. The main export is oil, of which Mexico is the world's third largest exporter, and before the revolution it was the largest exporter of silver; besides these exports are gold, copper, lead, rubber, henequen and ixtle, coffee, hides, sugar, tobacco, cattle, mahogany, vanilla. The imports em-

5.—Caved in workings, Waterson Mine, Ocampo.

brace all kinds of goods, which the large exports quite warrant, and this illustrates the principle that the country which can, by combined economical effort produce what others require, may also advantageously purchase what is necessary for its own needs. The trade of Mexico is mainly with the United States of America and is 60 per cent. of the total, Germany used to come second, and was followed by Great Britain. The problem in connection with this is worth pondering over from several points of view; transport, economic production, efficiency and delivery on time limit, and with regard to these, many fallacies are launched forth around the world, causing cessation of work and lowering of the dignity of labour, leading to lessened production and enhanced cost of the finished articles —this by the way.



6.—Mexican Railway Engine at Minaca' State of Chihuahua.

7.—Group of Staff and Employees, Waterson Gold Mine, Ocampo.

The industries of Mexico are mining and agriculture, cotton mills, cement works, iron and steel works, breweries, cotton growing. The railways cover a large area of country, and embrace 8,000 miles of line. The illustration shows one of the locomotives, which is of large size, about double what we are accustomed to, the cow catcher is a fitting part to observe, also the electric head light and the warning bell.

8.—Transport in the Sierra Madres.

In order to carry out the undertaking of examining the country and the mines amid the mountains, the mule is the best means of transport, and the illustration shows Mr. Milne mounted and ready for the road. The pathways vary as does

9.—Ruins of Cathedral at Bacis, State of Durange.

the scenery; some of the views shown were pleasant to look upon and a few are reproduced. At a halting place on the way a cave was shown and described; in it had lived a padre who devoted himself to help the Freighters who passed his way, and to signify their appreciation of his kindness these muleteers had placed hundreds of little wooden crosses in and around the cave. The service of the Mexican buzzard was commented upon as nature's scavenger to clear the atmosphere and sweep away debris prolific of hurtful germs.

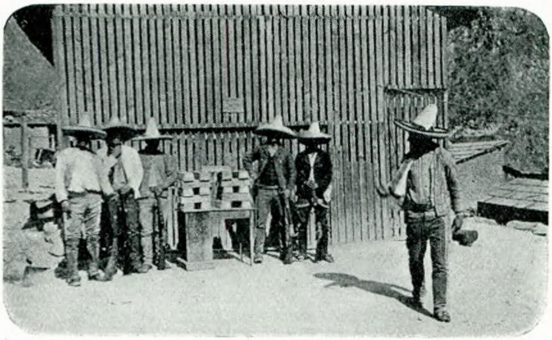
Several views of mountain scenery were shown and of these a few are reproduced; also one of the falls of Basasiaschie, 950 ft. high, for contrast the height of St. Paul's Cathedral was given, 375 ft., and of the Eiffel Tower, 985 ft.

10,—View of the Bacis River, State of Durange, taken from an altitude of 3,000 ft.

Views of Mexican villages showed the types of housing; these were followed by a most interesting troop of mules linked together by a long length of wire cable, each mule with a coil on its back, the next following on bearing a similar burden, up hill and down dale to the appointed place. Views illustrating the different types of men met with were shown, North Mexican Indians, mixed races and whites. A few of the prominent men met with were described in humorous terms, on account of their peculiarities and temperament. The road down the Aroya or River Bed, towards Ocampo and a general view of the place were shown, then the Waterson gold and silver mine, the stamp mill, cords of wood, ore carriers and wire ropeway, the adjoining church with its belfry and three bells suspended on raw hide thongs, the wonderful tone of the bells was commented on. The difficulty of transport in the mountains was illustrated by views of a steam boiler being carried downhill in a cradle by a crowd of men. Mines and mills, miners' cottages, groups of officials, a monkey-man, reminding one of the missing link and of Darwin's study. In the semi-darkness the traveller's experience of the prickly pear was related with humour. The signs of a gathering storm of rain were shown in the sky, followed by the sudden results of rush of water and the rise of the river by 30ft. in one night, the dam and intake, with the stamp mill after the flood. The mine manager's house, with the manager foreman, and Mr. Milne; also the views of the mountains and the river were pleasing to see on the screen. An old adobe cathedral of unknown ancient time was interesting, so also the views which followed. The bullion escort called for special attention and the sterling worth of the men who formed it, with incidents of their experience to safeguard the treasure entrusted to them.

11.—The coming storm as seen from the Mine Manager's house on hill top.

The two Rurales or mountain police attached to the mine, forming, as Mr. Milne said, the 1st and 2nd army corps; homeward bound guide with family group; Mexican fashion of grinding corn; a primitive plough; water wheel for irrigation; branding cattle; a group of wild horses with fine flowing tails, their beautiful eyes being commented upon. The delights associated with motoring in Mexico were impressed too deeply to be readily forgotten. The view of Mexico city evoked a descriptive sketch from the days of the early printing press and newspaper, 100 years before the Pilgrim Fathers landed at Plymouth Rock. The city is 7,347 ft. above the sea, too high for extreme heat and too far south for cold; the Zocalo, the principal square in the city, with a view of the Cathedral. One of the finest tramway services in the world is to be seen here. The Cathedral is built on the site of the old Aztec temple, in which the forefathers of the present Mexican people offered up human sacrifices, hundreds in a day. A view of the cathedral at Chihuahua, together with the Plaza or square and an evening concert of instrumental music provided by a convict band with a descrip-



12.—Bullion with armed escort and leader.

tion from Mr. Milne of the customs of the Mexican people, was appreciated. After showing a view at El Oro, 10,000 ft. up, the last place in Mexico which Mr. Milne visited before turning for home, he concluded his lecture—or as he preferred to call it his "Travelogue" on Mexico—with a recommendation to his hearers not to lose any opportunity which might present itself to them of visiting that most interesting country. The report of the excellent lecture—added to by a few of the views—lacks the personality and humour of the lecturer which prevaded it, yet may convey much matter of interest regarding the country and its environment.

The Chairman expressed the pleasure with which he had listened to the lecture, and felt assured that this had been the experience of all. The views and description had been very illuminating. Many revolutions had taken place in Mexico, but it was clear that there were good workmen, who took pride in their work and in their tools. The food was chiefly maize. The wire cables reaching across from the mines to the crushing plant; the difficulties connected with transport; the peculiar native hats or Sombreros of high conical shape and tremendous weight; speedy delivery of telegrams and cablegrams; quick changes of seasons and downpour of rain; the recruiting of the Rurales were points that impressed me; also the episode, during the revolution, where the men entrusted with the transport of gold were pursued, and to save it buried the treasure; the officer in charge was caught by the revolutionaries and refused to reveal the spot, submitting to be hanged rather than betray his trust. Fortunately he was rescued just in time to save the situation.

Mr. B. P. Fielden: I have much pleasure in proposing a vote of thanks to the lecturer for the enlightening and pleasant evening we have enjoyed. Those who have sailed along the coast line and have not had the opportunity of entering beyond the confines of the ports, have now been shown, with informative references, what the country is like in the interior. The important oil industry appeals to us as a point of interest, when we consider the question of how the growing demand is to be met and what we can export to pay for the oil we import or buy at out-ports. It is valuable information to obtain particulars of countries, such as Mexico, with which we exchange transactions in trade and commerce, and besides getting information at first hand from Mr. Milne, we have enjoyed his illustrated lecture and heartily accord our thanks.

Mr. A. Jobling: In seconding the vote of thanks to Mr. Milne for the delightful reminiscences of his travels through Mexico, I may say it has awakened very vivid recollections of a prolonged stay I once made in the vicinity of Tampico, and from my little experience of the district I can endorse all that Mr. Milne has said about that charming country. He has told us very little about his hunting experiences; these must have been as delightful as they were in my case. As each week-end came round it found me seated on the cow-catcher, similar to that shown on the screen, of one of the down goods trains, with a Winchester and a pocketful of sandwiches. The good humoured driver would obligingly drop me off at any likely spot that showed a promise of sport. It was during one of these trips, after being lost for hours in the jungle, that I first learnt to appreciate the drink that made Milwaukee famous. The creature that so perturbed Mr. Milne at night might have been one of those hideous iguanas, which are numerous in Mexico. It was one of these creatures that interested itself in my efforts to obtain a hanging nest 30 feet from the ground, and as it had intruded itself between me and safety I had to wait until one of the boys shot it. The country seems to be as varied as the wild life upon it, as you may cut your way through a jungle to find beautiful park like scenery open before you, reminding one of the countryside at home.

I think we have all highly appreciated the lecture and the splendid slides, and I heartily second the vote of thanks.

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Notes.

The following is quoted from "The Coal Merchant and Shipper" of April 1st:—

REDUCED USE OF OIL FUEL IN THE UNITED KINGDOM.—It will come perhaps as no surprise to our readers, says the "Petroleum Times," to hear that the use of oil fuel for industrial purposes in the United Kingdom is steadily on the decline. The fact is, that with coal at its present comparatively low price, it is impossible for oil fuel to be profitably utilised in its place, excepting for very special purposes. Quite a large number of the companies who had planned to discard coal, find it to their advantage not to change, while others who have been using oil under boilers for a long time are now going back to coal, simply because of the question of price.

There would be, we know, says our contemporary, a tremendous demand for oil fuel if it were one-half its present price, but even with the temporary lowness of ocean freights, so many matters have to be taken into consideration which affect its cost to the consumer on this side of the Atlantic, that it is impossible to hope for anything approaching a material cut in quotations. There may, of course, be some reduction shortly, but nothing but a wholesale break-up of present prices will cause oil fuel to oust coal for industrial purposes in this country. On the one hand, we are too near the coalfields; on the other, we are too far removed from the centres of heavy oil production.

There is no change to report yet in the London market, but prices have been advanced in the United States. Furnace fuel oil is quoted at £3 12s. 6d., and Diesel fuel oil at £5 the ton, naked, ex-wharf. The delivered prices are 10s. per ton more.

The Anglo-American Oil Company's fuel oil prices are:—Furnace fuel oil, 72s. 6d. per ton, ex-installation; Diesel fuel oil, 100s. per ton, ex-installation; furnace fuel oil delivered, 82s. 6d. per ton; Diesel fuel oil delivered, 110s. per ton.

For Ireland, furnace fuel oil, 112s. 6d. per ton, delivered; Diesel oil, 140s. per ton, delivered. The above quotations refer to oil in bulk.

An article on diamond drilling for oil in Mexico which appears in " Oil, Engineering and Finance," of March 25th, is specially interesting after the lecture by Mr. C. W. Milne. It is all the more so, in view of the demand for oil which has increased of recent years. The article is by Frank A. Edson, the pioneer of the application of the system described.

The well referred to is in the Parnico district, about 40 kilom. from Tampico, and the whole process of dealing with the boring and working arrangements, including costs, is described in detail.

There is another interesting article in the same issue, on "The Chemistry underlying the Theories of the Origin of Petroleum," in which the writer analyses and reviews the theories generally put forward to explain the presence of petroleum found in the various areas.

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Election of Members.

Members elected at a meeting of the Council held on Monday, April 10th, 1922:—

Members.

Arthur Robertson Downing, 7, Brunswick Place, Aberdeen.

Richard Frederick Francis, 41A, Broomfield Road, Surbiton, Surrey.

Herbert George, *c/o* Butterfield and Swire, Hong-Kong.

John Longstaff, 28, Christopher Street, Sunderland.

Herman Luhrs, 52, Moorside, Fenham, Newcastle-on-Tyne.

Bernard William Lund, 1, San Remo Parade, Westcliff-on-Sea.

Kenneth McIntyre, *c/o* Butterfield and Swire, Hong-Kong.

Frederick Richard Morris, 15, Elmwood Road, North Dulwich, S.E.

Ernest Murdoch, Comm'd. Engr., R.N., H.M.S. " P.38," Portland.

Alfred Colston Rees, 57, Gracechurch Street, E.C.3.

Bernard Dennitts Smith, 57, Dangan Road, Wanstead, E.11.

William Steele, 41 Granville Road, Stroud Green, N.4.

Arthur Howell Thomas, " Carningli," Priory Street, Cardigan.

Associate Members.

Harold W. Bugg, Villa Ons Nestje Heide Calmpthout, Antwerp, Belgium.

Robert Jolly, 122, Leadenhall Street, E.C.3.

George Smith, 5, Tantallon Terrace, Ibrox, Glasgow.

Arthur Whiteley, 30, Wood Street, Deansgate, Manchester.

Associates.

Walter John Stride Collins, 1, Park Place, East Greenwich, S.E.10.

Stanley James Johnston, New Zealand Shipping Co., Royal Albert Dock, E., and 24, Earls Terrace, Wellington, N.Z.

Graduates.

David Edward Davis, Sunnyside, Albert Road, Clydebank, Glasgow.

Alexander Davis Bean, 732, Dumbarton Road, Dalmuir, near Glasgow.

Companion.

Henry Charles Chandler, 12, Upper East Smithfield, E.1.

Transfers.

Associate-Member to Member.

Charles B. Barnett, Canton House, Church Street, Great Malvern.

Graduate to Associate.

James A. Robertson, *c/o* Mrs. Johnson, 39, Somerby Road, Barking, Essex.

* SIR GEORGE J. CARTER, K.B.E., J.P.

It was with great regret the announcement of the death of Sir George Carter, on February 9th, was received. He was elected a member in October, 1913, was one of our Vice-Presidents from 1918-1921. Born in 1860, he served his apprenticeship in Portsmouth Dockyard. Subsequently he was appointed assistant manager by Messrs. Armstrong, Whitworth & Co., at Elswick Shipyard, and in 1894 was promoted manager. In the course of his management the development of the business and the extension of the firm's operations at Walker-on-Tyne, came under his jurisdiction, the successful carrying out of the work

* Portrait reproduced by the courtesy of the *Shipbuilding and Shipping Record*.

resulted in him being elected to the Board of Directors. After about 25 years service with Messrs. Armstrong, Whitworth & Co. he received an invitation to join Messrs. Cammell, Laird & Co., as manager of their shipbuilding yard at Birkenhead. This he accepted and carried on the work with an energy which was highly appreciated and acknowledged, when he was elected Managing Director. During the war he devoted himself to assist in the shipbuilding problems, when acting as President of the Shipbuilding Employers' Federation. The excellent service he rendered to the Federation of British Industries is well known and has been commented on from time to time, his wise counsel and comments in regard to industrial labour are well worth pondering over for the National good, while the example of his life, his energy and organising ability stand out as a basis for all.