INSTITUTE OF MARINE ENGINEERS
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1925-26.

President: LORD INVERFORTH, P.C.

VOLUME XXXVII.

Fuel Injection.

BY CECIL HUGHES (Associate Member).

READ

Tuesday, December 22, at 6.30 p.m.

CHAIRMAN: THE HON. SECRETARY.

The CHAIRMAN: I have much pleasure in introducing Mr. Hughes, who is bringing a very interesting subject before us to-night. He has just returned from America where his demonstrations have been very well received, and it remains for us to give careful consideration to his proposals as affecting their applications in this country.

Introduction.—My recent five years of practical research connected with this subject, have enabled me to discover many new features (or at least new to me) referring to the pumping and injection of liquid fuels into internal combustion engines.

When I first started my investigation in this direction, for a sound means of dealing with liquid fuels I was fully cognizant of the infinitesimal extent to which liquids may be compressed, but had I then treated this law with much greater respect my objectives would have been most certainly achieved earlier.

The foundation of an injection system will only be found in the apparatus which puts the fuel under pressure, for on this alone depends the accuracy of metering against a head, which is the most essential part of the whole system, much more so when applied to engines which, as well as having to deal with various loads, have a range of speeds. Assume that at one period an engine will be idling and demanding say 50 c.c. per minute, and within the next few moments will be under load and will consequently be demanding, say 1000 c.c. per minute, it will then be clear that this sudden change of demand calls for a system which must be, one might say, "intelligent," particularly when the discharge pressures must be high, so as to provide that much sought after highly stratified vapour, which will enable an engine to put to best account the heat value of the fuel used.

It is a very simple matter to meter even small quantities of fuel when using low pressures and comparatively large jet orifices. It is also easy to obtain heavy pressures by various means, but it is another problem entirely to meter infinitesimal quantities under heavy pressures, such as are necessary to fulfil the requirements of the internal combustion engine.

I have learnt at much cost that fuels when under vacuum should be treated with the greatest suspicion, as the vacuous conditions which obtain at intervals in the ducts and suction sides of pumps, aid volatilization of fuel. This is particularly marked when pumping any of the paraffin series at slow reciprocations of a ram pump, for then volatilization of fuel becomes rapid, and often is the direct cause of a loss both in volumetric efficiency and in pressure. The fact that at a higher number of reciprocations this trouble is not so pronounced is a confirmation of this.

In one of the final forms of apparatus which I have completed for fuel injection purposes, I claim a pump having a variable or controllable discharge, without the necessity of altering the stroke or bye-passing, which has no packing, and is capable of supplying predetermined pressures, which are adjustable over a substantial range.

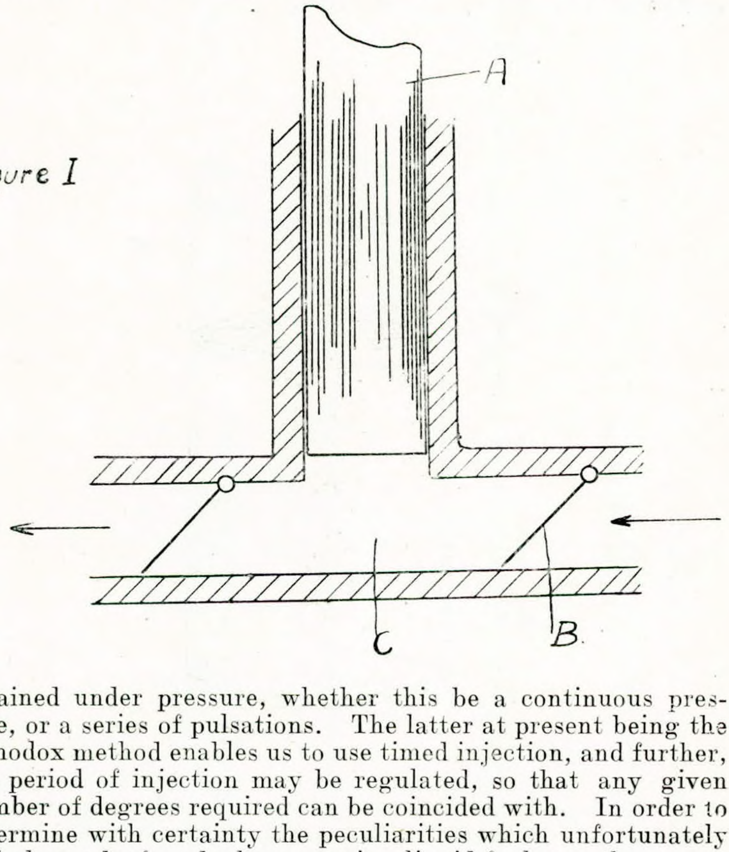
It is capable of functioning perfectly when driven at speeds varying from ten to ten thousand reciprocations of plunger per minute, and further, it maintains high efficiency at these speeds. The volumetric efficiency, when using certain pressures, gives as much as 40 per cent. above the apparently limiting 100.

I make no statement as to the actual benefit derived from such freak volumes obtained by a ram pump having certain duties to perform, but treat this as a point of interest apart.

In this paper I will endeavour to describe the functioning of my latest designs, but before doing so, I will explain the inefficiencies of my earlier experimental designs, which may allow the final arrangement to be better appreciated.

Fuel Injection.—Before attempting to consider the manner in which we can inject fuel to the best of advantage into the combustion chamber of an internal combustion engine, it is essential that we first of all determine the behaviour, under all conditions, of the pump, or the means whereby fuel can be

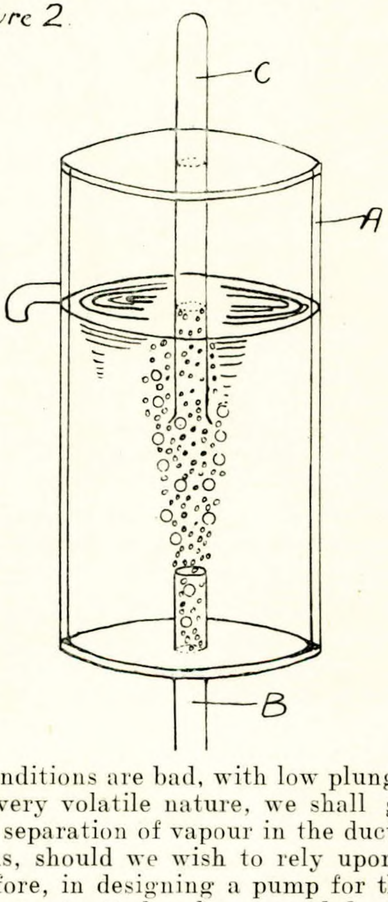
Figure I



obtained under pressure, whether this be a continuous pressure, or a series of pulsations. The latter at present being the orthodox method enables us to use timed injection, and further, the period of injection may be regulated, so that any given number of degrees required can be coincided with. In order to determine with certainty the peculiarities which unfortunately will always be found when pumping liquid fuels or other somewhat volatile liquids, it will benefit us much to go back to the very elementary stages of pumping, as these are to my mind of vital importance.

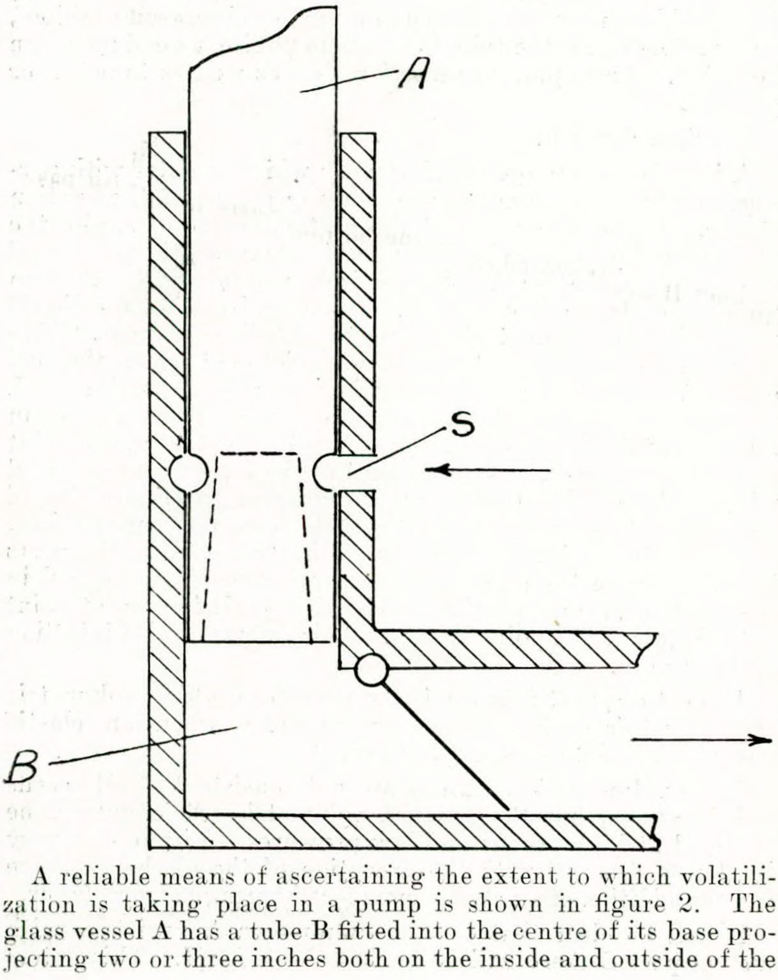
Figure 1 shows a reciprocating ram pump, fitted with flap valves. (This type of valve is shown for ease of illustration only.) It is of course obvious that as the plunger A is drawn outwards it leaves behind it a vacuous space causing the inlet valve B to be opened, and also causes the liquid to follow the plunger and occupy the volume vacated in the duct C. The nature of this liquid, the height it is lifted, its temperature, and the rapidity with which the plunger ascends, also the restriction offered by the suction valve, will have a great deal to do with the efficacy of the pump.

Figure 2.



If the above conditions are bad, with low plunger speed, and the fuel is of a very volatile nature, we shall get a certain amount of liquid separation of vapour in the duct C which will certainly upset us, should we wish to rely upon this for fine meterings, therefore, in designing a pump for this purpose it would be well to construct the plunger and duct so that even the amount of fuel which can adhere to the walls of the duct will be swept out on each stroke. This is comparatively simple, if a variable capacity be embodied which is capable of automatically adjusting itself. This variable capacity must be solid, that is to say it must not be elastic, similar to an air vessel, and it must synchronize with any alteration of the stroke, so that as the stroke is shortened, the duct becomes more confined in volume and vice versa.

Figure 3.



A reliable means of ascertaining the extent to which volatilization is taking place in a pump is shown in figure 2. The glass vessel A has a tube B fitted into the centre of its base projecting two or three inches both on the inside and outside of the vessel, to which the discharge of pump is coupled. If petrol or paraffin is used for this test, it can be relied upon that, should the discharge show negative, other fuels will never give trouble (in this pump) as far as volatilization is concerned.

The larger bubbles shown in figure 2 denote the presence of air, whereas the smaller ones prove volatilization is taking place. To what extent, the quantity of these smaller bubbles will give a good idea. Probably these smaller bubbles should be called specks as they are extremely fine. By placing a tube C, which must be sealed at its top end as shown in figure 2, these bubbles may be collected and further observations taken, or by introducing the tube C to a flame quite a good flash can be noted. This applies to heavier fuels as well as to petrol or paraffin.

Consider figure 3.

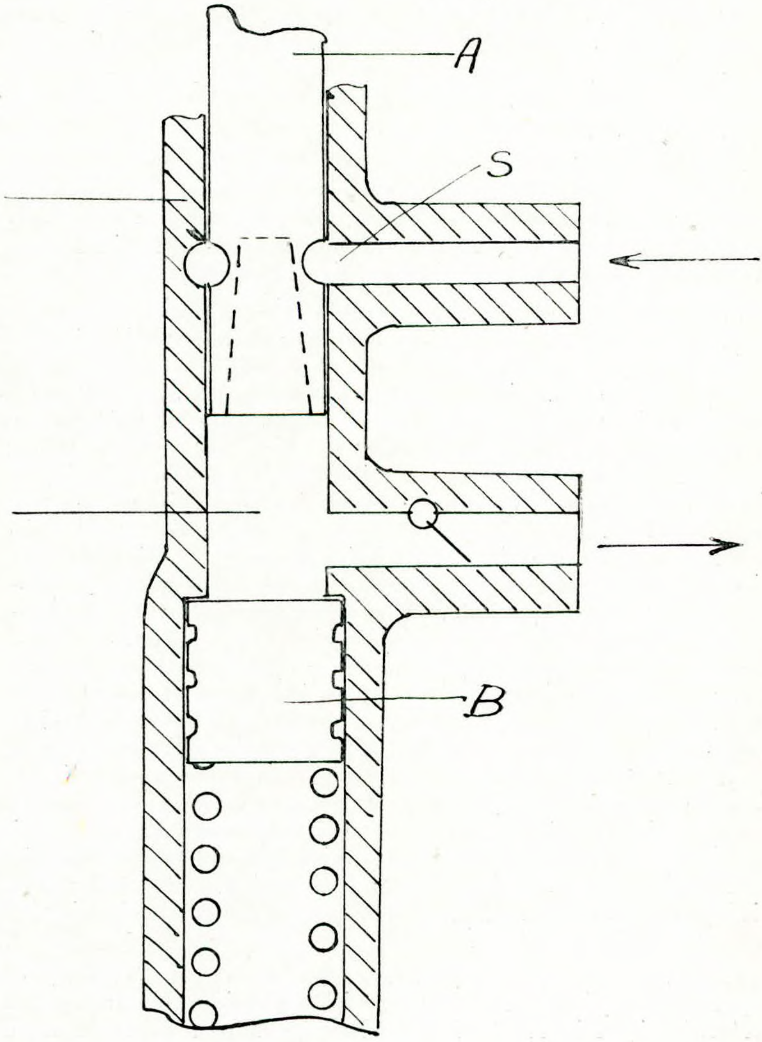
A is a hollow plunger having ports which register with passage S when the plunger is on the top centre of the suction stroke. If the plunger is at the bottom centre of stroke the plunger will have closed communication between the port S and the duct B so that as the plunger is drawn outwards a vacuum will be created in the duct B. Upon registration the liquid will rush into this duct via the port and hollow plunger, filling up the vacuous space, the extreme rapidity at which the fuel enters this duct is its own undoing. Even assuming high vacuum could be maintained by close fitting of the plunger in its guide, this design of suction is hopeless, not from the point of view of hammer, but on account of the long vacuous period which aids volatilization by expanding even the film of liquid fuel which has remained on the walls from previous strokes. This, together with the rapidity of the fuel passing the ports immediately destroys the slightest hope of maintaining fuel in the most solid form possible, which is a most important point until it gets to the point of exit. This refers to solid injection systems only.

A point of great interest is the remarkably high volumetric efficiency this design of suction provides when an elastic member is fitted as shown in figure 4.

These volumes above Unity are not consistent at all speeds and pressures, but the greatest volumetric efficiency will be obtained at high speeds and low pressures. Figure 4 is very similar to figure 3 with the exception of the discharge valve and the addition of an elastic member or spring laden plunger.

It will be clear that as soon as plunger A registers with suction port S there will be an inrush of liquid. This enters with such velocity that the elastic plunger B will give, and compress the spring, due to the pressure or impact of liquid over the area of the elastic plunger B. This incoming liquid,

Figure 4.



although to some extent reduced in density, brings behind it a stream which enters the duct before the suction port is closed by plunger A, so that more liquid is trapped (due to inertia) than is actually swept by the main plunger A.

Figure 5 is a diagram giving useful information with reference to the cycle of operations of this design. The diagram is assumed to be taken at about 500 lbs. per sq. in. (a fairly high pressure) consequently the freak volumetric efficiency is not shown, as the velocity of the liquid on such a small area as that of the elastic plunger, would have little or no affect at such a spring pressure.

Fuel pumps having variation of stroke for metering purposes have until recently proved to be the most reliable, and, but for the fact that the discharge tails off comparatively early with speed, I am of the opinion that they would still have a reasonable chance of upholding this statement.

The basic principle of this common type of pump is good, as it gives us two essentials, the first being that the liquid fuel follows the plunger, and, secondly it supplies a solid "break-up" pressure, which is a great feature when dealing with heavy fuels. In order to emphasise the importance of this, let us consider the orthodox jet or nozzle which has a restricted or small orifice, which is necessary in order to obtain spraying of liquid fuel. It will be found in practice that this minute passage will be a great source of trouble, and, in fact, will make fine meterings impossible, that is, if there is the slightest suspicion of elasticity in the pump, the discharge pipe, or elsewhere on the pressure side. To fully appreciate this, we have to realise that fuel oils contain beside foreign matters, ingredients (I admit this point is much contested) which actually form a dam when being driven by an indifferent force through restricted passages. This dam, or obstruction has to be broken down on each stroke, or better still, never be allowed to form, so that it requires solid breaking pressures to keep this restricted passage unobstructed. It is most interesting to watch the behaviour of discharge from a jet or nozzle when using oil fuels, that is, when there is elasticity somewhere on the discharge side. Now and again the dam which forms will burst, giving an uneven trickling discharge, and for a period it will cease to discharge at all.

The fact that sight feed lubrication pumps are capable of supplying very small meterings, with a considerable amount of certainty, is of interest when we have perhaps a dozen or more

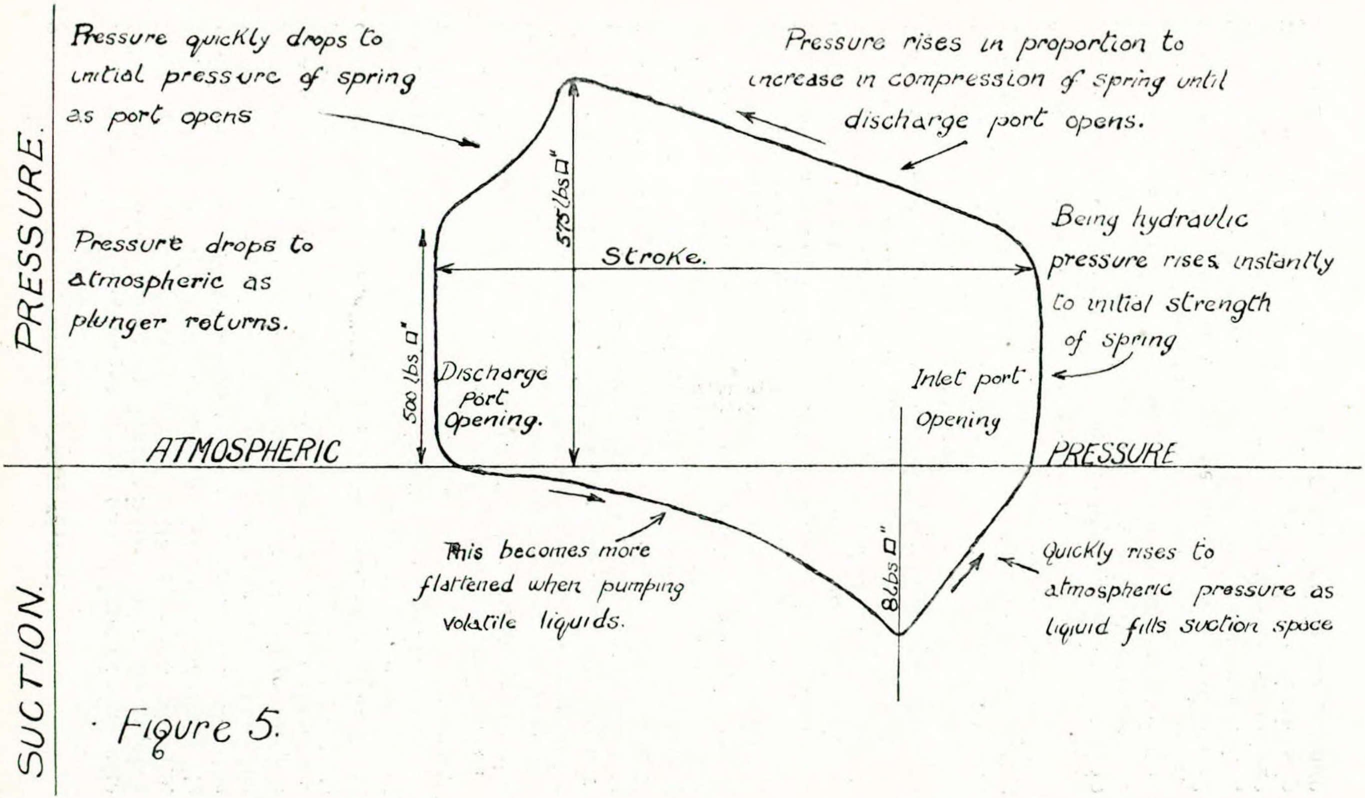

PRESSURE.
SUCTION.
Pressure quickly drops to initial pressure of spring as port opens
Pressure rises in proportion to increase in compression of spring until discharge port opens.
Pressure drops to atmospheric as plunger returns.
575 lbs □"
Stroke.
Being hydraulic pressure rises instantly to initial strength of spring
500 lbs □"
Discharge Port Opening.
Inlet port Opening
ATMOSPHERIC
PRESSURE
8 lbs □"
This becomes more flattened when pumping volatile liquids.
Quickly rises to atmospheric pressure as liquid fills suction space

Figure 5.

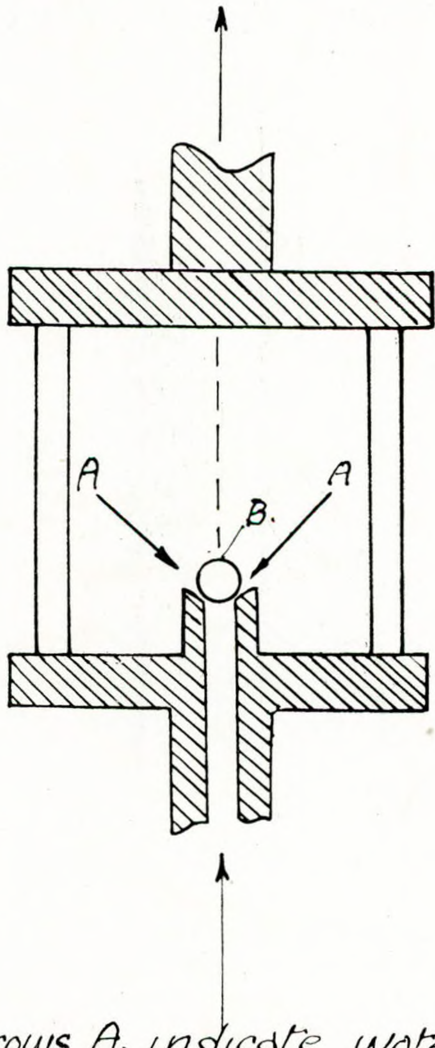
infinitesimal strokes of the plunger to one globule of oil. The total displacement of the ram (taking into account the number of strokes), displaces a volume far greater than one globule. This globule is only able to leave the jet on account of its weight and shape. Figure 6 shows in what manner the medium of water is used, and this, being heavier than the globule of oil, enables the globule to break away from the jet. The fact that a much greater displacement by plunger is necessary, proves that elasticity is in the whole body. As this is consistent in all lubricators of a given type, this minute and practically unmeasurable quantity is a point to be carefully dealt with when hoping to meter small quantities by the variation of stroke method.

In the construction of pumps dealing with liquid fuels of practically any description, I feel obliged to strongly criticise the use of packed glands, not that the packing is altogether unsatisfactory, or by any means unduly troublesome, but rather because I consider this totally unnecessary. Take the particular case of Figure 7. This shows a pump which has fine tolerances, and when under ordinary working conditions will maintain these high precision fits for long periods, providing the drive is well designed and gives no side thrust to the plunger, with consequent wear. The plunger, which is a good fit in the barrel in which it works, is ground, say, to half a thousandth, the bush has an annular groove or duct surrounding it, which it will be observed from figure 7 is placed on the drive end of the pump, and is connected up to the suction side of the pump by passage B immediately behind valve C. This groove therefore is kept at the same pressure as passage D, thereby returning to the suction side any small quantities of fuel which may pass the plunger.

One might fear undue loss, due to liquid slip from the high pressure side E to the low pressure groove F, but before doing so, consider the following: These measurements have been taken by me on more than one occasion.

The amount of liquid slip from the high pressure side E to the low pressure side F is about 5% of the total displaced by the ram against 500 lbs. per sq. in at 100 strokes per minute. The amount of slip from the high pressure side E to the low pressure side F, is about 1% of the total quantity displaced against the same pressure, only at five times the speed, *i.e.*, 500 strokes per minute, and at speeds over this, a percentage not worth considering. This is due to the fact that liquid slip between a plunger and its barrel is equivalent to the passage

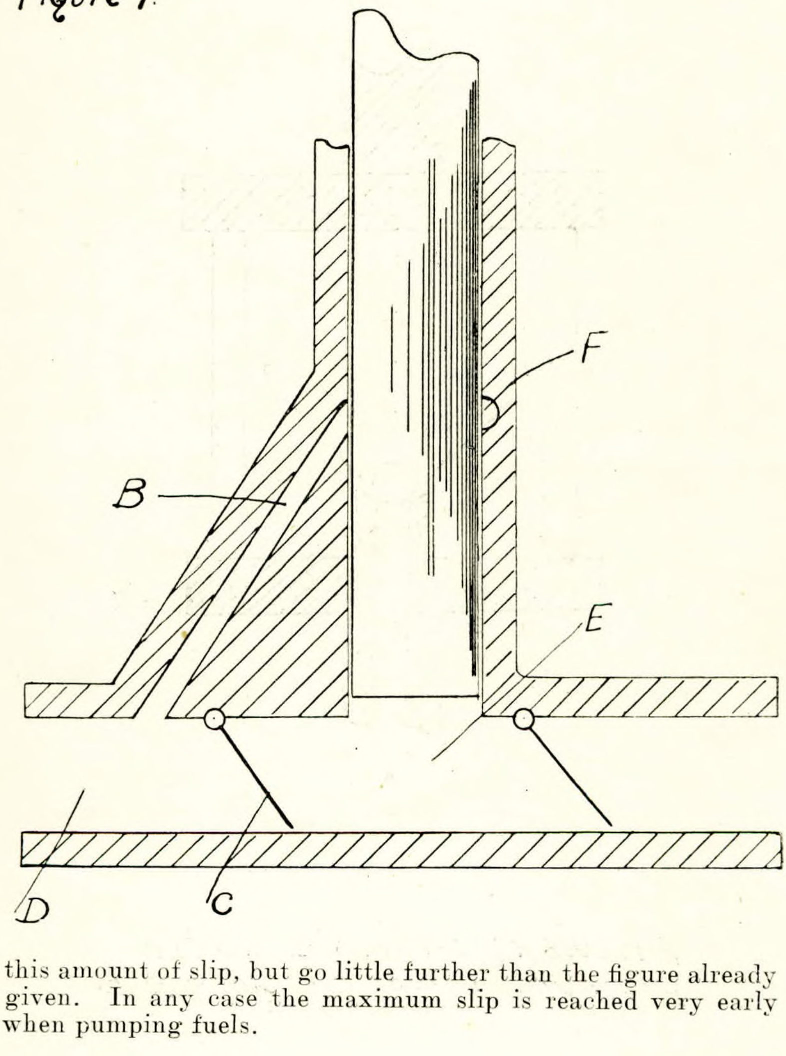
Figure 6



Arrows A. indicate water pressure under oil globule. B.

offered by a restricted orifice, therefore not more than a certain quantity can escape in a given period. We can definitely accept the fact that liquid slip is constant, and is in no way proportional to speed. Higher pressures of course increase

Figure 7.



this amount of slip, but go little further than the figure already given. In any case the maximum slip is reached very early when pumping fuels.

Figure 8.

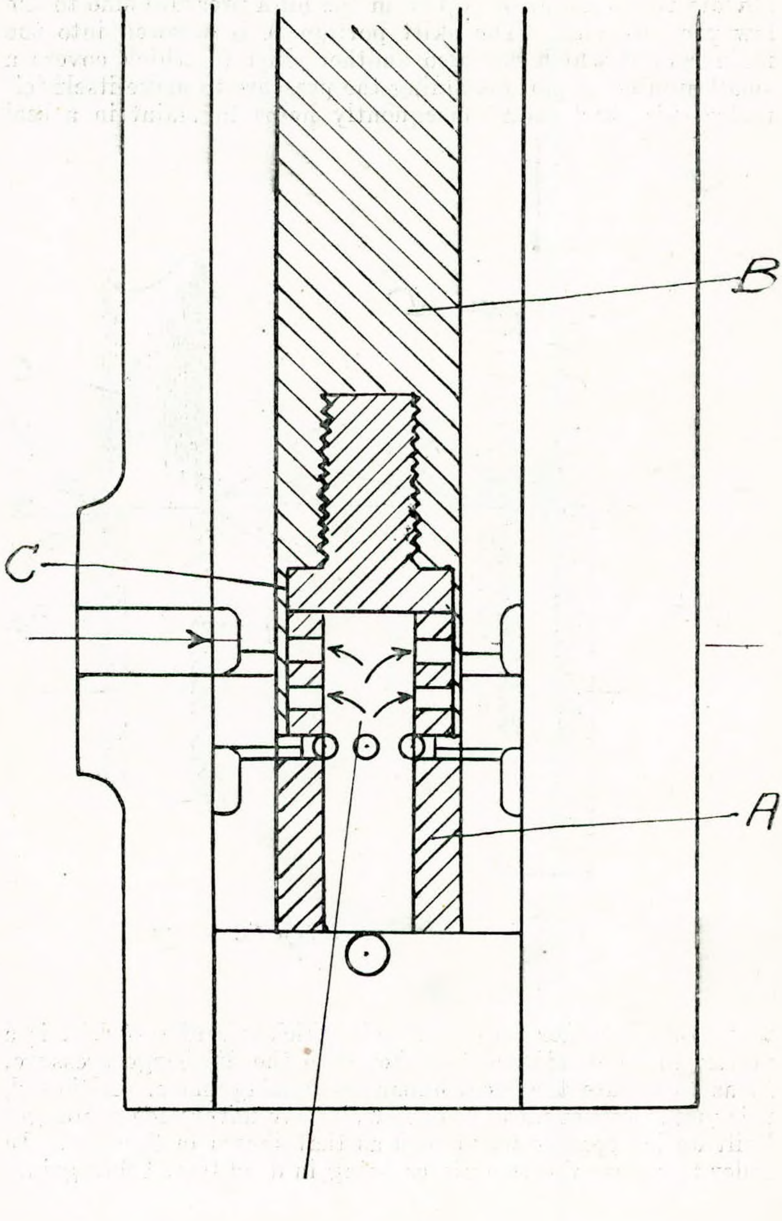
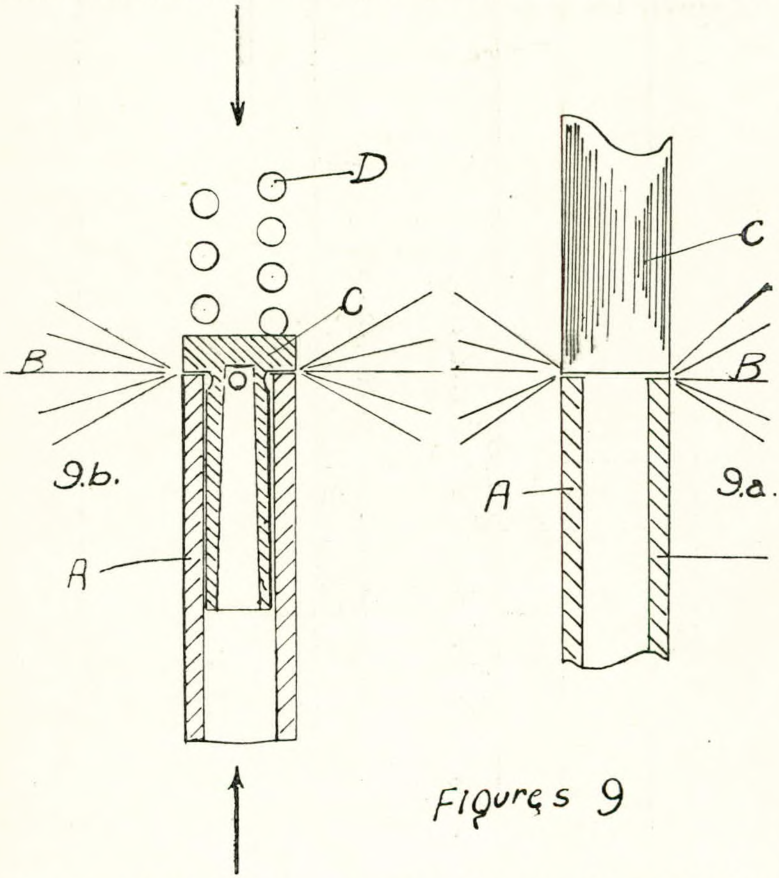


Figure 8 shows a design of plunger which further helps to obviate this amount of slip from the high pressure side to the low pressure side. The skirt portion A is screwed into the main ram B which has also another skirt C, which covers a small number of ports enabling the pressure to make itself felt under this skirt, and consequently helps to maintain a seal

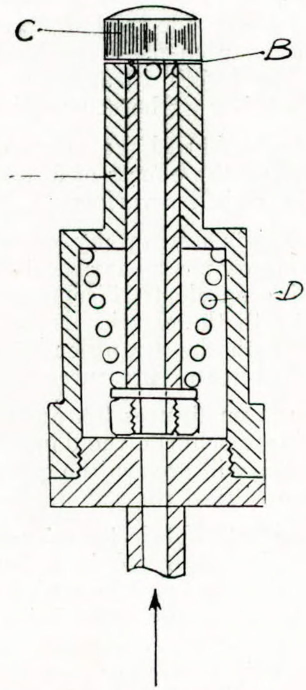


Figures 9

when fuel is under pressure. The thickness of the skirt is a matter to be considered together with the discharge pressure, so as to ensure the ideal expansion taking place. Although this metal bucket idea is not new, I have never seen a plunger built up in separate units such as that shown in figure 8. In order to ensure the two pieces being in dead line, I find grinding them both in one operation the most advantageous method, that is, after they are screwed together.

Figure 9 shows, in my opinion, a unique design of discharge jet, which in actual practice has proved to me substantially its superiority over other types of discharge nozzles, etc.; inasmuch as it supplies an exceedingly fine spray or mist at comparatively low pressures.

Figure 10.



A is a tube having a ground seat at B, C is a solid metal stop or strangler which has also a finely ground face at B, A and C are ground in together at face B. The discharge from the pump is coupled to the latter. The coil spring D has a screw adjustment for varying the tension of downward pressure upon the tube A and it keeps these two ground surfaces in contact, except during the period of pulsation from the pump, when the stop or strangler C will be blown upwards off its seat allowing the fuel to be discharged as shown in figures 9, which are alternative designs. Figure 9A is rather superior to figure 9B as it is immune from stickiness due to foreign matter on the guide, but it is far more difficult to construct on account of getting the faces at B in line.

The chief benefit of these types of sprayers will be found in the fact that the orifice is automatically governed by the pressure, rate of discharge, and quantity, so that under all conditions the orifice offers the minimum opening enabling highly stratified vapour to be obtained. This type of jet may be designed in many ways so that the spring pressure can be applied on the opposite side to that shown in figures 9 and 9A, enabling it to be adapted for a combustion head having high temperatures. The figure 10 offers a suggestion as to the manner in which this may be accomplished.

I would like to add that I have only found one particular steel which will withstand the effects of abrasion in this type of jet, and that is of the stainless variety.

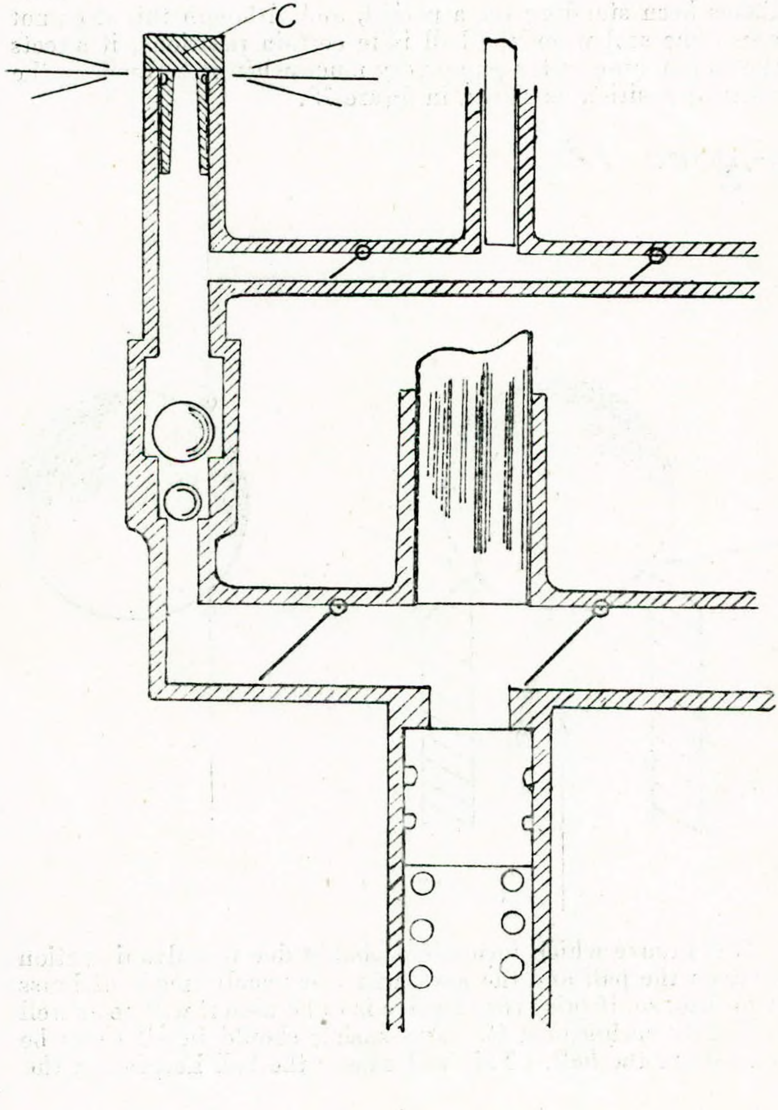
These types of jets during my experiments have hitherto proved to be troublesome as far as fine meterings are concerned, when using an elastic discharge as described in figure 4. That is owing to the elastic discharge pressure having to be set relatively with the strangler spring pressure, in order to obtain exact balance of pressures at the jet.

It will be seen from figures 9A and 9B that in the case of an elastic or spring discharge the downward pressure from the spring D on the stop will govern the quantity of discharge from zero up to the capacity of the pump.

In order to be able to obtain the numerous advantages of the elastic means of discharge and in order to successfully overcome the finer metering troubles which are chiefly due to the fine balance of the spring pressures being upset by inconsistent stickiness, foreign matter, sooting up, etc., I find that by fitting a minute auxiliary plunger pump as shown in figure 11, and coupling up the discharge from the main, which supplies the elastic discharge, that the minute volume discharged from the auxiliary supplies just sufficient solid pressure to ensure the lifting of the stop, or strangler C, which further prevents any obstruction in the form of a dam building up, as formerly described in this paper.

Figure 11 shows in what manner this auxiliary may be applied. There are of course numerous ways of driving this auxiliary without the necessity of driving an extra plunger as

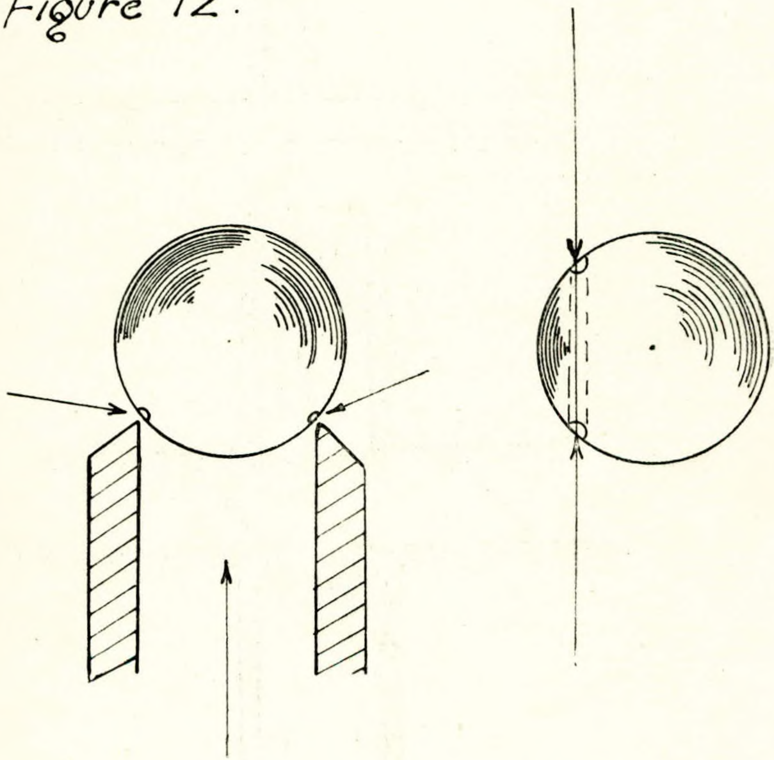
Figure 11.



shown. It can be part of the main plunger shown in figure 4, providing the general design is modified.

Although it is well known to the majority, that ball valves are cheap and fairly reliable, there is one failing I find in these. That is that a minute groove becomes eaten into the ball after it has been standing for a period, and although this does not affect the seal when the ball is in certain positions, it affects the functioning of the pump very much when it becomes in the vertical position as shown in figure 12.

Figure 12.



This groove which forms is probably due to galvanic action between the ball and the seat, which is usually made of brass or bronze, so, if this type of valve is to be used it will be as well to lightly spring-load it. The spring should in all cases be fastened to the ball. This will ensure the ball keeping in the same position. If it is not desirable to do this, some other means should be adopted. Figure 12 shows where leakage is apt to take place should the ball become in the position as illustrated. Probably the loss sustained by this leakage would not be a serious matter when dealing with large quantities but it becomes a most important point when metering minute quantities.

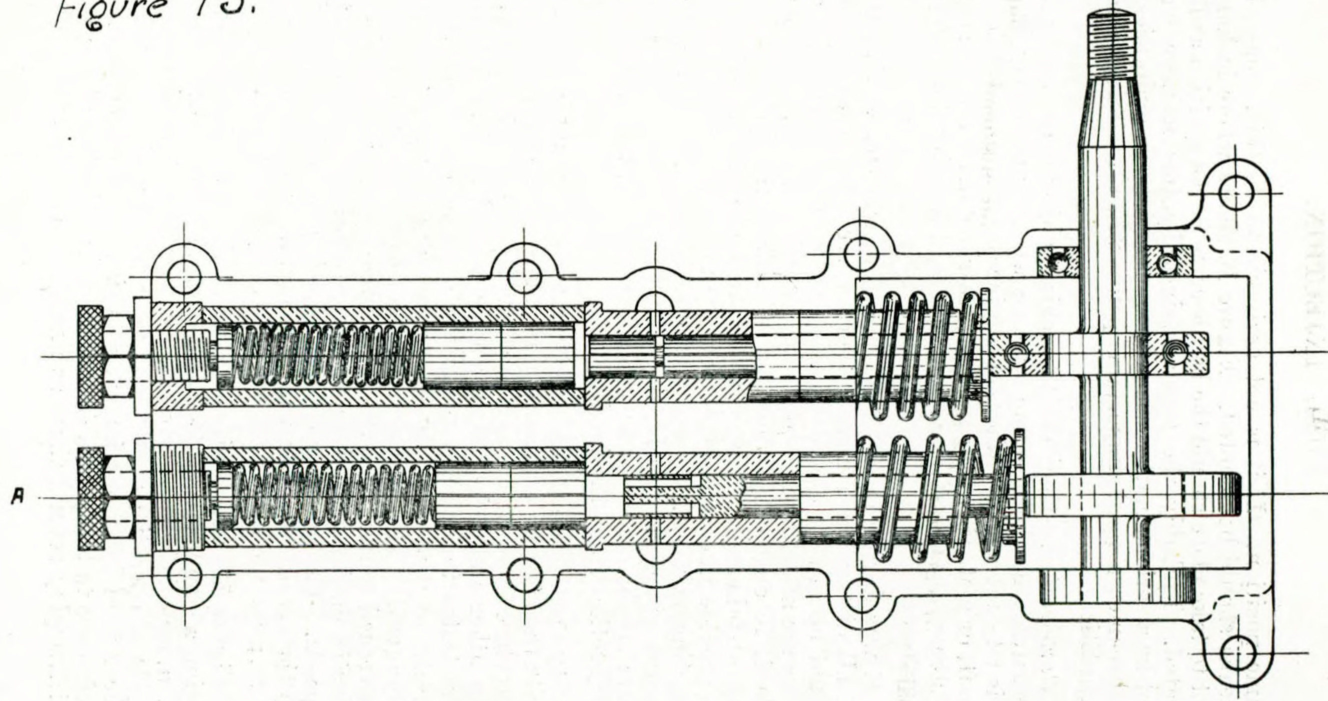
Carburation.—One of the chief objects of my recent researches has been to find a means whereby fuels may be supplied to internal combustion engines of the automobile, aircraft, or motor boat type, so as to displace the orthodox suction systems of carburation, and replace them by an injection apparatus.

It was during these many months of experiment that I first of all discovered a means whereby the discharge of a pump could be governed atmospherically, without destroying the pressure affect by incorrect strangulation of fuel. In the first place, to enable a carburation system of this principle to be successful commercially as well as mechanically, it is necessary to provide an equipment somewhere in the region of the cost of existing systems. It was for this reason that I adhered to a means which was capable of lifting fuel from a rear tank without that aid of the well known vacuum tanks, which are worked by suction from the intake.

My final design of carburetting apparatus totally does away with the existing carburetter, float chamber, and vacuum tank. I replace these with two separate units, one being a pump, and the other an intake, or automatic control for it. Figure 13 illustrates the type of pump having a bore of 7 mm. and a stroke of 6 mm., it has two main plungers and two elastic plungers. The discharge pressure of the pump will be governed entirely by the spring tension, which supplies an elastic discharge, this pressure remaining constant at all speeds. The quantity of discharge is practically proportional to the speed, therefore we have, say, a small discharge at 100 revs.; but the same pressure as at, say, 2,000 revs.

Figure 13, which gives a view of the general arrangement, being a simple straightforward one, will require little explanation, especially as I have already described in previous pages a cycle of operations which has close relationship with this, but there is at least one important point to be remembered with reference to this pump, *i.e.*, the pump at all times is capable of discharging several times as much as the engine to which it is

Figure 13.



fitted requires, which allows the one size of pump to be used on either a 10 h.p. or 100 h.p. engine, therefore it must be clear that when the pump is not discharging up to its full capacity, the elastic member, and main plunger, reciprocate the body of liquid between them, so that if the discharge be totally sealed up, and the pump running, no ill effects will follow, as would be the case if this pump were not fitted with an elastic capacity. Although I have mentioned that the pump is capable of discharging much more than the engine requires at any time, and the main plunger sweeps this surplus volume per stroke, there is little or no loss in energy absorbed in driving it, because the spring only stores up momentarily the amount of energy that is put into it, and reasserts itself upon the return stroke of the main plunger, which actually helps the latter to return. For this reason there is no trace of "bounce" from the main plungers at high speeds, even although using springs for the purpose of returning the plungers, the tension and gauge of which have been very questionable sometimes during experiments.

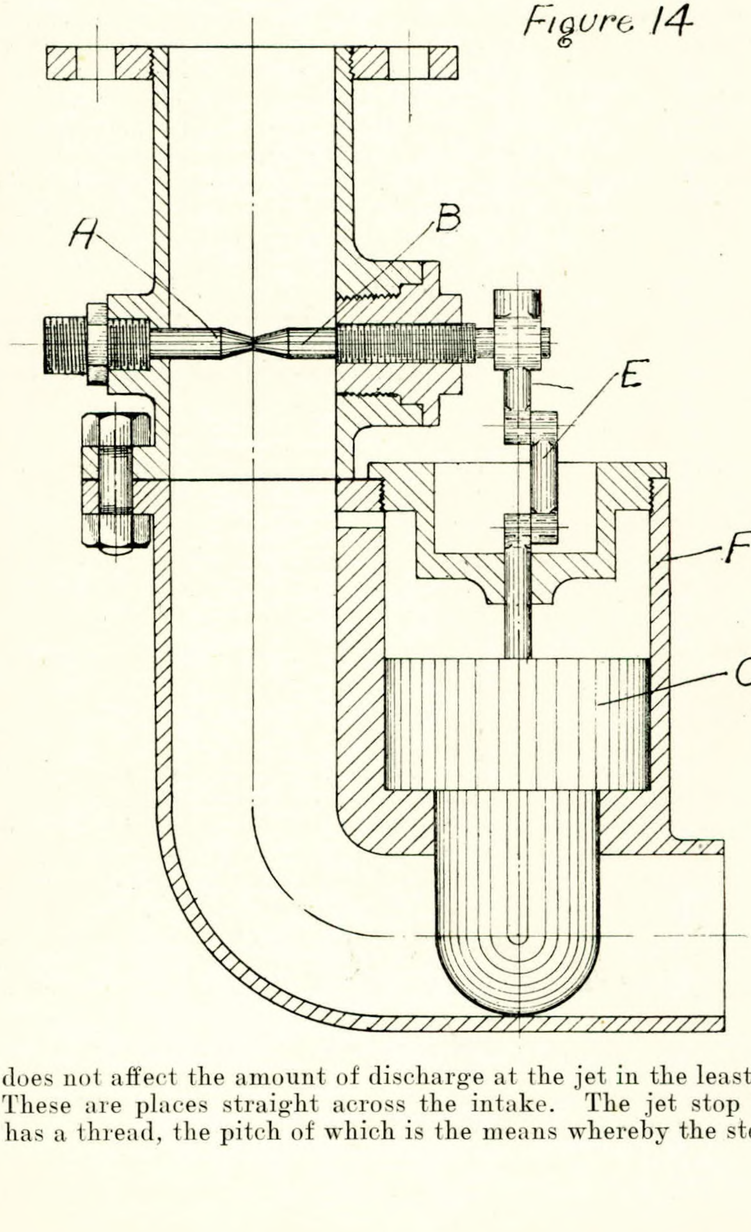
The main plungers are driven by ball races mounted eccentrically at 180 degrees, on a shaft which is supported by two ball races of a small type.

The plungers being set at 180 degrees, give one pulse which coincides with the induction stroke of a four cylinder, four cycle engine, when the pump is driven at engine speed.

In the case of a 6-cylinder engine this 2-plunger pump may be driven at one and a half times engine speed, in order to ensure that there will be no starvation of fuel between pulsations.

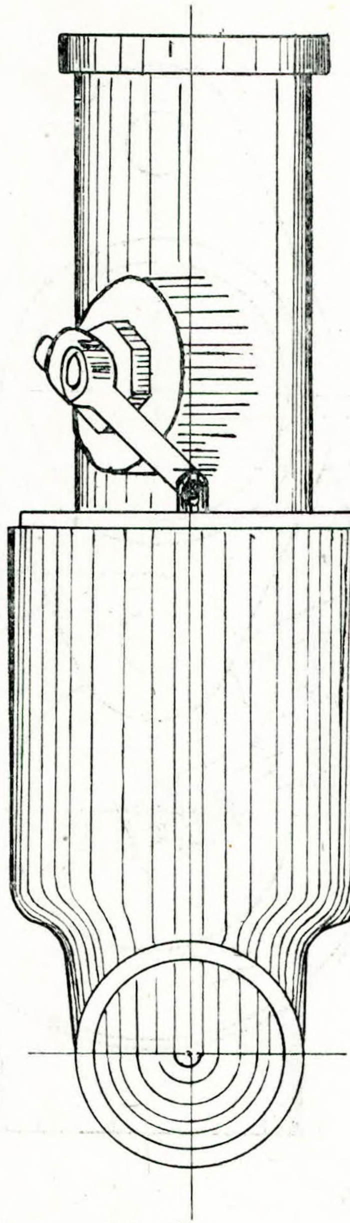
The adaptation of this system to an automobile engine is only made possible by the excellence of the automatic control. Apart from a pump as already described, control of mixtures hitherto seems to have been a great obstacle, because of their colossal number, and the peculiar demands an engine has upon the mixture. In the first place assume that a jet and air throttle were interconnected and had proportionate openings, it would be found useless in ordinary road practice, because engine speed governs the amount of air consumed, as well as the amount of throttle opening, consequently, under different conditions of engine speed and load, the fuel discharged would be entirely out of step with the amount of air consumed. Figure 14 shows a crude means of overcoming this difficulty. The jet A is similar to those described in figures 9 and 9A, and allows a discharge of fuel entirely proportionate to the lift off of jet stop B. (It should be quite clear that the pump speed

Figure 14



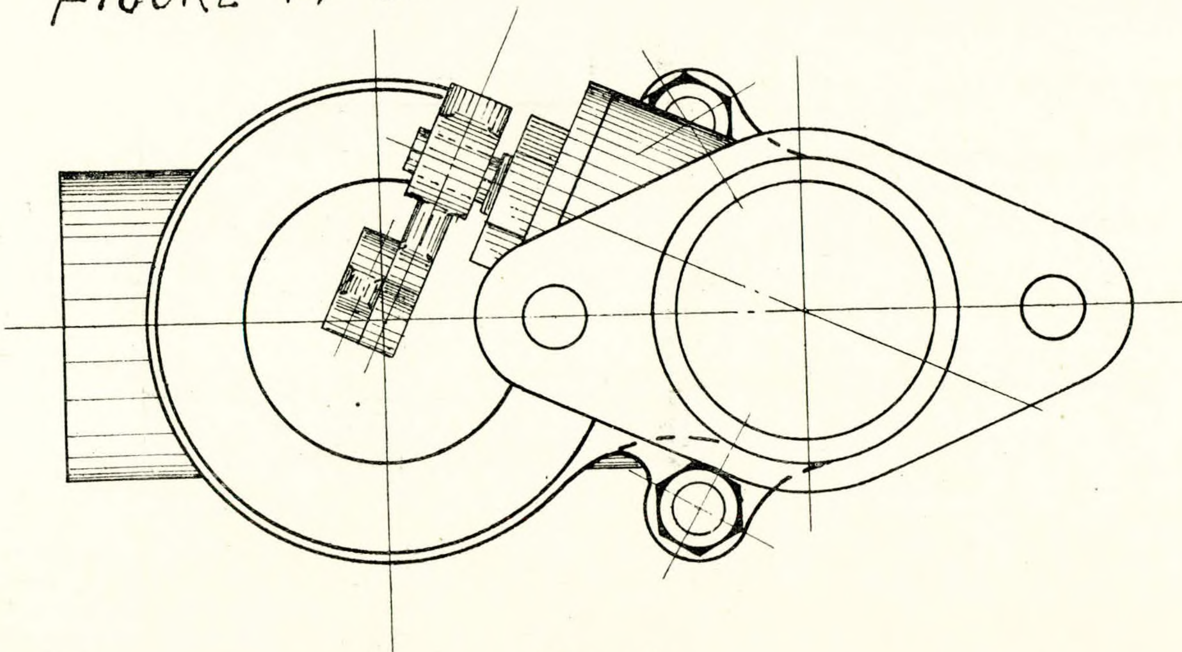
does not affect the amount of discharge at the jet in the least.) These are places straight across the intake. The jet stop B has a thread, the pitch of which is the means whereby the stop

Figure 14.a.



Showing offset.

FIGURE 14 b.



Plan Showing offset.

lifts off the jet A a given distance, that is when bucket C rises, due to the vacuum at D. The lower portion of the bucket C acts as a balancer plunger, and being attached to the top portion, lifts with it. In this design the motion of the bucket is imparted to the stop B by small cranks or levers E, the main barrel F, being offset from the axis of the jet and stop, allows an almost consistent movement throughout the lift off. A butterfly throttle which is fitted between the jet and the engine being the only control, it is operated in the usual way. In this method it will be clear that no choke tube is necessary. It is therefore of great benefit, as the usual wire drawing set up at high speeds does not exist, the dimensions of the intake being amply large enough to allow a surplus of air to enter the engine at the all out position. Practical experiments with this apparatus under the supervision of many engineers have proved the ease of starting from dead cold, which has been obtained in temperatures below freezing point. I consider this revolutionary, as it can be stated, that with the ordinary low compression touring car engine, a start has been obtained with a single turn of the starting handle, when using straight alcohol having a flash point of 8 degrees centigrade, or on the other hand it will deal with paraffin in the same manner without any preheating whatever.

A severe try out of this carburetting apparatus on a small car having a high speed overhead valve engine, fitted with aluminium pistons, has proved to my satisfaction the all-round efficiency that can be obtained.

After forty thousand miles of ordinary everyday running, micrometer measurements have been taken of the pump rams, etc.; and although petrol, benzol and alcohol fuels have been used at different times, the amount of wear that has taken place is hardly perceptible; I should judge this pump to be good for at least as much again.

The only troubles that have been experienced during this test have been a broken petrol pipe once, and a choked filter on two occasions; I may say the petrol was seldom filtered when poured into the tank. I deem it unnecessary to give any figures with reference to fuel consumption, as I feel confident that when the principle of this system is fully grasped it will speak for itself.

I look forward with interest to the pending developments of power alcohols and other petrol substitutes, as these can be substantially dealt with by this apparatus.

Figure 15.

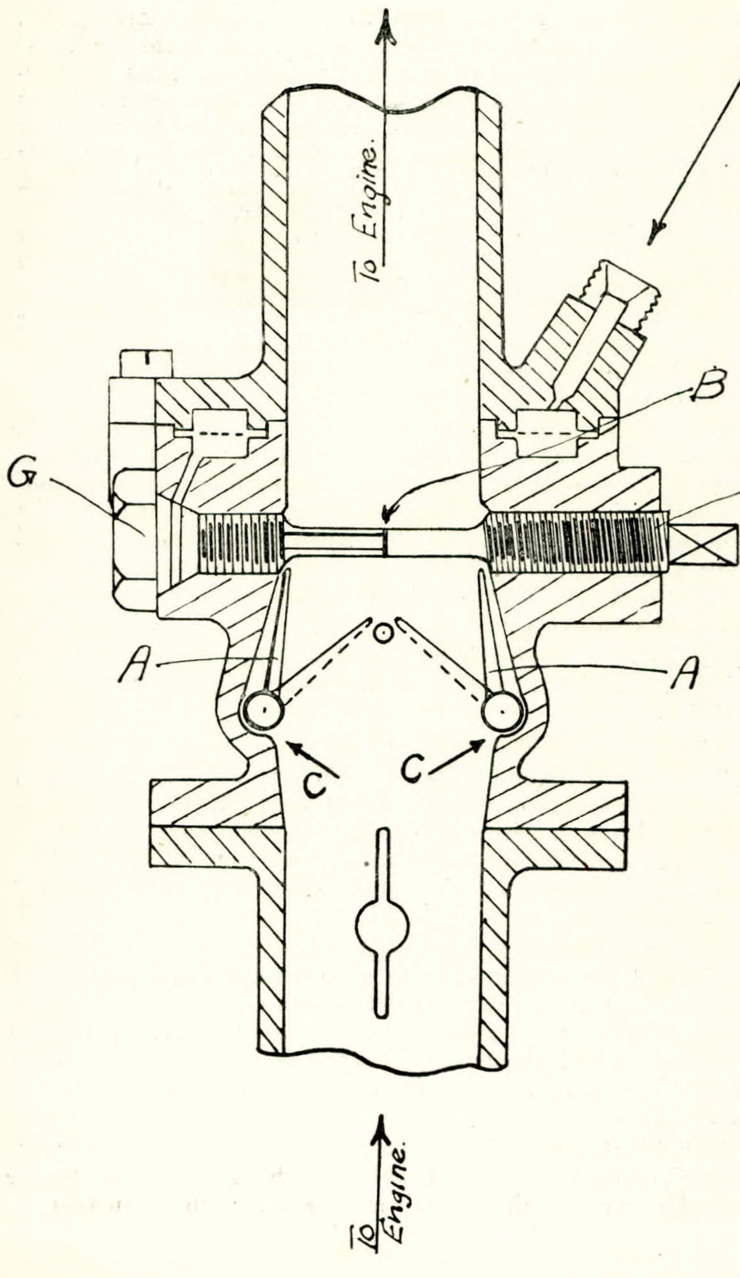


Figure 15 shows a design of control having automatic shutters or flaps A, the opening of which is always proportional to the amount of air passing them, the object being to concentrate the maximum velocity of air upon the fuel leaving the jet faces B.

In actual practice I find these shutters greatly improve the acceleration of the engine, and go a long way towards preventing the recondensation of fuel, which in the majority of cases is due to fuel being allowed to accumulate upon the walls of the intake which are not swept by passing air currents. Figure 15 shows the arrows C pointing to the hinges upon which shutters are pivoted. It can be imagined the amount of agitation any fuel would get from the velocity of air passing the back of these hinges, that is, in the event of any recondensation upon the back of the shutters, although this is extremely unlikely.

In spite of the benefits derived from this design by obtaining maximum air speed at the jet at all throttle openings there is little or no strangulation set up by the shutters which are lightly sprung together. The jet stop D is operated atmospherically as described in Fig. 14. A further advantage of this type of intake is the absence of obstructions such as butterfly throttle valves, which in this case are not placed on the engine side of the jets. E shows the entrance for fuel from the pump which goes through the annular filter F, finally through the cone-faced jet body G, which is screwed into the main intake.

The removal of this jet for cleaning purposes is simplicity itself, there being only one operation necessary.

For aircraft, motor boats, and automobile engines the chances of back fires due to positive fuel feed and consequent fire risks are greatly minimised, there being no local quantity of fuel near the engine such as float chambers contain; I consider this a most important point.

In cases where even distribution of charge is difficult to obtain in multi-cylinder engines, any number of intakes may be used, even if these are only supplied from one pump, in the event of one ram for any unknown reason becoming out of order, there is excess enough being dealt with by the other to keep an engine supplied without adversely affecting the carburation, that is, providing the swept volume of the pump is made large enough to allow of this.

Super-chargers.—I have observed at the same time that although these are excellent for obtaining power, they considerably increase carburation difficulties as far as the ordinary type of carburetter is concerned, particularly when the throttle is suddenly opened after coasting for a while, this is on account of the large volume under vacuum which is suddenly exposed upon the opening of the throttle. This brings in an excess of fuel which is almost fatal to the "open up." Even were these conditions reversed the engine would have a much better chance of recovery, from the point of view that an engine will recover from the effect of a weak mixture, but has the utmost difficulty in getting rid of a surplus of fuel. Apart from wastage this will lose sometimes valuable seconds when it becomes necessary to accelerate quickly.

It will become obvious after studying Fig. 15 that this design of intake is unaffected by these adverse conditions that are brought about by the super-charger.

The tendency at present being toward the pressure feed of air into the petrol engine, I think it can be relied upon that the fuel pressure system will also follow.

The Flettner Rudder.

BY F. ARNOLD BEST, A.M.I.A.E., A.F.R.Ae.S.

READ

Tuesday, January 26, at 6.30 p.m.

CHAIRMAN: MR. F. M. TIMPSON (Chairman of Council).

INTRODUCTION.—The Flettner Rudder consists of a main balanced rudder, free to rotate completely like a weather-cock, to the after edge of which is attached a small secondary rudder whose function is to control the angular position of the main rudder, the secondary rudder being controlled by the helmsman. Thus the small rudder steers the large rudder and the large rudder steers the ship.

The inventor's principle of using the current itself to operate the rudder was first carried out on large German aeroplanes during the War.

In aircraft, it is essential that the ailerons, etc., be controlled by hand and in the case of large machines, this involves the movement of very considerable areas so that the Flettner Invention proved to be the solution of a very real difficulty and of considerable help to the pilot in controlling his machine. As a result, several hundred large aircraft were fitted with the device and gave entire satisfaction in service.

As is well known, in the case of sea-going craft, engines of considerable horse-power are used to turn the rudder through the medium of strongly designed gearing.

After the war, the experience gained with Flettner Ailerons in air-craft was used to develop a rudder for ships with the object of reducing as much as possible the enormous amount of power necessary in steering them.

Marine experts ridiculed the suggestion on the grounds that conditions in the water are quite different from those in the air, and it was considered that the action of heavy seas on a rudder built on the Flettner principle would make steering quite impossible in bad weather. A foreign patent office actually refused to grant protection to the invention as they thought it could not be put into practice.

In spite of this prejudice, it is interesting to note that since the beginning of 1922 some 120,000 tons of sea and river going craft are fitted with rudders working on the Flettner principle and all of which are giving entire satisfaction in service.

In vessels up to 10,000 tons, the Flettner rudder is controlled entirely by hand without the aid of any engines or other auxiliary steering devices. In larger ships the only additional effort necessary is that required to overcome the greater pressure on the secondary rudder due to its increased area and also increased friction in the transmission gear.

In order to obtain some idea of the effect necessary to steer a ship with the Flettner rudder it should be remembered that instead of moving over a large rudder it is only necessary to move a small one having a superficial area equal to about one twentieth of that of the larger rudder. This means an immediate saving of effort equal to 95%.

THE THEORY OF THE ACTION OF THE FLETTNER RUDDER.—The action of the Flettner rudder on the ship depends, as in the case of all rudders, on the development on its surface of a normal pressure by means of deflecting the streams of water which impinge upon it, either by reason of the vessel's motion through the water or owing to the action of the propeller or both. The difference between the Flettner rudder and the ordinary rudder lies in the method by which its angular position is controlled. Whereas the ordinary rudder is governed by means of a tiller (or some variations thereof) positively fixed to the rudder head, the Flettner rudder is controlled by the action of a small auxiliary rudder hinged to the trailing edge of the main rudder and operated independently by the helmsman.

The method by which this is accomplished is as follows:— The main rudder is mounted on a stock which is carried in bearings at the stern in the usual way, but as no tiller or other such device is fitted the rudder is free to rotate completely, sufficient clearance at the propeller being given to allow of this.

The axis of the main rudder is so arranged that it is partially balanced but sufficiently under-balanced to remain amidships when no helm is given to the secondary rudder. By giving a certain amount of helm to the secondary rudder, the balance of the main rudder is upset and it swings until it

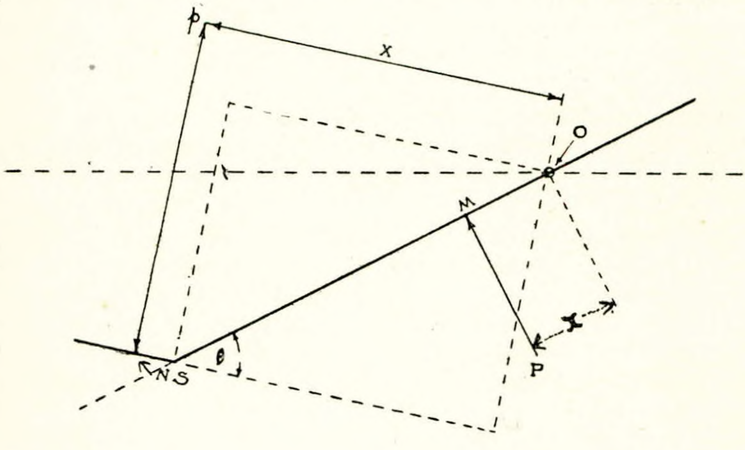
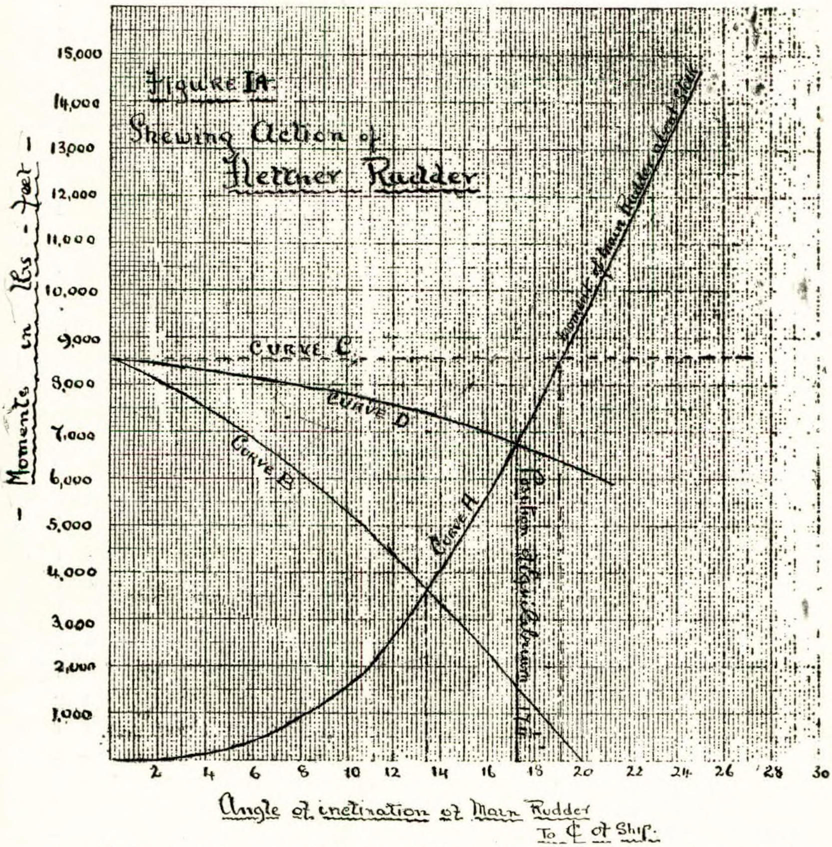


FIG. 1

reaches a position depending on the amount of helm given to the secondary rudder. Fig. 1 illustrates the manner in which equilibrium is obtained. P and p are the normal pressures acting on the main and secondary rudders respectively at M and N the centres of pressure corresponding to their angles to the direction of motion. When helm is given to the secondary rudder the whole rudder will swing until the moments of p and P about the rudder stock are equal. Thus for equilibrium $Px = pX$, and if θ is the angle between the auxiliary and main rudder (produced) $X = OS \times \cos\theta + SN$, where OS is the distance of the axis of the auxiliary rudder abaft the axis of the stock and SN is the distance of the centre of pressure of the auxiliary rudder abaft its own axis of rotation. Hence Px = p (OS cos θ + SN). To take a concrete example, suppose the main rudder to be 12ft. x 8ft. = 96 sq. ft. and the stock to be situated 1·7ft. from the leading edge; further sup-



pose the secondary rudder is 12ft. x 1ft. or 12 sq. ft. and is hinged directly at the trailing edge of the main rudder. Suppose the secondary rudder is set at an angle of 20° to port of the main rudder and not afterwards altered, and let the speed of the ship be 10 f.p.s. Fig. 1a shows approximately the action of the rudder as follows:—

Curve A shows the increasing moment of the main rudder about the axis of the stock as the rudder swings over.

Curve B shows the decreasing moment (about the stock of the main rudder) of the secondary rudder as the main rudder swings. This curve is based on the assumption that the direction of motion of the secondary rudder relative to the surrounding water is the same as the fore and aft direction of the ship. Owing, however, to the fact that the streams of water impinging on the secondary rudder are probably more nearly flowing in the direction of the main rudder, the moment exerted by the secondary rudder probably more nearly approaches Curve C.

As in practice the angle between the secondary rudder and the main rudder is caused to diminish as the main rudder swings, the state of affairs obtaining might be expected to approximate to Curve D. If this is so, the main rudder would come to rest at about $17\frac{1}{4}°$ as will be seen from the figure.

The example is of course purely hypothetical and serves merely to illustrate the principle upon which the rudder works. In practice the main rudder is of stream lined section and the auxiliary rudder is also balanced. The actual proportions of main and auxiliary rudder and the position of the stock have been determined experimentally from models run in the experimental tank.

From these researches it has been established that the best proportion of the auxiliary to the main rudder is as 1 : 8, the correct proportion of the area of the main rudder before and abaft the stock has been found to be 1 : 2·35, and the greatest thickness of the main rudder occurring at the stock is about $\frac{1}{6\cdot6}$ of its length.

The auxiliary rudder of course exerts a small turning moment on the ship in the opposite direction to that produced by the main rudder, but its effect would be very small. Suppose for example that in the above hypothetical case the rudder stock is 100ft. abaft the c.g. of the ship, then the moment due to the main rudder turning the ship to starboard would be 721,000 lbs. ft. whereas that due to the auxiliary rudder tending to turn the ship to port would be only 113,500 lbs. ft., leaving a net turning moment to starboard of 607,500 lbs. ft.

In practice, in order to obtain quick and decisive action of the main rudder at small angles of inclination, the auxiliary rudder control gear is so designed that a rather larger angle than would otherwise be necessary is given to the auxiliary rudder at first and then as the main rudder swings through the angle between the main and auxiliary rudder is slightly diminished. When the propeller is rotated to give astern motion to the vessel, the water in the neighbourhood of the rudder is very soon drawn forward by the screw even though the vessel herself may still be moving ahead. As soon as this happens, the rudder, acting like a weather-cock, swings completely round, its trailing edge then being forward. In this position the rudder can again be controlled by the auxiliary rudder and the action of the helmsman will be the same as though he were steering the ship astern with an ordinary rudder.

THE MECHANICAL MEANS EMPLOYED IN GOVERNING THE RUDDER.—As already stated earlier in the paper in the case of vessels up to 10,000 tons, the Flettner rudder can be entirely operated by hand direct from the bridge without the necessity of any form of power steering gear. In vessels above this tonnage, however, it is advisable to adopt some form of electrical transmission in which case a motor of ½ h.p. will suffice to control the complete gear. As an alternative to electricity, adaptations of the Telemotor system are under consideration. The entire operating gear, apart from the transmission, is carried on the main rudder head and is of quite small dimensions. The conditions with which it has to comply are as follows:—

(1) It must transmit the movement of the steering wheel to the secondary gear.

(2) It must give such movement a variable quantity, *i.e.*:—

(*a*) At small steering angles a relatively quick movement must be given to the secondary rudder, thus producing rapid and positive movement of the main rudder.

(*b*) As the angle of the main rudder, relative to the ship, increases beyond a certain point, the angle between secondary and main rudders must diminish.

(3) It must co-ordinate the relative movements of main and secondary rudders so that:—

(*a*) When the rudder is moved by outside agency, steering is automatically given to the secondary rudder in order to return the former immediately to its original position.

(*b*) When the ship goes astern and the rudder rotates through 180°, the action of the steering wheel is not reversed, but remains the same as it would be when going astern with a normal rudder.

These conditions have been carried out by means of several different types of operating gear, but as space will not permit

FLETTNER RUDDER CONTROL GEAR AND EMERGENCY STEERING ARRANGEMENTS

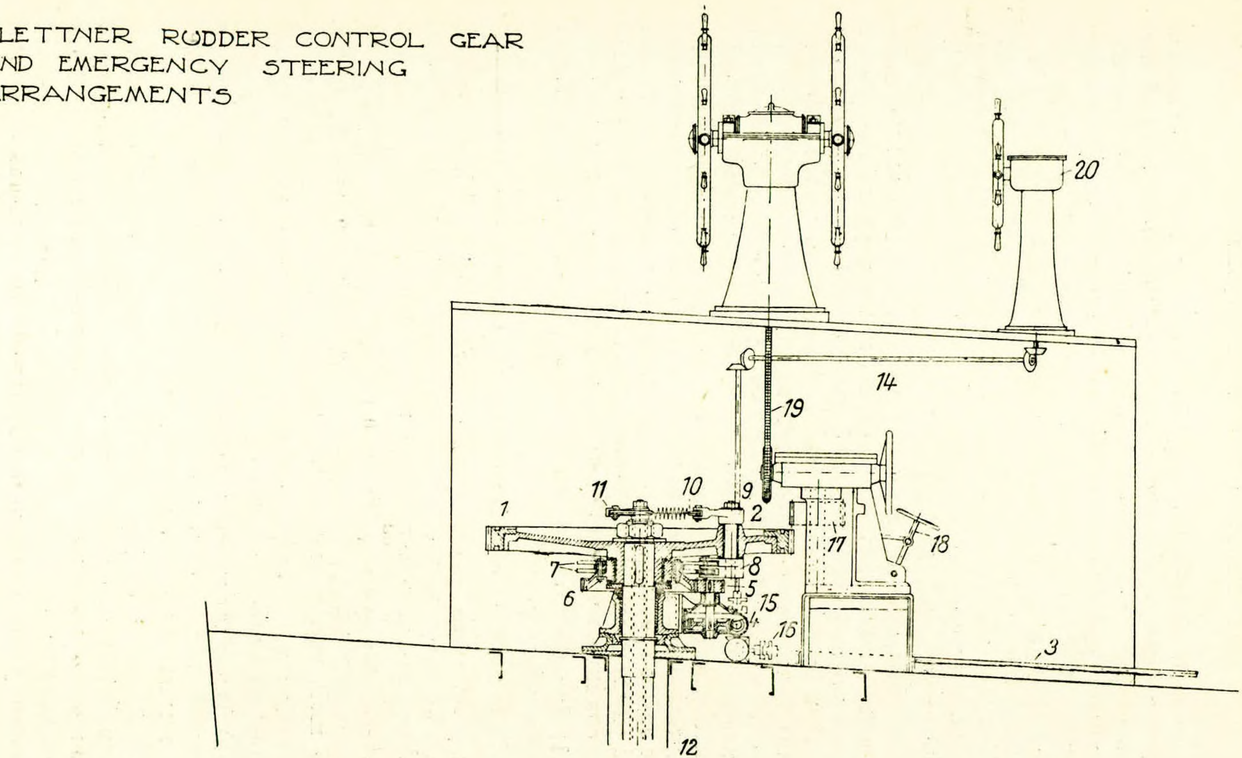


Fig 2.

a detailed description of all the gears in use, it is proposed in this instance to describe in detail the type of control gear fitted to the M.S. *Sorrento,* which is one of the latest vessels to be equipped with a Flettner rudder.

Condition I.—In this type of gear the turning movement of the control rod (3) given by the helmsman through the wheel on the bridge is transmitted through a worm and worm wheel (4) to a pinion (5), which engages with a spur wheel (6) which is arranged to turn freely on the hub of the quadrant or gear wheel (1) and which is fixed to the main rudder shaft. Since the spur wheel (6) is fixed to the two camplates (7) arranged above it, the camplates may thus be turned relatively to the main rudder. The rollers at the ends of the rocker arm (8) run on the periphery of the cams, one on the upper and one on the lower camplate. The spindle of the rocker (2) is carried in a bearing fitted into one of the spokes in the main quadrant and which is fixed to the main rudder. The rocker spindle (2) thus moves with the main rudder. Actually, therefore, the helmsman causes the camplates to move and these in turn move the rocker spindle, the movement of this latter is then transmitted by means of levers and link to a spindle which passes down the main rudder stock and so to the auxiliary rudder. To take up any possible shocks on the secondary rudder, the link (9) is provided with a double acting spring buffer.

Method of Operating.—The helmsman wishes to go to port. Through the medium of the steering wheel on the bridge he turns the pinion (5) in a counter clockwise direction, thus moving the spur wheel (6) together with camplates (7). Owing to the profile of the cams an angular movement is given to the rocker (8) and thus by means of the link motion (9-13) the secondary rudder is turned to starboard. The action of the stream on the secondary rudder now causes the whole rudder to make the desired movement to port so that the rudder stock follows the movement of the spur wheel (6) through the same angle of rotation less the amount of secondary helm required to give equilibrium. In this manner the helm can be put hard over to either side through an angle of 35-45° in a few seconds.

Condition 2.—Requirements called for under 2 are governed by the contour or profile given to the camplates.

Condition 3 (*a*) In view of the fact that the main rudder is perfectly free to move through 360°, the control gear must be so designed, that in the event of the main rudder receiving a blow from a wave or other object, the secondary rudder will automatically take up such a position relative to the main rudder as will immediately return the latter to the position originally set by the helmsman. Referring now to Figs. 2 and 2 b it will be seen that any movement of the main rudder causes a simultaneous movement of the toothed quadrant (1)

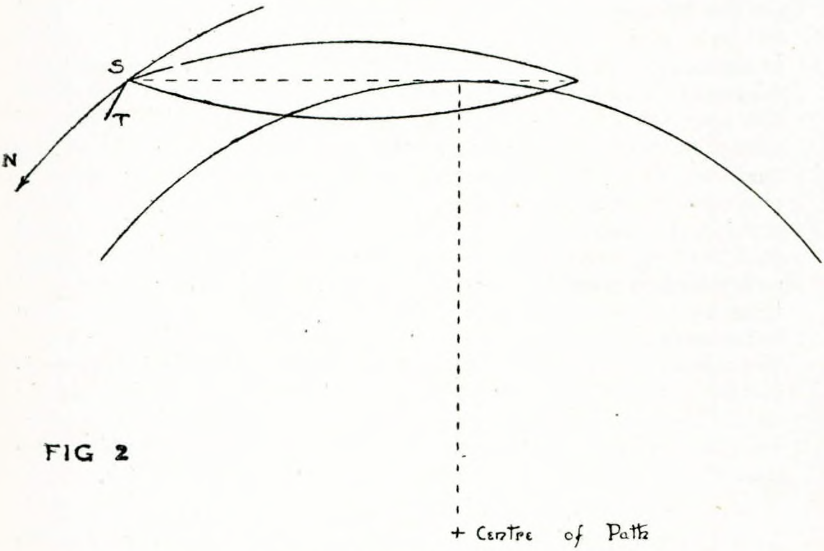


FIG 2

since it is keyed to the rudder stock. Further, since the rocker arms are attached and have their bearings in one of the quadrant spokes, any movement of the quadrant will cause the rocker arms and their rollers to travel round the camplates. Due to the profile or shape of the camplates, an angular movement is given to the rocker arms which immediately moves the secondary rudder through the links and rods (9-13) as shown in Fig. 2 b. This latter, of course, takes place without any movement of the wheel on the bridge, and were it not for indicators showing the position of both the main and secondary rudders, such deviations of the main rudder from its course would occur unknown to the helmsman.

Condition 3 (*b*) When it is desired to go astern, the secondary rudder is put hard over and as soon as the direction of the stream changes, due either to the reversing of the propeller or the stern way of the ship, then the main rudder, complete with quadrant and rocker arms is automatically drawn round

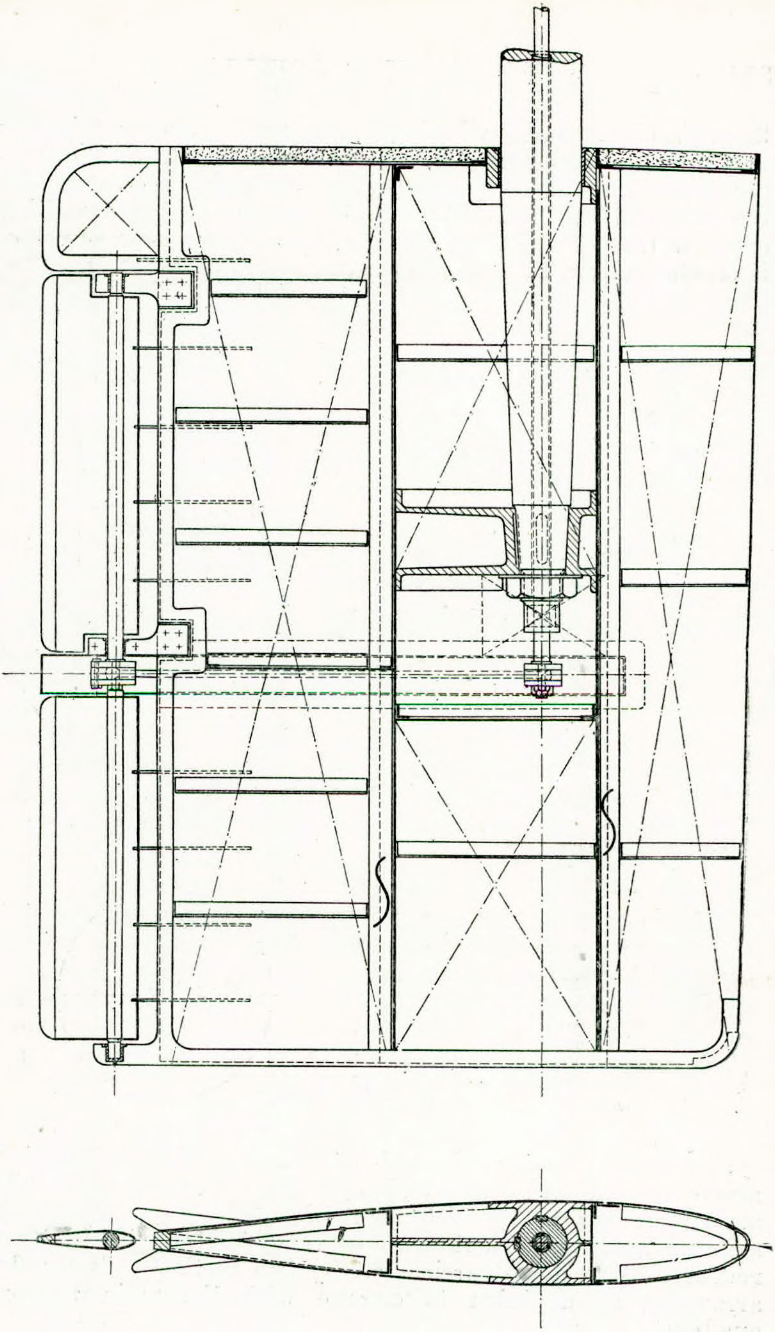


Fig. 2a.

through 180°. This swinging of the rudder does not in any way interfere with the control gear arrangements, as the cam-plates remain stationary and the rockers which are carried on the main quadrant, travel round the cams and take up a position opposite that to which they adjust themselves when the vessel is moving ahead.

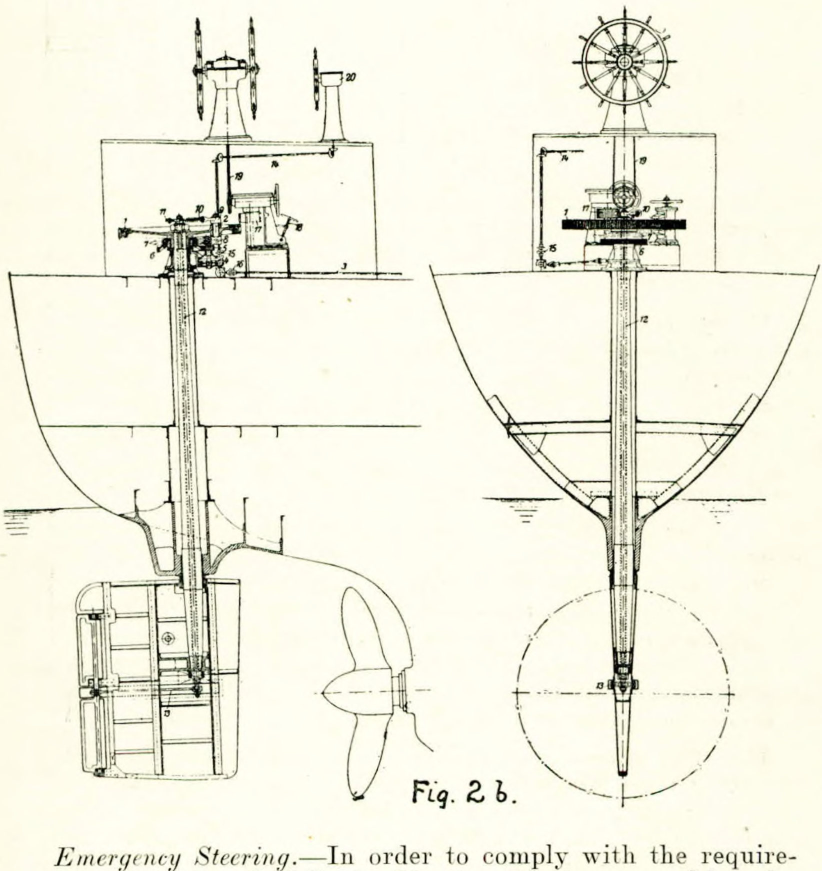


Fig. 2 b.

Emergency Steering.—In order to comply with the requirements of the Board of Trade, Lloyds and other control boards, arrangements must be made for the introduction of emergency steering by hand. In the case of vessels fitted with Flettner rudders, this can be carried out by two methods, firstly, by arranging for a pinion to engage with the main toothed quadrant.

If reference be made to Figs. 2, and 2 b, which shows the type of control gear fitted to M.S. *Sorrento*, it will be seen that the emergency hand gear can be immediately coupled up by meshing pinion (17) with the main toothed quadrant (1), this is carried out by means of the hand wheel (18). A second method of steering in cases of emergency is by means of the wire rope system.

In certain vessels fitted with Flettner rudders, the toothed quadrant is replaced by a wheel having a grooved rim, which in cases of emergency will accommodate a wire rope, the ends of which can be led on to two drums, which can be rotated by an emergency hand wheel through a reduction gear. Alternatively the rope can be attached to winches.

Owing to the favourable degree of balance of the rudder and to the corresponding reduction of load, the emergency gear, etc., can be constructed much smaller and lighter than would be possible with a normal rudder.

Under emergency conditions, the Flettner rudder can therefore be operated more easily than the ordinary type of rudder; furthermore it has the advantage of a smaller turning or twisting moment than the normal unbalanced type of rudder.

It should be added that in practice the main quadrant is equipped with a brake so as to facilitate the coupling up of the emergency steering arrangements.

Construction of the Rudder and Its Components.—No real difficulties present themselves so far as the construction of the rudder is concerned. In the case of M.S. *Sorrento*, see Fig. 2 b, which is fitted with the latest type of Flettner rudder, the actual rudder is of the spade type and streamlined in section. It is hollow and water-tight and built up of plates riveted and welded on to steel sections and is fitted under a cruiser stern specially designed to take the rudder.

The after edge of the rudder is fitted on either side with a number of fins which serve to guide the streams horizontally on to the whole of the area of the secondary rudder. These fins also protect the secondary rudder from damage likely to be caused from floating objects.

The rudder is keyed on to a hollow stock at a point approximately half way down its height. The amount of balance given to the whole rudder is 30%.

An inspection door is provided in the centre of the main rudder for the purpose of examining in dock the secondary rudder control arrangements. This door also permits access to the nut which holds the rudder on to the keyed and tapered stock.

The secondary rudder is balanced 28·5%, and as seen from the Fig. 2 a it is fitted with a spindle or stock which is carried in three bearings. These bearings are made in two halves and are carried in covers which are bolted to the main rudder. They can therefore easily be taken apart for renewal.

The rudder stock is carried in a trunk up to the main deck as shown in the Figs. 2 and 2 b, and is fitted with an upper and lower bearing, while the weight of the complete rudder installation is carried by a ball bearing which can be seen immediately above the upper main bearing. The main bearings are lined with bronze and lubrication is carried out under pressure, leakage of oil being taken care of by suitable packing. The lower bearing is carried in a steel casting which is riveted to the shell, floors and stern frame.

Should it be necessary to unship the rudder, the auxiliary rudder control rods must first of all be disconnected, after which the nut is removed and the rudder lowered off the stock. Should it then be necessary to withdraw the stock, say in order to renew the collar bearings, the control gear must first be taken apart and the stock lifted out through a hole in the control gear deck house.

The collar on the shaft immediately above the deck is to prevent it from falling through the trunk during the taking apart of the control gear.

ADVANTAGES OF THE FLETTNER RUDDER OVER THE ORDINARY RUDDER.—EASE OF OPERATION.—Up to the present time there are some twenty cargo and passenger ships in service, all of which, with the exception of M.S. *Odenwald*, are steered entirely by hand direct from the bridge. These vessels range in size from 160 up to over 9,000 tons deadweight. The M.S. *Odenwald*, which is owned by the Hamburg-America Line, and was built by the Deutsche Werft, is a vessel of 8,700 tons, and is fitted with a Flettner rudder in conjunction with an automatic gyro compass. A report on her maiden voyage is included in the appendix. In addition to vessels of the size mentioned, there are also in service a number of small tugs and some 90 Rhine barges varying in size from 270 to 3,000 tons deadweight. Prior to fitting Flettner rudders, the latter type of craft were steered by a horizontal wheel and in certain parts of the river they required as many as four men to control them. As a result of fitting Flettner rudders, they are now quite easily handled by one man.

The rudder has proved its efficiency both in single and twin screw ships. It gives superior manœuvring power compared with the usual rudder, and under normal conditions offers no more resistance. At extreme angles of helm, it is far more efficient in action than a normal rudder and offers far less resistance to forward motion. The superiority of the control when going astern is most marked compared with an ordinary rudder.

Some idea of steering efficiency can be gained from the picture which was taken from the stern of the M.S. *Sorrento* during her trials. In this case the ship was steaming at 11 knots and the effect of putting over the helm first hard to port and then hard to starboard is clearly shown.

No Loss of Effective Helm Angle.—It is well known that when a ship turns under helm her motion through the water becomes oblique and she develops a "Drift Angle." This drift angle, or the angle between the centre line of the ship at any point, and the direction of motion of the same point, is greatest at the stern, as will be seen from Fig. Y. In this Figure the approximate flow of the water past the rudder ST will be in the direction indicated by the curved line SN, hence the effective angle at which the rudder is operating is the angle between the lines SN and ST at the point S, and, as will be seen, this is very much less than the apparent angle of helm, *i.e.*, the angle between the rudder and the middle line of the vessel.

Now the Flettner rudder, being operated by the surrounding water only, sets itself at the angle desired by the helmsman, not with the centre line of the ship, but with the direction of flow of the surrounding water. There is in this case, therefore, no difference between the effective helm angle operating and the angle desired by the helmsman. It is considered that this advantage largely, if not wholly, accounts for the remarkable results obtained with the Flettner rudder.

Reduction of Stress when Steering Astern.—With an ordinary balanced rudder, *i.e.*, one which is slightly underbalanced for motion ahead, a very heavy torsional stress is produced when going astern because the centre of pressure is much further from the stock. With a Flettner rudder, no torsional stresses in the stock can occur at any time since the sum of the moment of pressure of the auxiliary and main rudders about the stock is always nil when the rudder is in equilibrium and when it is not in equilibrium, the torsion is merely expended in moving the rudder and not in twisting the stock.

Improbability of Sea Damage and Damage from Wreckage.—Damage to ordinary rudders due to heavy seas is of quite common occurrence. Apart from the energy in moving masses of broken water on the surface, the orbital motion of the wave particles themselves is capable of dealing heavy blows to any fixed object, such as an ordinary rudder, with

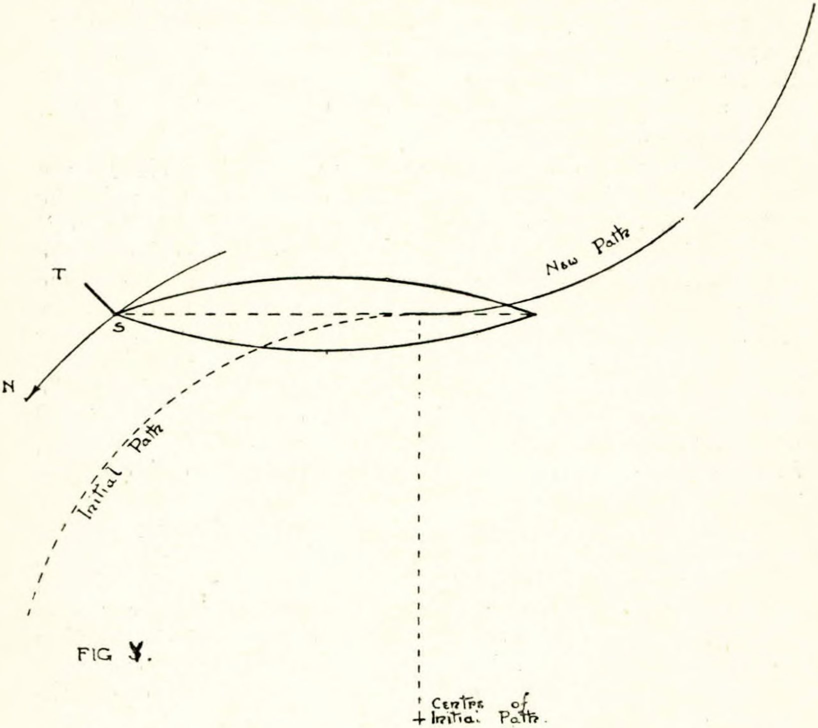


FIG Y.

which the particles come in contact. The Flettner rudder being free to rotate away from any such external pressure is extremely unlikely to receive any damage therefrom. It is just conceivable that the centre of effort of a blow from a wave might coincide with the axis of the stock in which case a heavy bending moment might be induced, this, however, could only occur if the blow were received from a wave on a part of the rudder only.

In a similar way the Flettner rudder is much less likely than an ordinary rudder to be damaged by sunken wreckage.

If the rudder is at any time deflected by a blow from any external source, the operating gear of the auxiliary rudder is so designed as to give the requisite motion to that rudder to restore the main rudder to its original angle without conscious effort on the part of the helmsman.

ADVANTAGE WHEN REVERSING A TURN. — When an ordinary rudder is used to reverse a turn, somewhat similar circumstances are obtained, but in this case the streams impinge on the rudder at a much larger angle than the apparent helm angle. From Fig. Y it will be seen that the effective helm angle as drawn is nearly 90°, which means that most of the energy given up by the water on striking the rudder will be used to check the speed of the vessel and very little to turn her. Here again the Flettner rudder places itself at the desired angle to the stream lines and so produces the maximum turning effect and a much smaller retarding effect.

ECONOMIES.—Turning now to the question of the saving in cost, the following figures, which were supplied by the A.G. *Weser* are of interest:—

M.S. *Gauss.*

1. *Electric Rudder Gear.*

	Weight.				Price.
	Tons.	Cwts.	Qrs.	Lbs.	
Rudder	1	14	3	10	
Rudder Stock		19	2	21	
Normal type of stern frame with Rudder post ...	5	16	0	15	
Electric Steering Engine complete with all accessories including steering wheel, controls, etc. ...	5	0	1	16	
Total weight of electrical steering gear	13	11	0	6	
Total cost of electric gear...					£1,227

M.S. *Kepler* & *Olbers*.

2. *Flettner Installation.*

	Tons.	Cwts.	Qrs.	Lbs.
Rudder with secondary Rudder	2	6	1	23
Rudder stock and secondary Rudder spindles, etc. ...	1	19	1	13
Stern frame and Rudder frame	5	3	1	10
Rudder control gear, deck housing and emergency steering gear	2	9	0	24
Control Rods and steering wheel		17	1	8
Total weight of Flettner Installation	12	15	2	22

Total cost of Flettner Installation, including Royalty of £150 ... ... £1,099

Saving in cost of Flettner Installation per ship £128
Saving in cost on two ships £256

The above is a comparison of the cost and weights of the steering installations fitted to three sister-ships, each approximately 1,700 tons deadweight and which were recently built for the Neptune Steamship Co. of Bremen. The M.S. *Gauss*, which was the first of these vessels to be built, was fitted with an ordinary type rudder and an electrical steering engine. The sister ships M.S. *Kepler* and *Olbers* were both equipped with Flettner rudders. From the figures shown above, it will be seen that there is a saving of weight in favour of the Flettner gear of approximately 1 ton, while the saving in cost per ship amounts to about £130.

Unfortunately the author has no other figures available, but it is claimed that in the case of larger vessels, the saving both in cost and weight is much greater, *i.e.*, up to 20%.

Further economy is shown owing to the fact that since in Flettner rudder equipped vessels, no steering engines are used, no fuel is required for steering, nor is there any wear and tear on steering engines.

SPACE OCCUPIED.—Owing to the deletion of the steering engine, the space occupied by it can be used for other purposes. The deck is free from chains, in cases where these would be otherwise used, whilst the operating gear on the rudder head is contained in a small and compact housing and takes the place of a large and cumbersome quadrant.

CONCLUSIONS.—The Flettner rudder is not a new and untried invention and it will be seen from the Appendix that already a number of sea-going and other craft have been fitted with the Rudder and there are other vessels under construction which are also to be fitted with this type of steering gear.

The very definite advantages of the rudder as to its performance in comparison with rudders of the normal type, have been proved beyond question.

Apart from the satisfaction given in ships owned by Dutch, German and Scandinavian owners, the rudder has proved itself of great value in the navigation of rapid and shallow rivers.

In conclusion the author cannot finish the paper without thanking Messrs. Mordaunt M. Parker, M.Sc., and R. W. B. Billinghurst, A.M.I.Mech. E., for assistance rendered in its preparation. He is also indebted to Messrs. Wm. H. Muller & Co., Rotterdam, and N. V. Flettner's Scheepsroer Maatschappij, Rotterdam.

APPENDIX.

CAPTAIN'S REPORT OF THE MAIDEN VOYAGE OF THE *Odenwald*. —Translated from a report, dated Colon, 5th May, 1923. (Voyage, Antwerp to Colon, 20 days.) Parts dealing with matters irrelevant to the present subject are omitted.

"Sunday, 14th April, 3 p.m. When manœuvring in Antwerp Dock, the ship answered her helm directly one of the engines was started up, and no difficulty was experienced due to the twin propellers.

Flushing was passed on the 15th April, at 8.15 p.m. We changed pilots and set our course seawards. No difficulties were experienced during the trip down the river. Although the transmission gear worked stiffly, the ship answered her helm well. At 10.14 a.m. we dropped the sea pilot near the Wandelaar light-ship; the motors were opened out to full speed and the sea voyage started. The automatic steering gear was at once switched on and this kept the ship on her course within 1 to 2 degrees either side. Dover was passed at 4.40 p.m. Wind W.N.W. 2/3. Heavy westerly swell running.

16th April, 9.44 p.m., passed Quessant.

On April 17th, 7.5 a.m., the steering refused to work. The main rudder was accordingly locked by its brake, and the Flettner transmission disconnected to see whether the seizure was in it or in the rudder. The bevel wheels of the transmission in the steering wheel housing were found to be seized up and immovable. The shafting was dismantled by the engineers and put right. In order to lose no time, we steered with the propellers and found we could hold the ship within 5 to 8 degrees on either side of her course. The repair was completed by about 9.30 a.m. The transmission was re-assembled and steering continued with gyroscopic compass gear.

18th April. The wind shifted on the south, force 5/6, a high sea. The ship rolled heavily at times. Towards evening the westerly swell increased. The automatic steering gear kept the ship within 1½ to 2 degrees on either side of her course. I watched the rudder for a long time at the after steering station. It oscillated 2 to 3 degrees to either side, and worked easily. During April 19th, wind and sea increased still further. A heavy south westerly sea was running with a wind force of 7/8. The ship rolled severely. Speed 4-5 knots at 110 revolutions. Held course within 4 to 5 degrees with automatic gear and 4 to 6 degrees with hand gear. The Flettner rudder worked very well. It yielded three or four degrees to each sea and returned immediately to its position. In the evening the wind increased to force 9/10 with a very high,heavy sea. The rudder oscillated smoothly from 5 to 7 degrees according to the strength of the seas, but always came back at once to its position. I have watched the movement of the rudder frequently and for long periods and consider that it works perfectly in a heavy sea and with more certainty than an ordinary rudder. With the latter, we would have had to use preventer tackle yesterday or even earlier, in view of our light loading and the heavy sea, to guard against breakage of the rudder chains, whilst rudder, steering engine and tackles would have been subjected to severe stress.

On one occasion the indicator in the wheel house on the bridge oscillated rapidly through nearly 180 degrees. I satisfied myself immediately, by inspection at the after steering station, that the rudder was working smoothly as before. The after electric steering indicator was overhauled and it was found that the contact springs were out of adjustment. The electrician rectified the fault and the bridge indicator worked normally again. In spite of the very high and heavy sea in which the ship laboured heavily and at times hammered severely, the automatic steering gear in conjunction with the Flettner rudder could keep within 4 to 5 degrees each side of the course. The hand gear which worked more easily to-day, held the course within the same degree of accuracy.

In the night, April 19th to 20th, the wind shifted to N.W. with a force of 9/10. The ship still laboured very heavily in the very high cross sea. The cargo worked loose in No. 3 hold, shelter deck. The hatch was opened up and the cargo restowed. While this was taking place the ship was put head to sea to reduce the rolling as much as possible. During the morning of April 20th, the wind veered to N.N.W., force 9/10, with heavy squalls. Hove to with engines at 90 revolutions, to avoid damage to ship and motors. The rudder still oscillated smoothly, but not more than 5 to 9 degrees on either side of its proper position, according to the strength of the seas. Switched off the automatic gear and steered by hand, since hand steering involved less movement of the helm with the ship rolling and sheering about in the heavy sea. In the afternoon the storm slackened and at 5.20 p.m., I tried to bring the ship on her course, and went ahead at 110 revolutions. On our proper course we had the N.W. sea on the beam and the resulting severe rolling of the nearly empty ship brought the intake valve of the cooling water too often out of water, so that it sucked air instead of water. To avoid risk of damage to the engines, I steered a southerly course. With a falling northerly wind, we steered on our new course alternately with the automatic gear and by hand. Deviation to either side, with the former, 3 to 4 degrees; with the latter 4 to 5 degrees.

By keeping a straight course, the automatic steering gear saves many a sea-mile on long voyages, since on each change of helmsman, deviations occur before the man accustoms himself to the steering. Our crew on this trip are excellent and most willing, which goes far towards accurate steering. They would be able to steer far better, however, were the hand transmission geared up to a ratio of 1 to 2.

After this two days' storm with a force of 9/10 during which the rudder was subjected to very heavy seas from all directions, I am satisfied that the new Flettner rudder has proved itself excellent, both in good weather and in the worst, and that it surpasses by far the ordinary type in reliability, smooth working and economy in maintenance. As regards ease of steering also, as I have already instanced under various weather conditions, it is to be regarded as extremely good. After the repairs to the transmission gear, this became thoroughly run in by the amount of work which was put upon it by the automatic steering gear during the storm, so that it now turned more freely and could be worked with greater ease by hand. I should like, however, to make the suggestion that the shafting should be hollow and provided with ball-bearings in various places, also where necessary with thrust bearings, particularly in the steering-wheel housing. Moreover, the gear ratio fitted, of 3 to 1, should be altered to 2 to 1, to reduce the number of turns which must be made by the steering wheel, and thus conduce to steadier steering.

During the following days the wind and sea went down, so that on April 22nd there was almost a calm, accompanied by a northerly swell. I steered alternately with hand and automatic gear, keeping within ½ to 2½ and ½ to 1 degrees respectively, on either side of the course. At 5 p.m. we passed the island of Santa Maria in the Azores.

We held the fine weather up to Sombrero Island, which was passed on May 1st, at 2 a.m. The Flettner rudder, in conjunction with the automatic gear, worked perfectly and kept a good course. In the afternoon St. Croix Island was passed. In the Caribbean Sea we picked up a fresh north-east trade, reached Christobal on Sunday, May 5th, at 6.19 a.m., and anchored behind the breakwater. Length of voyage 19 days 23·9 hours. Total distance run, 4,815 sea miles. Average speed 10.03 knots. Draft 12ft. forward, 15ft. 6in. aft.

During the entire trip, the Flettner rudder gave no trouble. It worked perfectly, as already mentioned. The gyroscopic compass with automatic steering gear must also be described as entirely satisfactory, although several small running repairs had to be made to the automatic gear during the course of the long sea trip."

Hamburg, 28th May, 1925.

REPORT ON THE TRIAL TRIP OF THE M.S. *Sorrento.*—On the 20th May, 1925, a trial trip of about two hours duration was carried out down the river Elbe with the M.S. *Sorrento,* which was recently handed over to her owners, Messrs. Robert M. Sloman, junr., of Hamburg.

The object of this trial trip was for the purpose of thoroughly testing out the Flettner rudder installation with which the ship is equipped.

The steering proved a complete success, it being possible for one man to hold the vessel on its course quite comfortably by hand. In altering course the rudder responded in a very remarkable manner, without any unnecessary effort being exerted on the hand steering wheel. Turning circles were made both to port and starboard, and were estimated to have a diameter of only twice the length of the ship. Furthermore, while steaming down the river at full speed, the helm was put hard over, so as to bring the ship practically across the stream. She was immediately brought back on her course without in any way reducing the speed of the engines.

These difficult manœuvres convinced everyone on board as to the efficient steering possible with the Flettner rudder.

We would like to draw special attention to the tests carried out at slow speeds, especially in regard to the steering of the vessel after shutting off the engines. Whilst entering Hamburg with the tide, that is to say with the current running in the same direction as the ship, and notwithstanding the fact that the wind was against us, the ship was still capable of being steered for seven minutes after the engines had stopped, that is to say going absolutely dead slow. Furthermore, it was possible to bring the ship right into the sailing ship harbour, and up to the quayside without any assistance from tugs.

The Flettner rudder control gear in the wheel-house worked silently and gave entire satisfaction.

Signed on behalf of the Steamship Company by Messrs. Robert M. Sloman, junr.; Inspectors L. Piotrowski and L. Blanck, Captains M. H. Matzen and E. Knickelbein, 1st Officer F. Buschenhenke, Pilot J. Heins, Asst. Pilot Nillhagen, and Capt. Hauptmann of the A.G. *Weser*.

Hamburg, *25th July*, 1925.

The M.S. *Sorrento* left Hamburg for the Mediterranean with a full cargo on 31st May, 1925.

During the voyage fifteen different ports were visited. The majority of the ports which we called at were in Spain and Italy, and were very narrow and small.

The vessel answered her helm at various draughts and under all kinds of trim quite satisfactorily, as long as there was any weigh on the ship.

As soon as the vessel stops, and it is desired to go ahead again, a few turns of the propeller is all that is necessary in order to bring the rudder into action, and give directional control. During the voyage the ship steered very well in rough weather, and in spite of very high seas.

My opinion is that the manœuvring possibilities of the ship fitted with a Flettner rudder installation are better than with the old type of rudder.

Signed: E. Knickelbein,

Capt. M.S. *Sorrento*.

SHIPS IN COMMISSION FITTED WITH FLETTNER RUDDER GEAR.

Name.	Type.	Owner.	Tonnage.	H.P.
"Frigido"	Refrigerator Ship	Wm. H. Muller & Co., Rotterdam	160	200
"Odenwald"	Motor Cargo Ship	Hamburg-Amerika-Linie, Hamburg	8700	3100
"Oranje I."	Tug	N. V. Brandstoffenhandel en Reederij, Amsterdam.	—	500
"Oranje 1"	Rhine Barge	Do.	1850	—
"Marietje"	Motor Boat	Do.	—	—
"L V"	Passenger Steamer	Ung. Flues-u. Seeschiffshrts, A. G., Budapest	21	240
"Konigsberg"	Motor Cargo Ship	Norddeutscher Lloyd, Bremen	9320	3200
"Oranje 6"	Rhine Barge	N. V. Brandstoffenhandel en Reederij, Amsterdam	1800	—
"Oranje 7"	Do.	Do.	1800	—
"Dordrecht"	Ferry Steamer	Stadt Dordrecht	—	150
"Dordrecht"	Do.	Do.	—	150
"Oranje 8" "Oranje 9"	Two Rhine Barges	N. V. Brandstoffen en Reederij, Amsterdam	2860 each	—
"67270"	Danube Freight Barge	Erste Donau-Dampfschiffahrtsgesellschaft, Wein.	661	—
"Jupiter" "Mars" "Merkur" "Possidon" "Apollo" "Pluto"	Six Rhine Motor Barges	Rhenus Transport A. G. Basel (Fendel-Konzern)	270 each	400 each
"L anenburg"	Motor Ship	Neue Norddeutsche Flussdampfschiffabrts-Ges., Hamburg	185	80
"Molln"	Do.	Do.	185	80
"Neptun"	Rhine Barge	Neptun Transport A. G. Basel (Rhenania-Konzern)	1000	—
"Hansa"	Paddle Steam Tug	A. Dames, Hamburg	—	600
"Sorrento" "Amalfi"	2 Motor Cargo Ships	Rob. M. Sloman	2700 each	1050 each
	2 Motor Cargo Ships	Dampfschiffshrtsges, "Neptun," Bremen	1675 each	800 each
"Braunkohle V"	Paddle Steamer	Versmigungesellsch, Rhein-Braunkohlenberg-werke m.b.H. Koln A/Rh.	—	900
"Charente"	Motor Ship	Fearnley & Eger, Oslo	1900	900

SHIPS UNDER CONSTRUCTION TO BE FITTED WITH THE FLETTNER RUDDER.

Name.	Type.	Owner.	Tonnage.	H.P.
"Soemba" "Flores"	2 Flotilla Leaders	Dutch Navy	—	—
"Oranje IV"	Paddle Steamer	N.V. Brandstoffenhandel en Reederij, Amsterdam	—	2000
"U.Z.27"	Motor Boat	Reichswahrministerium	—	300
"Munchen"	Tug Steamer	Wasserstrassenmaschinenamt, Rendsburg	—	—
	9 Rhine Barges	"Neptun" Transport A.G. Basel	1000 each	—
"Meteor"	Rhine Barge	Schiffer Blum	1500	—
	10 Rhine Barges	N.V. Walsum, Rotterdam	1800 each	—
"Agnard"	Tug	Nederlandsche Rijnvaart-verseniging, Rotterdam	55	525
	2 Screw Tugs	Isthimian Steamship Lines	—	—
	Rhine Barge	Schellenberger, Erlenbach, A/M.	1000	—
		Leidel	1350	—
	2 Tugs	Gebr. Wiemann, Brandenburg, a/Navel.	—	250
1 Flettner Motor and Rotor		Rob. M. Sloman, Jun.	3000	—

The CHAIRMAN: Mr. Best has given us a very clear description of the Flettner rudder, and is prepared to answer any questions on the subject.

I will first ask the Honorary Secretary to read a contribution which has been received by correspondence from Capt. P. T. Brown.

Captain P. T. BROWN, M.C.: I am sure members will appreciate and thank Mr. Best for the work he has done to present this most lucid paper on the Flettner rudder. In "The Practical Aspect of the Steering of Ships," given last session, I alluded to this rudder and gave a list of the advantages that were *claimed*. The author of the present paper finds and *adopts* other advantages. I would suggest that his enthusiasm is not yet justified. The list given in this paper of vessels built and under construction in which the Flettner rudder is fitted, shows that only two nations have so far tried this device, and it is worthy of note that no British vessels are included.

The reason for this appears to me to be that British owners and their advisers are extremely practical men and I would like to mention a few points on which, in my opinion, Mr. Best's optimism is open to criticism.

Improbability of Sea Damage and Damage from Wreckage.—In a sea way this rudder is free to rotate and is therefore less likely to receive any damage by blows from waves. This, I think, is a perfectly sound claim, but it only applies to the rudder itself. If the rudder is set spinning about while the vessel is labouring in heavy weather, what is going to happen to the vessel? I suggest considerable deck damage.

In regard to damage by wreckage I am totally in disagreement with the author. I think that this and also the possibility of damage by striking sunken piles and by fouling of ropes constitute real objections to the device.

Economies.—These tables are unconvincing. We are informed that a saving of £128 is effected in one ship and £256 in two. We can, therefore, assume that over £1,000 would be saved in eight ships. As a matter of fact it comes out at about two shillings per gross ton, which is not sufficient of itself to be an inducement.

In regard to weights, the suspended weight of the Flettner rudder is 4 tons 5 cwt. 3 qrs. 8 lbs. and that of an ordinary type 2 tons 14 cwt. 2 qrs. 31 lbs. This 55% increase in weight is a great disadvantage. It means that a very much stronger construction will be necessary in the stern. This might easily negative that £128. The principle of action of this rudder is good and the saving in steering engine power constitutes a very real gain, but I fear Mr. Best will find shipowners very conservative when it comes to adopting the idea.

Mr. F. O. Beckett: There is just one point which is brought out in the photographs which have been shown on the screen, which is not dealt with in the paper, namely, the revolving of the Flettner rudder from ahead to astern. Most of us have experienced trouble during the manœuvres connected with docking. There seems to be very little clearance when the rudder reverses, insufficient, I should think, to clear a ⅝ in. rope. I should like to know what trouble the engineers would have it they did foul a rope.

In the case of a ship lying at rest or nearly stationary requiring steering way, would this rudder come into operation as quickly as the ordinary hand tiller? Vessels to be fitted with this rudder must evidently have a stern built specially. It appears to me that unless the long shaft which carries the rudder is not well supported in the stern, or the stern made to suit it, in altering its centre of gravity when the ship was labouring, and pitching particularly, there would be a possibility of the stock breaking off at the neck.

Mr. H. S. Humphreys: I have not had an opportunity to study this paper, but a few points occurred to me during the reading of it.

Are there any stops provided, so that when the rudder is put hard over to maximum efficiency, say 42° or thereabout, the steersman cannot put the rudder over any further? Also, when the vessel is turning round on say, port helm, does the effect of the rudder turning through 180° when coming astern have any curious effect on the vessel's head canting the right way as she is coming round? With regard to dumb barges, what provision is made for steering the vessel when she is being manœuvred for position? How are you going to get the barge's rudder to help you to assist the tug?

With regard to barges on canals where you have a great deal of debris and floating stuff, it appears to me that this stuff would surely get into the mechanism of the secondary rudder unless some provision is made to avoid ropes, small wires, rubbish, etc., getting into the clearance spaces.

Finally, I would like to ask whether the author could give any idea of the cost of fitting a Flettner rudder to a small coasting motor vessel of say, 600 tons dead weight. Reverting to my first question regarding a stop,I meant a stop in the steering position so that a man could not put the helm further over; that is, a stop to prevent the steersman going blindly on.

The Author: There is a stop fitted for this purpose.

Mr. W. Hamilton Martin: I note in the list of ships under construction which are being fitted with Flettner rudders, two Dutch flotilla leaders are included. As far as I know, these are 35 knot vessels, of 35,000 H.P. Have any tests been carried out on these rudders approaching this speed, or are they of special design? The Dutch Authorities would seem to have very great faith in this rudder if this is correct.

Mr. M. M. Parker: I have read Mr. Best's paper with very much interest.

I should like to ask the author if he can throw any light on a point that has worried me. As the Flettner rudder is like a free plane moving obliquely through the water, the pressure helm curve or equally the moment-helm curve probably exhibits the usual hump at the critical angle, which one might expect somewhere between, say, 25° and 35°. It occurs to me that the presence of this hump on the curve would lead one to expect that in the neighbourhood of the critical angle there would be two points of equilibrium for a given setting of the helm, one on either side of the critical angle. If this were actually the case, then if the rudder happened to be deflected by a wave or other cause, it might subsequently come to rest at its other point of equilibrium. Perhaps this state of affairs might lead to some oscillation of the rudder in the neighbourhood of the critical angle. Has Mr. Best observed such wobbling on any of the trials he has attended? Or again, it may be that the horizontal section of the rudder, being streamlined, alters the critical angle to some higher value outside the scope of ordinary rudder angles, or even eliminates the hump from the curve altogether.

The fact that the Flettner rudder sets itself at the desired angle to the stream and not to the ship suggests that by its means we may soon determine what is really the angle at which the rudder produces its maximum turning moment on the ship, and it is probable that this will be found to be different for each individual ship, and will be of the form $(\phi + \theta)$ when ϕ is the drift angle varying from ship to ship and θ is the angle between rudder and stream for maximum efficiency, which should be nearly the same for all ships.

The AUTHOR's Reply: Captain Brown is incorrect when he says that only two nations have so far tried this rudder, as it has been taken up by Scandinavian owners in addition to the Dutch and Germans. He also mentions that British owners have not adopted it: perhaps that is due to conservatism and also to the bad times through which we have been passing in the shipping industry. As regards damage from wreckage, my reply is that I do not think that in a rough sea the rudder would spin or move about to the extent inferred by Captain Brown. Both the *Odenwald* and the *Konigsberg* have been running long enough for serious trouble to occur, and so far as I know no complaints have been received about any extraordinary behaviour of the ship as compared with a ship fitted with an ordinary rudder, in fact to the contrary. One of the best tests as regards the rudder standing up against floating wreckage is steaming in waters full of lumps of ice, and I may tell you that some time ago, in fact before the Scandinavian owners placed their orders, a very severe test was carried out on the *Odenwald*. This vessel was taken down the River Elbe during the breaking up of the ice during the winter of

1923-4. An inspector from the Norwegian Control Board (Bureau Veritas ?) following the ship down the river in a tug, and he ascertained that the rudder came in contact with many pieces of ice, but was not in any way subject to shock or stress.

The vessel was also tried going astern, and as soon as the rudder came up against any blocks of ice it immediately gave, and as far as could be ascertained the auxiliary vanes were not buckled or damaged.

I think you will agree that waters abounding with blocks of ice afford a very good test indeed.

With regard to the question of the auxiliary rudder being fouled by hawsers or ropes, undoubtedly the rudder could come into contact with such ropes, but I do not think that the clearance is sufficient for the rope to get between the top part of the vane and the main rudder itself. I do not think there will be any chance of a rope getting wedged in there. The auxiliary rudder itself could be made sufficiently strong to withstand any damage in that direction. The control rods being made of high tensile steel have not much chance of becoming bent or damaged; furthermore, they are protected.

A rope could of course get in between the propeller and the rudder, but in the past few years ships of the Dutch Navy have been fitted with this type of rudder and they have had no difficulty. The difficulty in any case is one which can be overcome by suitable skeg construction.

Mr. Beckett raised a question regarding the behaviour of the rudder at slow speeds. I may say that so long as there is any current flowing past the fin the rudder will function. Supposing you are absolutely at a standstill and you want to turn the ship, if there is no way on the ship or no current, the rudder will not function. To overcome this difficulty and to put the pilots and captains of vessels at ease who have any doubt about the efficiency of the rudder at slow speeds, a small electric motor could be fitted to the quadrant. For example, the *Konigsberg* has been so fitted, with a motor of $5\frac{1}{2}$ H.P., so that when going dead slow they operate the motor coupled to the main quadrant and so work the main rudder. In other words they do away with the fin. I think the question of this behaviour at slow speeds is more due to prejudice than anything else. A certain pilot came on board a German ship fitted with the Flettner rudder and complained about the way in which she answered her helm at slow speeds. A few weeks later the same pilot was on board another ship not completely finished, but fitted with the Flettner rudder. On this occasion he said the vessel steered better than any he had ever handled! He did not know that the vessel was fitted with this rudder.

Mr. Humphreys raised a question about stops on barges. I showed a lantern slide of one of the quadrants in which a stop was fitted on either side so that when manœuvring through canals or narrow waters and you put the Flettner fin hard over, you come up against the stop and put into action the main rudder, so that it is quite possible to work the main rudder and the fin through the same wheel. It is a question of designing suitable control gears to give these requirements.

With regard to the cost of fitting a small coaster, I would like to have more particulars of the vessel, and to answer that question in writing, also the other questions raised by Mr. Parker.

The two Dutch boats are not destroyers, they are gunboats fitted for river work. I was on the trials of one of them the other day, and it gave entire satisfaction. The official trials are taking place in a few days time. Of course, the rudder has to be designed to suit the circumstances; for a warship or a fast destroyer you would want a different design of rudder from that suitable for a mercantile motorship.

The CHAIRMAN: I am sure we are grateful to Mr. Best for the paper he has given us, and his further description of the Flettner rudder and its operation. I have great pleasure in moving a vote of thanks to Mr. Best for the trouble he has taken on our behalf. The vote of thanks was seconded by Mr. R. P. Palmer.

———o———

Discussion on Paper by Mr. Cecil Hughes (Assoc. Member) on "Fuel Injection," read 22nd December, 1925.

Mr. Hughes: It is possible that this paper may appear to be elementary in the extreme. I have had to go back to some of the simple details concerning the pumping of fuels, and although they are very elementary, I can assure you that they are the crux of the whole problem.

Mr. J. H. Anderson: Is it intended that this apparatus should be carried about in an ordinary motor car?

Mr. Hughes: It is most certainly not the intention of the author to carry this apparatus about in a motor vehicle, but same may be attached to an engine. This particular apparatus which I have shown to-night, is for use on engines suitable for an automobile, an aeroplane, or a motor boat. It has numerous applications whether for lubrication or injection, either in internal combustion engines or furnaces, or in anything else where fuel injection is required.

Mr. Anderson: If this system is concerned with ordinary petroleum spirit it seems to me that it is not a good addition to the ordinary method in use in a motor car, as it will take away some of the power of the engine. It seems to be something superfluous to the modern car. I have a light car with a good old fashioned carburetter which has never given me any trouble. One statement of the author's strikes me as being open to challenge, namely, "that the fuel consumption is a factor which one need not go into." As I consider that this is the principal thing to be investigated, the only point regarding any new carburetter one considers, is, whether that carburetter will give more miles per gallon than the type used in modern motor cars. It seems unnecessary to add pumps, mechanically driven with ball races, etc., to an ordinary motor car.

Another point which occurs to me in connection with a variable load on the engine as when going up hill, has this pump any means provided by which one can get the fine automatic adjustment which one can get with an ordinary jet? Then there is the difficulty due to variable weather conditions, etc.; can you get the same fine adjustment as regards admitting oxygen and fuel? Also what is the effect on starting? How is the carburation effected at that particular moment? The principal question is, what results would this apparatus give with an oil which we have to use, which is of great density and thickness.

Mr. Hughes: Mr. Anderson may be content with his present carburetter, and be satisfied to refrain from attempts to improve in that direction, personally I am not yet satisfied with anything made by man, I am glad Mr. Anderson refers to "a good old carburetter," for in my opinion that's what they all are. I fail to see any perceptible advance made during the last fifteen years in carburetter design.

To assume the author considers fuel consumption of no importance is a misunderstanding on the part of Mr. Anderson. May I repeat I do not wish to give my own fuel consumption figures, I prefer others to obtain them. Referring to Mr. Anderson's remarks that "Fuel consumption is the only point to be considered," I beg to differ.

The question of drive is no difficulty, the plungers may be driven off an existing cam shaft without ball races, etc. Variable loads on an engine, fine adjustments, weather conditions, starting, etc.; are met by the automatic control which governs the pump discharge.

I think you will agree that, although I could have stated that I have a vehicle which will do 40 m.p.g. and 50 m.p.g. when fitted with this pump, that is one of the points which it is preferable not to include in the paper. It is one of those points on which I am sensitive.

Mr. Anderson: I am not interested in motor cars; the car I mentioned is a private car of my own. It is these figures of mileage economy that we are interested in.

Mr. Hughes: With regard to the question of variable load, I dealt with this in the final part of my paper. I fully understand and point out that loads may differ on an ordinary road; for example, the engine may be tugging up a gradient slowly at 25 m.h.p. In that case the throttle may or may not be, according to the carburetter, wide open, but the amount of air consumed will depend on piston speed, as well as throttle opening, because the engine will be travelling slowly. On the other hand the opposite might occur; you might be coasting down-hill on a very fine throttle opening, and if you study carefully that system of atmospheric control you will find that there is at least one system of carburetter functioning very well with a small jet opening in proportion to air velocity.

Mr. Anderson: If I were travelling up hill I do not think I should experience any trouble; I should put my foot on the throttle control and get all the movements I required. When I am coasting I do not use any fuel; it is not necessary. You would not use any more fuel than is necessary for the speed required.

Mr. Hughes: Having been accustomed to motoring for 16 years, I quite appreciate your latter remarks. If you follow this system out carefully you will find that you have correct functioning when going down hill as under any other conditions.

As regards the effect on starting, I have given a few notes in the paper regarding starting on alcohol, and on paraffin. Mr. Anderson says that he has a vehicle which has never given him any trouble. At the same time there are a great many people who have had an entirely different experience on starting up at low temperatures in this country. With this system of carburetter, you get a pulsation on the first turn of your starting handle.

Mr. Anderson: What efficiency would this pump have on the class of oils used for larger engines where the oil is in such condition that you have almost to dig it out? I am now referring to the use of an oil that has had the spirit and kerosenes and probably the gas oils topped off.

Mr. Hughes: You already use a pump for dealing with such oils. This type of pump would not be more adversely affected than any other. Of course I cannot claim to give the same mechanical efficiencies when dealing with such fuels as you describe, but it will give a greater range of control which must be recognised as a great asset.

Mr. Anderson: What effect would the elasticity of the pump have on the heavy fuels?

Mr. Hughes: No ill effects whatever.

Mr. Anderson: What would be the effect of this pump working against a pressure of 3,000/4,000 lbs. per sq. inch?

Mr. Huhges: In what quantities?

Mr. Anderson: In large quantities for a large engine.

Mr. Hughes: I would not claim to give you a pump of this type to deal with tons of liquid per minute. The chief difficulty we are dealing with in the case of heavy fuels is the viscosity of the fuel. If you will give me an actual figure I will tell you.

Mr. ANDERSON: Say $\frac{1}{2}$ to 1 gallon per minute against 3/4,000 lbs. per sq. in.

Mr. HUGHES: I think that is a large amount for a single plunger against such a pressure.

Mr. ANDERSON: It is average practice.

Mr. HUGHES: With this pump I am doing something which you cannot do with any other. Suppose I ask you to meter 5 c.c. per hour with your pump against 3/4,000 lbs. per sq. in. with a pump capable of discharging large quantities, you are up against severe trouble.

Mr. ANDERSON: I am afraid I do not grasp what exactly is the effect of this pump. You demonstrated how it was possible to stop the discharge with your finger.

Mr. HUGHES: I can increase the pressure to almost anything you require up to tons per sq. inch if necessary. It is merely set at the moment at a low pressure for demonstration purposes. I regret you do not yet grasp the details of this pump.

Mr. W. BROOKS SAYERS: I have not been concerned with internal combustion engines for some years past, therefore it is new to me to see in the paper that the attempt seems to be made to vary the quantity of fuel injected per stroke. My early experience with internal combustion engines was with Crossley gas engines, then with Hornsby-Akroyd oil engines and very early types of Diesel engines, and in every one of these a hit-and-miss device was used so that the same quantity of fuel was always injected. I was once interested in the problem of getting a steady drive, and I endeavoured to get Messrs. Crossley to govern by varying the quantity of gas in the charge; i.e., instead of missing two or three strokes, to vary the gas per stroke. They did it on a few engines, but they complained that varying the mixture was not economical, and that it did not give good combustion. It seems to me that apart from the question of automobiles, if you had a large Diesel engine with 8, 10 or 12 cylinders, you could regulate by cutting out some of the cylinders instead of varying the quantity of fuel. The important point in the question of high efficiency in any internal combustion engine is to maintain exact proportions of air and fuel.

Mr. HUGHES: Mr. Brooks Sayers remarks are closely connected with the subject of the paper, but the particular experiences referred to, although available, are rather out of date, and as I have pointed out in remarks regarding air and fuel metering there has been so much trouble with the various methods attempted or adopted from time to time that even the best of them have been but a partially successful means whereby we have been carried over our troubles. In my opinion the cutting out of the cylinder has been and is a necessary evil.

Mr. Brooks Sayers: I quite appreciate that if this pump will deliver a precise quantity in a more reliable manner than any other pump, that is a very important point as regards securing economy of fuel.

Mr. Hughes: You could build a pump on orthodox lines which could meter quantities perfectly, or as nearly perfectly as required for all practical purposes; but you cannot do that and maintain a range such as this pump gives with its elastic discharge. It gives a range from one globule to 3,000 or 4,000 c.c. or more per minute.

Mr. Brooks Sayers: Is the essential feature the spring control?

Mr. Hughes: No, an elastic discharge is not new; it has been used before. What is new is that this pump has no packing round the rams, yet there is no leaking past the glands, gives the advantages of spring control without disadvantages experienced hitherto, supplies a variable pressure and other desirable features as described.

Mr. Brooks Sayers: What is the reason for that?

Mr. Hughes: If you refer to Fig. 7 that is explained. The groove F. is kept at the same pressure as the duct B, so that as fast as any slip takes place between duct B and groove F it is carried back to the suction. I consider the other points are already described quite clearly.

Mr. Brooks Sayers: It appears to me that working with these very fine clearances would cause a lot of trouble. I have tested steam engines years ago at makers' works at Birmingham, and a certain clearance was allowed to get a certain steam consumption, but I was informed that after the engine left the test bed, the clearance was increased, otherwise the engine would seize up and give trouble after delivery!

Mr. Hughes: The clearances allowed are quite adequate to prevent trouble such as has been referred to.

Mr. J. H. Anderson: Some years ago I was in charge of an engine department at Messrs. Vickers, and we used to get a very fine fit, but as soon as the engine went into the testing shop the clearances were increased.

Mr. Hughes: I regret the phrase 'a very fine fit' conveys very little to me. A smith might consider 1/64th in. a very fine fit, a mechanic ·0001 in., and an instrument man ·00001 in.

Mr. A. F. C. Timpson: We are told that this pump will run at speeds up to 10,000 strokes per minute. As far as I can see, the plunger is making a vacuum depending on the length of stroke, until it uncovers the suction part.

Mr. Hughes: You will see two mushroom valves in the elastic members, so that the liquid follows the plunger.

Mr. Timpson: I was under the impression that the pump came back and created a vacuum. I now note that there are valves to allow the liquid to follow the plunger on the suction stroke.

As regards the volumetric efficiency of 140%, I assume that that means that you get 140% of the swept volume?

Mr. Hughes: In one case we get a higher volumetric efficiency than unity, due to the sudden pressure of the liquid which enters with a high velocity before the suction is closed. That is shown in Fig. 4, but that does not refer to model shown in section.

Mr. J. H. Anderson: How long has this pump been in practical operation?

Mr. Hughes: About six months on the market and five years being developed.

Mr. Anderson: Would you accept and examine a similar pump which I have had for two years?

Mr. Hughes: I feel flattered, having received many such offers.

Mr. J. C. Thompson: I notice that this pump deals with pressures up to 500 lbs. and is meant to replace the carburetters of petrol engines. For motor boats that is a certain advantage, particularly if you can start from cold, but how does it apply to a Diesel engine using a pressure of about 5,000 lbs. per sq. inch? For a Diesel engine we have one fuel pump per cylinder; is it the author's intention to have one of his pumps to replace all these fuel pumps? He runs his pump at constant speed; therefore for one pump to supply all the fuel to the engine, governing must be done by operating valves in the fuel supply pipes.

Mr. Hughes: The pressure of 500 lbs. is only referred to in a given instance—it is quite possible to obtain 5,000 lbs. It is most certainly the intention of the author to replace a number of pumps by one.

Mr. Thompson: Assume a 4 or 8-cylinder engine; will you require one pump for each cylinder?

Mr. Hughes: No.

Mr. Thompson: Then you will have one pump supplying all cylinders?

Mr. Hughes: Yes, you want a pulse for each stroke of the four, assuming same is 4-cycle. Do you refer to one plunger as one pump?

Mr. Thompson: If you take an 8-cylinder engine for speed variations. You may want to cut out one cylinder. Could you cut out one pump?

Mr. Hughes: Yes. That depends on whether you are using one plunger for one pump, two or more. We are originally talking about forcing fuel into an intake. I wish it to be clear that if we are injecting direct into the cylinders and supplying one pulse per working stroke it is quite possible to cut out a cylinder as required.

Mr. Thompson: You may require that all cylinders are firing and the engine to run at varying speeds. How are you going to control that? You might have either light loads or low speeds; how would you govern the injection of fuel into the cylinder? I understand that you have to set the springs to the pressure you require. With a solid injection engine you require about 4,000 lbs. per sq. in.

Mr. Hughes: The pressure would remain constant, say 4,000 lbs. per sq. in., but the quantity discharged which would chiefly govern the speed, would be controlled atmospherically.

Mr. Thompson: We do not want it atmospherically. We are talking about a Diesel engine. The air in a Diesel engine cylinder is compressed to 500 lbs. before the fuel is injected.

Mr. Hughes: That air going in can be adapted to vary the quantity of fuel. I am quite aware that we are discussing the Diesel engine.

Mr. Thompson: We have to deal with such huge volumes of air.

Mr. Hughes: That makes matters much easier. You can vary the quantity of air without affecting the stroke of pump, which remains constant. Although we are quite confident as regards the application of the pump to the Diesel engine we have not carried out experiments with larger types of Diesel. The pump should have an important field of application in the Diesel engine and in lubrication systems generally because you are concerned with the same problems when dealing with oil which have to be pumped.

Mr. Thompson: As regards the glands, your pump has no glands, but neither have we in our existing pumps and they answer very well.

Mr. Hughes: Mr. Anderson said that he has a pump which is similar to this. Will he guarantee that it is the same in detail?

Mr. Anderson: No. I happen to have about two dozen pumps similar to this. You have just said that you have not applied this pump to a Diesel engine, and I fail to see, therefore, how you can discuss its effect when applied to a pressure of 4,000 lbs. per sq. inch.

Mr. Hughes: The effect of metering fuels against 4,000 lbs. per sq. in. can be tried out in a more efficacious manner than applying to an engine for such a test. I understand your point. I am dealing with the metering of small amounts of fuel under pressure, and at the same time the capability of dealing with large quantities of fuel under pressure. I admit that it is quite easy to do one or the other, but not both with the same pump. I consider it inexpedient to cite a pump similar to mine without actual surety of details, as one slight alteration would upset the whole system.

Miss V. Holmes, B.Sc.: I am particularly interested in the first part of the paper, as it deals with heavy oil injection. In the early part of the paper the author says: "In one of the final forms of apparatus which I have completed for fuel injection purposes, I claim a pump having a variable or controllable discharge, without the necessity of altering the stroke or byepassing, which has no packing, and is capable of supplying predetermined pressures, which are adjustable over a substantial range." I am still in the dark as to how you propose to govern the injection. I assume that Fig. 11 shows the final form of the pump; if so, I do not see what means are provided for governing the speed of the engine (i.e., to vary the discharge by means of the speed of the engine or to vary the discharge by hand as is required in a marine engine).

Mr. HUGHES: If you refer to Fig. 9, and the jets shown therein, you will see that the quantity discharged at the jets will be in relation to the spring pressure and the jet itself.

Miss HOLMES: Then do you govern the engine by the spring pressure?

Mr. HUGHES: We have a type of fuel valve which has a solid stop (see Fig. 15), and that governs the orifice.

Miss HOLMES: I thought that applied to the petrol engine only.

Mr. HUGHES: The system would be similarly met to a great extent for a Diesel engine. In either case the discharge would be governed at the jet orifice.

Miss HOLMES: In the case shown you do it by varying the spring pressure.

Mr. HUGHES: In Fig. 9b we govern the quantity by applying a suitable spring pressure.

Mr. W. BROOKS SAYERS: Does the system deal with maintaining a constant speed?

Mr. HUGHES: The speed of pump will not necessarily govern discharge.

Miss HOLMES: Does your governing gear compress the spring? If so, you are making the governor do work.

Mr. HUGHES: Yes, in certain designs it keeps the quantity of air in step with the quantity of fuel at all speeds and loads, although the governor may do the work, it may consist of merely a diaphragm, subject to pressure from engine.

Miss HOLMES: Referring to that type of fuel valve, the idea of using a slit instead of small holes which may become choked is certainly an advantage, but it has been done before. For example, the Ruston fuel valve sprays through a fine saw-cut, and I think much the same result is got with a conical needle valve of very limited lift, and a single hole, as in the Campbell engine. I do not know whether the degree of opening ever actually varies with the pressure, but it could obviously be made to do so if desired. There is one criticism I should like to make of your valve, and that is that there is a dead area in your combustion chamber into which the fuel does not spray. You mention stratification as though it were an advantage in Diesel engines. I do not think that this is the orthodox view;

it is generally considered desirable for the oil and all the air in the combustion chamber to become completely mixed as soon as possible.

Mr. Hughes: The orthodox view of stratification may not be considered advantageous, but I consider stratification will be as necessary in the Diesel engine of the future as the cylinder itself, which must by virtue of its principle run at a high number of revolutions. And when fuel has to be injected, burnt and ejected all within the fraction of a second as it will in the Diesels of the future, I feel sure the present views must go.

With reference to the design of jets, the dead area can be to a great extent eliminated by slight modification in design.

Mr. A. F. C. Timpson: With a solid injection engine particularly, one wishes to get a timed injection of fuel. The timing is controlled in an air-atomised engine by the fuel valve, but with a solid injection engine that is not the case, the pump delivering direct to the cylinder.

Mr. Hughes: I quite understand the absolute necessity of timing, but we have not reached the commercial stage necessary to enable me to disclose the innermost details of design, but you may rest assured that the heart and soul of the problem is in the pump.

Mr. Timpson: On a solid injection type of Diesel or semi-Diesel the pump is of no use unless it delivers at the time required.

Mr. Hughes: You can get any timing required. The fuel may be timed to be discharged at the jet to coincide with any certain number of degrees.

Mr. Timpson: Supposing that a single cylinder pump is running at engine speed, on a two-cylinder four-stroke engine. The pump will come to the top of the stroke once per revolution. How do you arrange that the fuel gets into the right cylinder? I ask this question as you claim with a single cylinder pump to be able to deliver at a number of different points and to control the time and quantity of the supply.

Mr. Hughes: On account of cylinder pressure acting upon the controller or governor at a given moment.

Mr. J. H. Anderson: Is it not that your pump runs at a variable speed as a constant pressure pump? It is more or less a constant pressure pump, and therefore it would always be pumping oil into a Diesel engine. I imagine that it is only suitable for a petrol engine. Therefore no amount of timing will meet the requirements.

Mr. Hughes: I am afraid you still fail to grasp the working of this system. As already described the period of injection may be timed.

Mr. Anderson: Then it must be positively geared to your main engine?

Mr. T. R. Stuart: When I read this paper my first comment was that it was the clearest paper I have read. The diagrams are excellent. But when the model was passed round it struck me that I had not seen an induction or discharge valve. I got the model back and still have not seem a suction or discharge valve, and if anyone less sophisticated than myself was on a dark road at night in a car fitted with this pump, I think he would be rather bewildered. It seems that we are at cross purposes, and that it is a constant pressure pump. I should like to know whether there is a suction or control valve, and also is the model full size or not?

Mr. Hughes: There are no discharge valves whatever. If you look at Fig. 13 there is no discharge valve shown.

Mr. Stuart: There are two valves shown in Fig. 11.

Mr. Hughes: That figure is not descriptive of the model shown. I have other types of models which I can show.

Mr. Stuart: I think that should be explained in the paper. My point is that as there is no valve, that is one objection.

Mr. Hughes: Fig. 13 shows that, but perhaps not very clearly. If one plunger went out of action, the other one would keep the whole system working without any adverse effect.

Mr. A. F. C. Timpson: This paper is termed "Fuel Injection," and fuel injection is required on both solid and air injection engines. As far as I can see, there is a possibility of getting a given quantity when used for air injection through each fuel valve, but I do not see how you can pump a given quantity of fuel into any particular cylinder at a given time. With an ordinary fuel pump you have a valve, but there you have only one suction valve and one delivery valve; here you have two suction valves and a delivery part, so that as far as the number of parts is concerned you are no better off. If you had an ordinary suction pump with a movable spring loaded cylinder head you would have, in effect, precisely the same thing.

Mr. HUGHES: I claim from experience that the double banking of valves is most essential and as I have no discharge valves I am most certainly better off.

Mr. J. L. CHALONER: I feel that the author's title of "Fuel Injection" is rather misleading in as much as only a very specific aspect of this important and extensive subject is being discussed in the paper. The author considers petrol engines only, and in principle his intention is very sound, because a positive injection of fuel in conjunction with a constant speed engine represents a development in the right direction. The difficulties of replacing carburetters are by no means insignificant. Certain well designed engines show a fuel consumption of 0·45 to 0·5 lb. per B.H.P. hour, and moreover carburetters are not expensive items compared with fuel pumps such as described by the author. I have examined many pumps, some of which have proved very successful, but in my opinion a composite plunger such as it is the author's intention to use is a very doubtful proposition practically.

The author has made much of what he terms "elastic discharge," but it has been established for some time now that no particular advantage accrues from this practice. As marine engineers we are principally concerned with the elimination of air injection for use with residual fuels. I am afraid the author has not appreciated yet the essential characteristics of the Diesel cycle, nor is he fully conversant with the physical and chemical properties of liquid fuels.

Mere talking around a subject without producing facts and figures in support of one's conviction leads nowhere, and the author has hardly produced enough data to enable one to gauge the commercial potentiality of his system as applied not only to petrol but also to cheaper fuels.

Mr. HUGHES: I am very glad that Mr. J. L. Chaloner says in principle my idea is very sound. The fact that Mr. Chaloner has made attempts with forced feed to the induction pipes of an engine proves my case. Or at least his figures do.

In a recent paper read by Mr. Chaloner, "High Speed Oil Engines," his figures show improvements in fuel consumption to be nearly 100% when using pump feed to induction over Zenith carburetter, when using as fuel, a fifty fifty mixture of benzol and kerosene. These figures appear to me to be so extremely good, that I assume Mr. Chaloner bumped into a snag somewhere.

Mr. Chaloner condemns the use of what he terms a composite plunger. If this gentleman were fully conversant with latest metallurgical developments, I feel sure he would not make such a remark. Curiously enough the plungers are the one thing that do not, and have never given us a moment's trouble.

Referring to my term "elastic discharge," I do not know why this should be mysterious, and until I find a more suitable definition, shall be obliged to stick to it.

Referring to the remarks about allowing for an inventor's optimism, I as "the pessimist" am well known.

I should recommend Mr. Chaloner a visit to America, he will probably then talk about the inexpensive pump which can be manufactured when it is fitted into a petrol engine for shillings, not pounds.

With reference to Mr. Chaloner's remarks referring to this paper not dealing with the subject as he thinks it should have done, I quite agree, but would ask him to kindly make allowances, as this paper is original and does not contain information the author has obtained from books. Mr. Chaloner says nothing about the use of alcohol or other fuels in petrol engines. I presume he thinks petrol will last for ever.

Mr. A. F. C. Timpson: Regarding carburation and wiredrawing, I see no particular disadvantage in a reasonable degree of wiredrawing, but is that not what Mr. Hughes is adopting in order to obtain a stronger current of air for his jet?

Mr. Hughes: The idea is to get a certain speed at the jet in order to mix the fuel and air completely. That is not wiredrawing; it is far in advance. There is ample opening to allow the air to get through. I consider wiredrawing another matter.

Mr. Timpson: The average carburetter nowadays has a very well designed choke tube, and you can get the mixture through without much loss at a wide range of engine speeds.

Mr. Hughes: If you enlarge your choke tube, you destroy your acceleration, but if you use my system you gain one advantage without losing the other.

Mr. J. H. Anderson: I am full of mystery even now as regards this paper. If the author would supplement the paper and the discussion by showing how he is going to apply this system to an 8-cylinder Diesel engine, using it as a constant pressure pump without any control of admission to cylinders, we, as engineers, would be very grateful indeed.

In my opinion the title of the paper is very much misleading, and the idea of the pump with an elastic delivery due to a spring buffer is certainly not new. We have these spring reliefs working up to 750 lbs. per sq. in. for the past fifty years or more, the credit of which should belong to the late Lord Armstrong.

I have great pleasure in proposing a hearty vote of thanks to the author.

Mr. Hughes: I thank you very much. I am very sorry that the title of my paper was not made broader, but I feel sure that it is sound from the point of view of the method of dealing with fuels, because I have shown you a means of utilising an elastic discharge and at the same time obtaining the many other advantages which I have described.

———o———

ESSAYS FOR AWARDS.

Marine Practice in Oil Firing of Boilers

By "A. REV."—H. R. Tyrrell (Student Graduate).

Introduction. — Advantages. Disadvantages. The Three Methods of Pulverising Oil Fuel. The Chemistry of Combustion.

Body.—The Thornycroft System. The Wallsend-Howden Mechanical System. The Wallsend-Howden Air Pressure System. The J. S. White System. The White System.

Conclusion.—Fire Fighting Methods.

Owing to the rapid advance of the internal combustion engine during the last few years, oil fuel has come largely into prominence for steam generation, particularly for marine purposes. Oil fuel may justly have the following advantages over coal firing:—

1. Increased boiler efficiency, due to cleaner surfaces.

2. Less bunker space required (in the ratio of about 38:44).

3. 1 lb. of oil gives about 19,000 B.Th.U., against 14,500 B.Th.U. for coal.

4. Reduction of stokehold staff, as one man is able to regulate a number of burners.

5. No necessity to open fire doors for stoking.

6. Oil is easily transferred to the bunkers, thereby dispensing with the operation of coaling.

7. No ashes or clinker and, with proper regulation, practically no smoke.

8. The steam pressure is more constant. (See Figs. 5a and 5b).

9. The burners can be extinguished when steam is not required.

The disadvantages are:—

1. Increased cost compared with coal. Oil at the present time being approximately about £3 to £4 per ton and coal 24/- a ton. 2. Danger from inflammable vapour. 3. Risk of oil entering steam side of heater and thus entering boiler with feed water. 4. Possible leakage. 5. Loss of protection in warships.

There are three methods of atomising oil:—

Firstly. *By means of a steam jet.*—In this case the fuel is led to the burners by means of gravitation. The oil flows through the burner, where it is joined by a small jet of steam—acting on the ejector principle, thus causing it to spray. It is sometimes said that greater heater power is secured by steam atomization through the dissociation of the hydrogen and oxygen of the steam and their subsequent ignition in the furnace. It is true that the flame thus obtained is intensely hot, the fact remains that theoretically as much heat is absorbed in breaking the steam into its component elements as is subsequently given off by their re-uniting, so that the net gain in respect to heating power is nil, whereas the percentage of loss in the total steam generated by the boiler is a serious waste. The saving of this is an important factor in the superior efficiency of mechanical atomizing. This type of burner is very noisy in operation. Variation in steam pressure may cause the flame to be blown out.

Secondly. *By means of compressed air.*—This system is practically the same as the previous system, except that compressed air is the pulverising medium. Air compressors are required and these are more complicated than oil pumps and, therefore, are more liable to breakdowns.

Thirdly. *By mechanical means.*—This system is undoubtedly the best, both from a point of view of cheapness and ease of regulation. It gives a silent and regular flame. The oil is pumped from the storage tanks to the settling tanks. If the double bottom tanks are used for storage it is sometimes necessary to slightly warm the oil as it passes through the pipes. It is allowed to remain in the settling tanks for about 7 hours, during which time it is heated to about 110° F., when it is found that the oil readily separates from any water mixed with it. The oil is next passed through the cold filter to the heater by means of another pump. In the heater its temperature is raised to a few degrees above flash point. After leaving the heater it passes through the hot filter and finally reaches the burners.

The following table gives the average percentages of the elements contained in the different kinds of fuel at present available.

	Sp. Gr.	C	H	S	N	Ash H_2O & O	B.Th.U.	Flash Point °Fah.	Fire Point °Fah.
Borneo	·963	86·74	10·67	·03	·05	2·51	18830	225	294
Texas	·922	86·30	12·22	1·33	·06	·09	18400	160	215
Californian	·962	84·43	10·99	·59	·65	3·34	18806	228	258
Roumanian	935	87·11	11·87	·16	·15	·71	19320	244	298
Mexican	·910	84·10	12·29	2·95	—	·66	18862	192	244

It is a very simple matter to calculate the approx. weight or volume of air required to burn 1 lb. of oil.

For example we may take Roumanian oil.

$$C + O_2 = CO_2$$
$$12 \text{ lbs.} + 32 \text{ lbs.} = 44 \text{ lbs.}$$

therefore, 0·8711lbs. of carbon requires $\frac{32}{12} \times \cdot 8711$ lbs. of oxygen

$= \quad 2 \cdot 323$ lbs. of oxygen

Similarly $\quad H_2 + O. = H_2 O.$

$$2 + 16 = 18$$

therefore $0 \cdot 1187$lbs. of hydrogen requires $\frac{16}{2} \times \cdot 1187$ lbs. of oxygen

$= \cdot 949$ lbs of oxygen

also $S + O_2 = SO_2$

$32 + 32 = 64$

$\therefore \cdot 0016$ lbs. of sulphur requires $\cdot 0016$ lbs. of oxygen and the total amount of oxygen required

$= 2 \cdot 323 + \cdot 949 + \cdot 0016$

$= 3 \cdot 2736$ lbs.

But as air only contains 23°/₀ of oxygen by weight, the amount of air required $= 3 \cdot 2736 \times \frac{100}{23}$

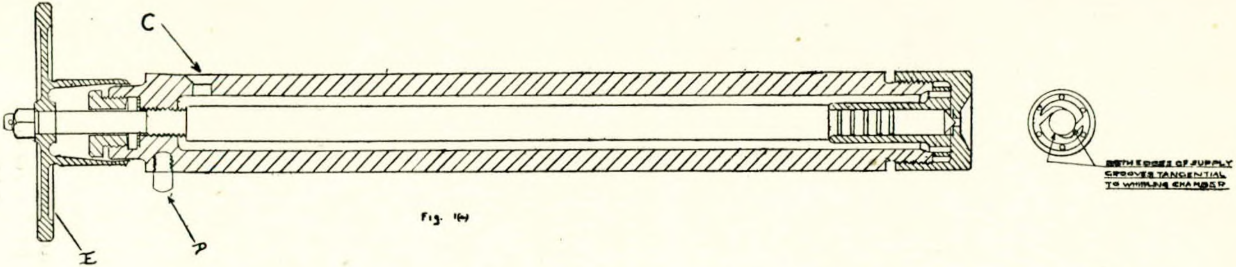
$= 14 \cdot 23$ lbs.

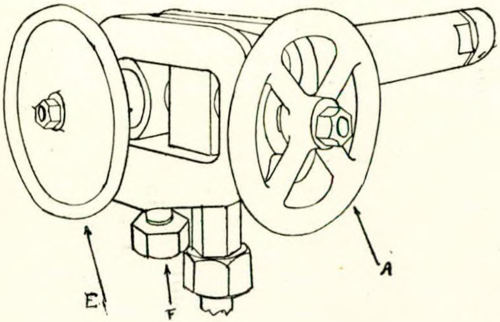
Therefore, theoretically 1 lb. of Roumanian oil requires 14·23 lbs. of air for complete combustion; in practice, however, a 10% increase is required on the above figure, at the same time it has to be considered also that a certain amount of air passes up the funnel with the other gases, this gives 15·65 lbs. of air required or at 200° F. about 238 cubic feet.

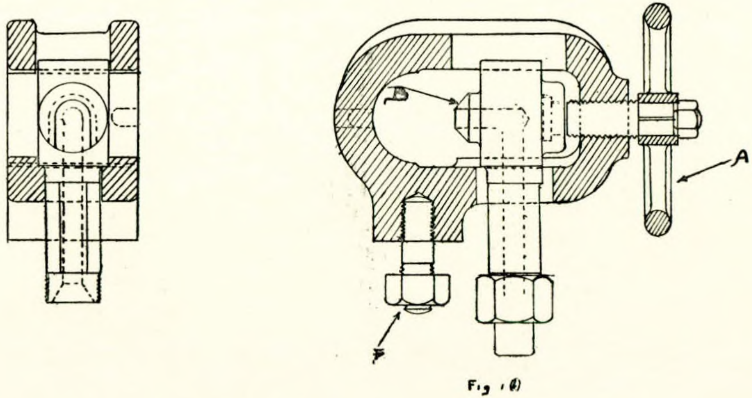
THE THORNYCROFT SYSTEM.—Fig. 1 (a) gives a sectional view of the burner. The central spindle is of tool steel and fitted with a fine thread for adjustments. At the end of the tube is the sprayer head, which is made in two parts, the cap centre and the cap. In the cap centre are cut two spiral grooves leading tangentially into a whirl chamber round the axis. The oil flows along the tube into the outer circumference of the cap and then through the two grooves into the whirl chamber. By the time it reaches the exit hole its angular velocity is considerable, so that it passes through the exit hole with a spiral motion, and on leaving the hole the centrifugal force disintegrates the oil, so that it flies out in a cone of fine spray. For efficient working the oil pressure should be from 50-60 lbs./square inch up to 150 lbs. or 200 lbs./sq. inch.

As will be seen in Fig. 1 (b) the sprayer tube is readily detachable for cleaning. By unscrewing handwheel "A" the cone "B" is withdrawn from "C" thereby releasing the sprayer tube. The stop-pin "D" is to ensure alignment in the holder. Handwheel "E" is to adjust the oil jet. The stud "F" is for bolting on to a suitable bracket on the furnace front.

The main pump draws oil from the tanks through a system of piping, arranged so that the pump can draw from any tank,







Thornycroft O.F. Sprayer and Quick Change Adapter.

and delivers to the heaters and from thence through delivery filters and distributing boxes to sprayers on the boiler fronts. The pumps are fitted with air vessels. A spring loaded relief valve is fitted on the delivery side of the pump to ensure constant pressure. Any oil coming from this valve is led back to the suction side of the pump. This relief valve is graduated to 25, 50, 75, 100, 125 and 150 lbs./sq. inch. A bypass valve is also fitted from delivery to suction side, so that the temperature or pressure may be altered. The filters consist of double layers of steel gauze and are so arranged that either can be cleaned out whilst working. The heater consists of a cast iron or steel body enclosing a number of steel tubes through which the oil passes. The drain from the heater is carried away to the feed tank through a drain collector fitted with a gauge glass. Water should be drawn periodically from the collector for observation purposes, as any oil leakage past the heater tubes might get into the boilers and give serious trouble.

The pumps, heaters and filters are all in duplicate and mounted upon an oil tight tray as seen in Fig. 2.

When lighting up with no steam available, oil is drawn from the main suction pipes or from tanks by means of a two or three throw hand pump (in the case of small installations hand gear is fixed to one of the main pumps), delivering through a portable "U" tube and thence to a sprayer on the boiler front. When using this the pipe from the distributing box to one of the sprayers is disconnected and the "U" tube inserted in the furnace in front of the deflectors, the ends being coupled to the distributing box and sprayers. A piece of waste or asbestos soaked in paraffin oil put round the "U" tube before inserting into furnace is now lighted by a torch to heat the oil in the tube. The temperature of the oil is adjusted as found necessary by moving the heating tube further in or out of the furnace. When the temperature of the oil has been raised sufficiently by the waste a torch should be inserted and the shut off valve which admits the oil to the burner slowly opened and the oil ignited as soon as sufficient steam is raised to start up the main oil pump, the heater steam should be opened up, and the pipe from the portable "U" tube disconnected, and the main supply connected. Care should be taken that there is no pressure in the oil pipes before disconnecting and a bucket should be placed underneath the burner to catch any oil which may drain from the pipe while it is uncoupled.

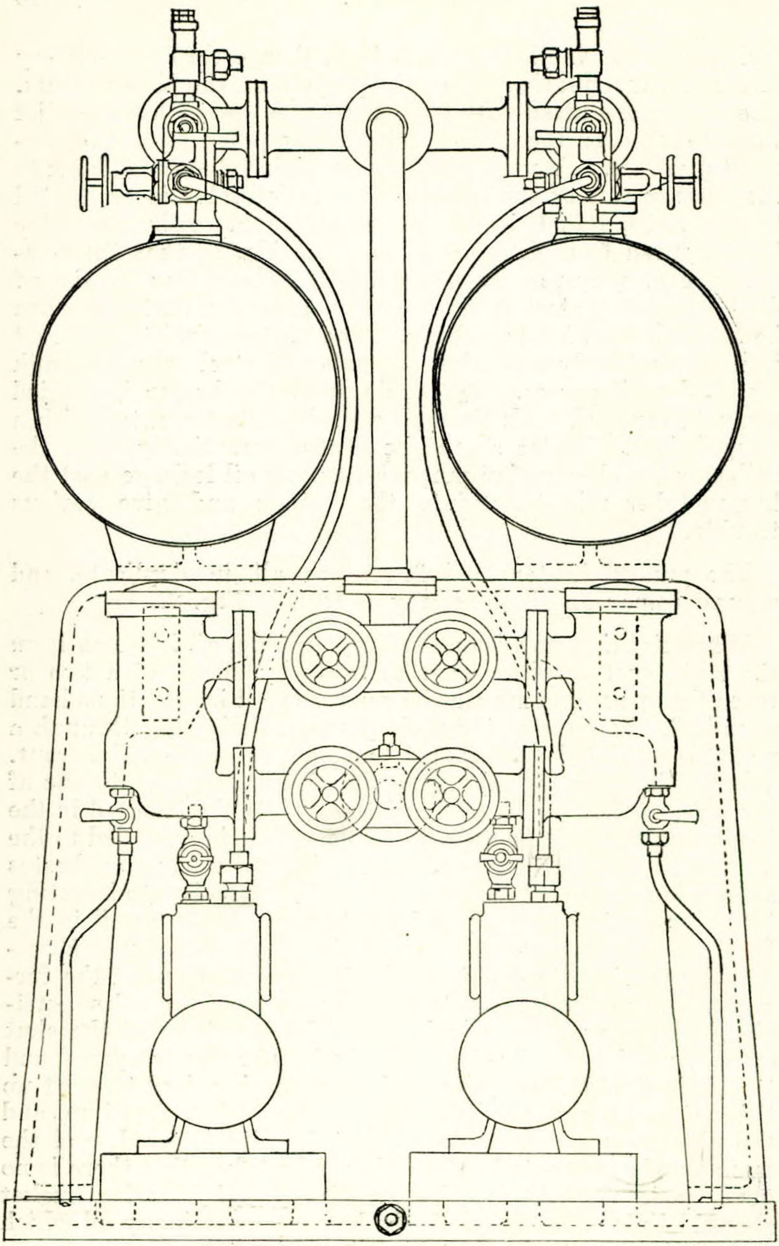


Fig. 2.—End View.
Thornycroft arrangement of Pumping Plai t.

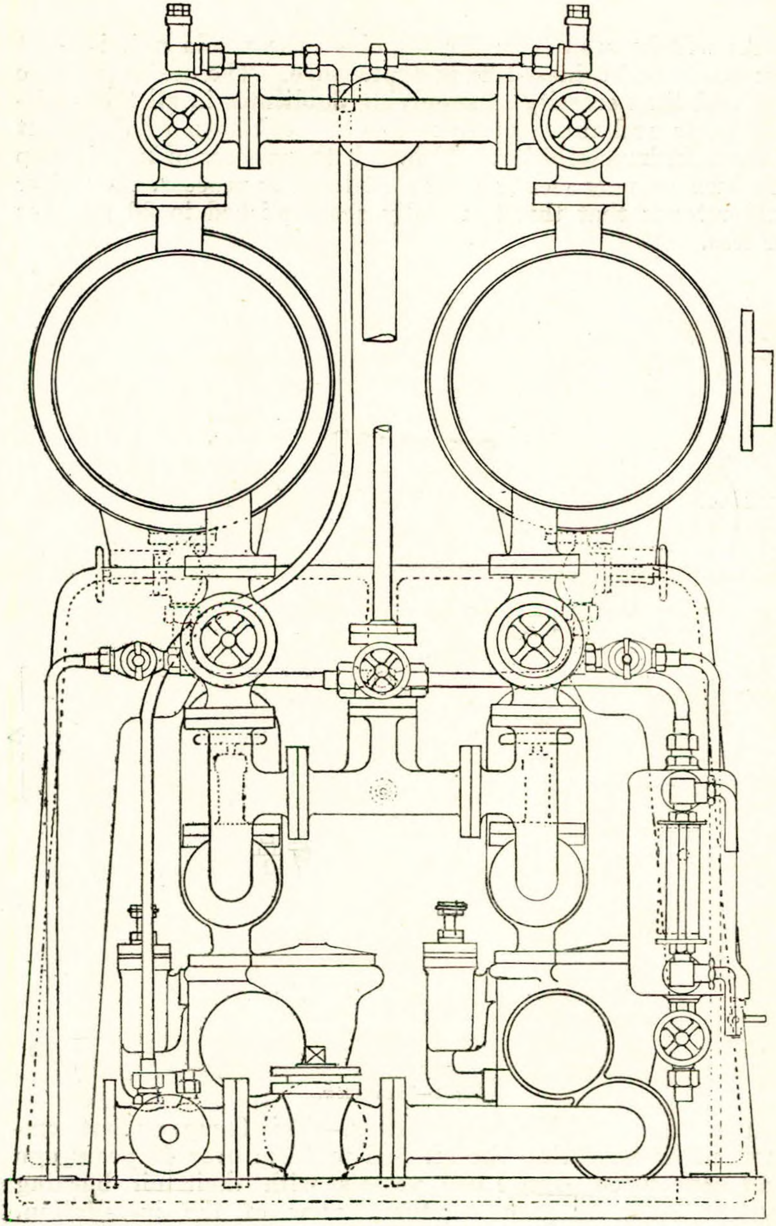


Fig. 2.—End View.

Arrangement of Pumping Plant, having Pumps, Heaters and Filters in duplicate.

As will be seen from the drawings the whole unit is most compact and business-like in appearance. The designers have realised the necessity of supplying duplicates in all the working parts and this feature makes a breakdown of the plant almost an impossibility. Although the process of lighting up the burners may seem a somewhat lengthy process, the writer understands that this is usually accomplished in 30 minutes or less.

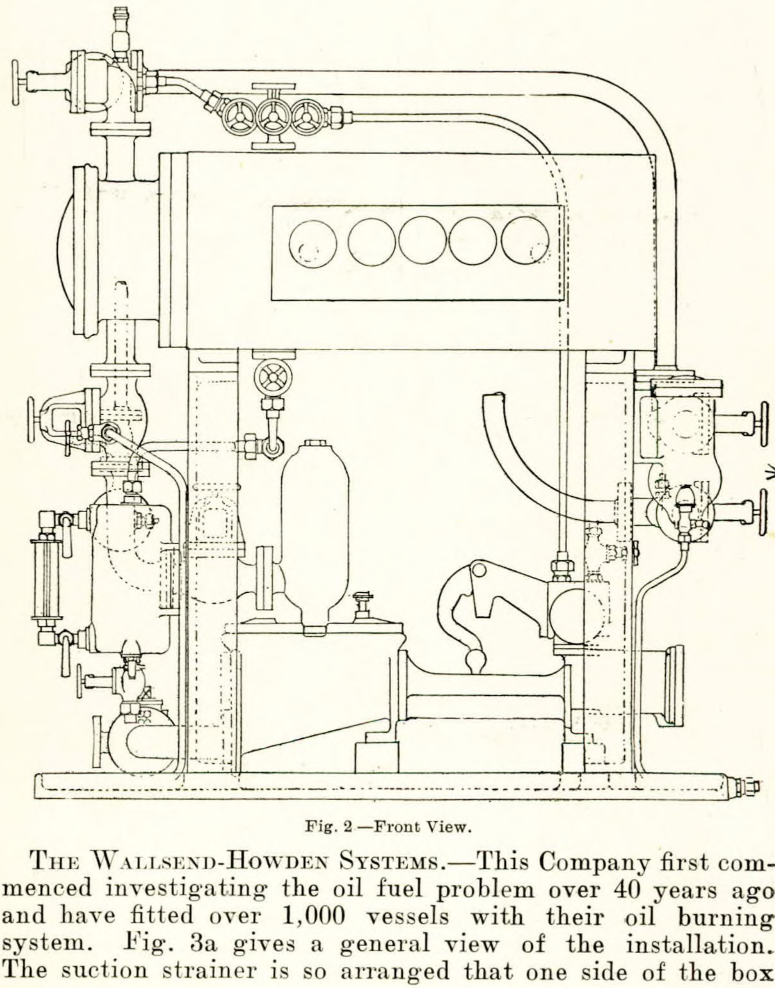


Fig. 2.—Front View.

THE WALLSEND-HOWDEN SYSTEMS.—This Company first commenced investigating the oil fuel problem over 40 years ago and have fitted over 1,000 vessels with their oil burning system. Fig. 3a gives a general view of the installation. The suction strainer is so arranged that one side of the box may be cleaned while the other is working, but there is only one pump and heater. The heater is so constructed to allow lateral movement of the tubes under temperature variations. It will be noted, however, that the duplex suction strainer is a separate unit and not as in the case of the Thornycroft system mounted upon the installation tray.

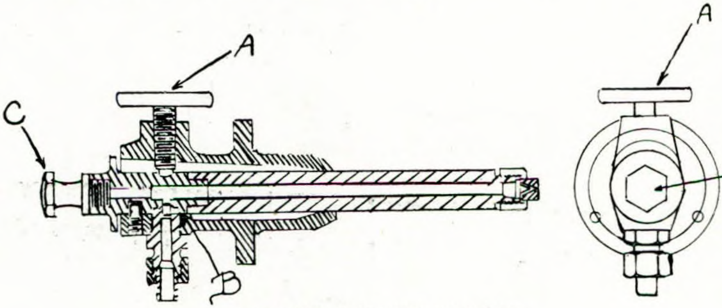


Fig 3.b

The burner is very easily removed by unscrewing the hand wheel "A" and lifting the burner tube clear of the lower connection "B" and then withdrawing the tube complete by means of the hexagonal knob provided "C." The oil in this burner is not given a rotary motion, but a simple straight jet. The air director consists of two concentric trunks with vanes fitted in the annular space between them, through which the air supply is admitted to the furnace. The vanes impart a whirling motion to the air, which 'catches up' with the oil particles, ensuring early combustion.

The Wallsend Low Air Pressure System.—This system is particularly adaptable for motor ships, where there is a supply of air under pressure, e.g., from the air-bottles. It is generally fitted to a Cochran type boiler, as seen in Fig. 3d. Air is used to atomise the oil and is supplied by a blower (or from the air-bottles) at a pressure of not lower than 15 ins. W.G. (0·55 lbs./sq. inch). The blower may be driven by an electric motor, when the burner may be lighted at once without the use of any special steam raising apparatus. Only a portion of the air required for combustion is taken from the blower, and the rest is admitted to the furnace by means of an air director, so that very little power is absorbed by the motor. Fig. 3c shows the connections. The oil is fed to the burner from a gravity supply tank, the oil on its way to the burner passing through a strainer and electric or steam line heater if required.

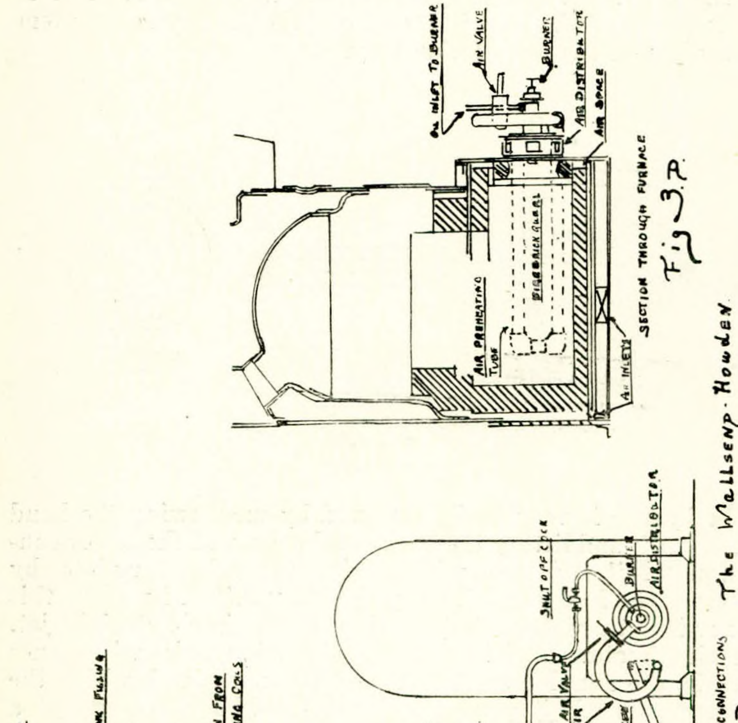
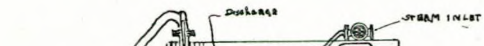


Fig 3 P.

Fig 3 C. The Wallsend-Howden Low Air Pressure System

This system has the disadvantage of being somewhat noisy in operation, but has the advantage of a low capital cost.

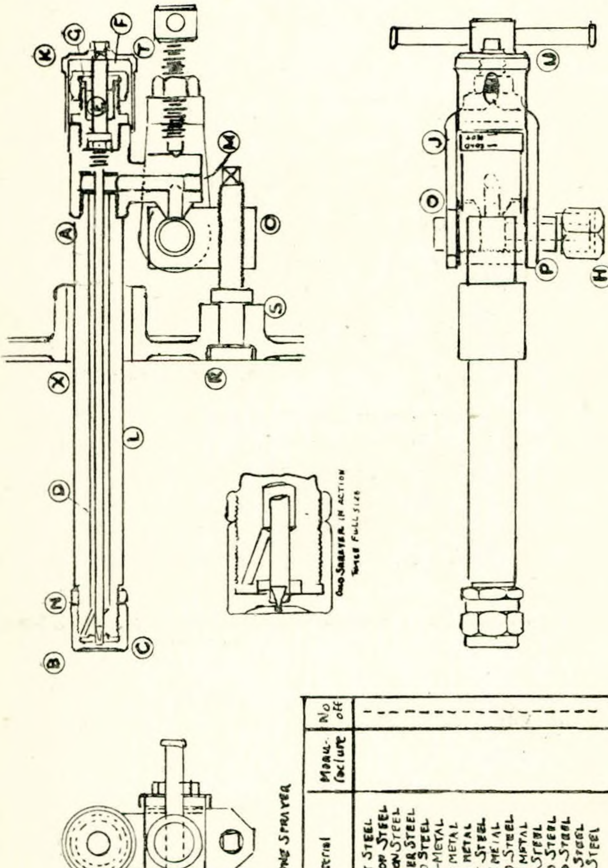
THE J. S. WHITE SYSTEM.—This system is somewhat similar to the preceding in general outline. The duplex suction strainer is mounted with the heater, etc., upon an oil tight tray. The oil fuel pump is usually steam driven and of the horizontal or vertical direct acting type, or it may be electrically, or belt driven, and when preferred, two pumps may be fitted. The heater is constructed of steel tubes fixed in an iron chamber. The burner may be of the "Hot or Cold Oil" type, or the "Hot Oil" type. Fig. 4 (a) shows the former type.



Compact Double Pump Unit Arrangement of Oil Fuel Installation with Horizontal Pump.

Fig. 4a.—J. Samuel White System.

Fuel oil of viscosity up to 900 seconds (Redwood No. 1) at normal temperature can be burned efficiently with this type of burner, without pre-heating. The oil enters the body of the burner under-pressure, and then passes round the spindle to an annular chamber surrounding the slot plate "C." One, two, three, or four slots are provided in this plate according to the capacity of the burner, and are arranged tangentially to a central chamber, termed the whirl chamber. The oil passing through the slots into the whirl chamber receives a rotary motion and is discharged through the small orifice in the end cap in the form of a fine cone-shaped mist. To light up with cold oil, the spindle "D" is protruded through the orifice as shown in Fig. 4a. In this position the oil, when discharged through the orifice, strikes the collar on the end of the spindle and is broken up into a fine mist, which readily ignites on the application of a torch. When sufficient steam has been raised for use in the fuel heater, the burner is adjusted to operate on hot oil by merely screwing back the spindle into the hot position. The burner head may be easily removed by unscrewing the bolt "T." As will be seen from the Figures 4a and 4b



THE J SAMUEL WHITE
Patent Burner for use with Hot and Cold Oil.

Fig 4a.

LIST OF MATERIAL FOR ONE SPRAYER

Mark	Description	Material	Manufacture	No off
A	Burner Head	Cast Steel		1
B	Cap	30 ton Steel		1
C	Slot Plate	30 ton Steel		1
D	Sprayer Spindle	Silver Steel		1
E	Handwheel Spindle	Mild Steel		1
F	Gland Nut	Gun-Metal		1
G	Gland	Gun Metal		1
H	Union Nut	Gun Metal		1
J	Yoke	Cast Steel		1
K	Handwheel	Gun Metal		1
L	Burner Body	Mild Steel		1
M	Plug	Gun Metal		1
N	Lock Nut	Wt Steel		1
O	Bearing for Yoke	Mild Steel		1
P	Bearing for Yoke	Mild Steel		1
Q	Coned Block	Wt Steel		1
R	Coned Block Spindle	Wt Steel		1
S	Coned Block Spindle Collar	Wt Steel		1
T	Joint Screw and Nut	Wt Steel		1
U	Tommie and Buttons	Wt Steel		1
V	Stuffing Box	Gun-Metal		1
X	Collar	Wt Iron		1

the whole unit is very simple and compact. It will also be noted that the pump (or pumps) can be operated by means of (1) Belts, (2) Electricity, (3) Steam. This system is used in H.M. Navy to a small extent, two of the most notable instances being the flotilla leaders *Broke* (30·5 knots) and *Vampire* (35 knots).

Arrangement of Pumping and Heating Plant

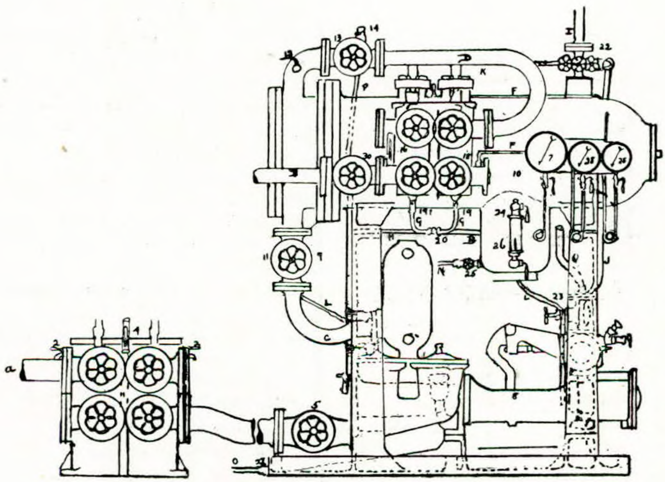


Fig. 3a.—Wallsend-Howden Liquid Fuel System.

THE WHITE SYSTEM.—This system differs from the preceding in the fact that vertical heaters are fitted instead of the usual horizontal type. The simplex unit comprises one heater, one pump, suction and delivery filters, air vessel, etc. The duplex unit comprises two pumps, two heaters, etc., one pump being fixed to the tray and the other fixed about half-way up the heaters, this allows the overhauling of one pump without interfering with the other. On both these units an exceptionally long air vessel is provided, thus ensuring an even supply of oil. The units are made in sizes from 200 H.P. to 6,000 H.P. and the burners from 40 to 400 boiler horse power. The White burner has a small strainer placed immediately before the diaphragm, and held in position by a spring. This makes the burner practically immune from a choked jet. Another very important point regarding this type of burner is the safety device fitted to the shut-off valve on the burner, whereby it is impossible to disconnect the burner from the holder, unless the valve is shut. There are several types of fronts made by this company, the most important one being the cone front. The cone has radial heating vanes and is covered by an outer sheet iron casing, so as to form passages down which all the air entering the furnace must pass. The front casing

LIST OF FITTINGS

Nº		Nº	
1	Duplex Suction Strainer	16	Thermometer
2	Relife Cocks	17	Duplex Discharge Strainer
3	Thermometer Pot	18	Tail Coupling for Gauge Pipes
4	Thermometer	19	Cocks Discharge Strainer Drains
5	Valve Pump Suction	20	Y Piece Discharge Strainer Drains
6	Tail Coupling for Gauge Pipe	21	Non Return Valve
7	Pressure & Vacuum Gauge	22	Valve Box Steam to installation
8	Weir's Simplex Oil Fuel Pump	23	Valve Exhaust from Pump
9	Valve Heater inlet	24	Gauge Glass
10	Oil Fuel Heater	25	Water Collector Cock
11	Cock Drain From Healer	26	Gauge cock
12	Cock Steam to Heater	27	Tail Coupling Drain From Tray
13	Valve Heater Outlet	28	Pressure Gauges
14	Valve Heater Escape	29	Non Return Valve
15	Thermometer Pot	30	Installation Master Valve.

LIST OF PIPES

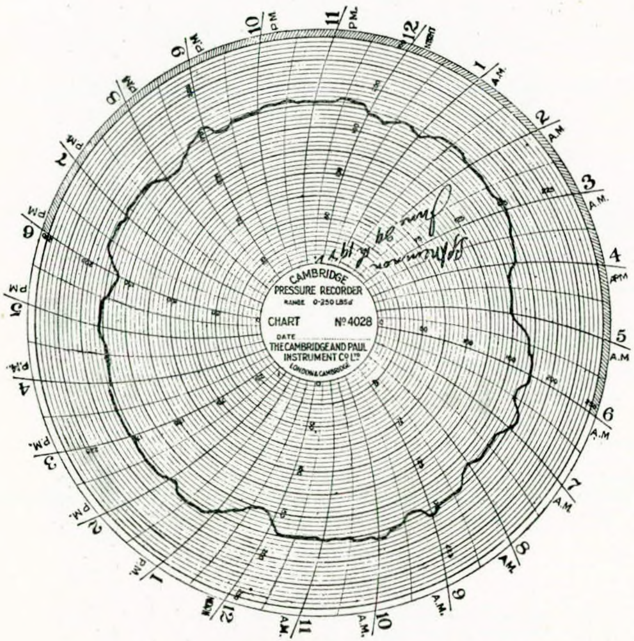
Nº			
a	O. F. Pump Suction	I	Steam to installation
B	Suction to Gauges	J	Steam to Pump
C	O. F. Pump discharge to heater	K	Steam to Heater
D	Healer outlet	L	Drain From Healer
E	Discharge to Burners	M	Drain From Water Collector to Tray
F	Discharge Strainer to Gauge	N	Drain From Water Collector to Tank
G	Discharge Drains to Suction	O	Drain From Tray
H	Discharge Drain to Suction	P	Heater escape to Suction
		Q	Exhaust From Pump

Fig. 3a.—Wallsend-Howden System.

becomes heated and the radial vanes impart this heat to the air, which passes into the furnace at about 220° F. The burner is surrounded by a jacket tube, on which operates a sliding cone to govern the location and spread of the flame. There is a further arrangement of air-regulating cones which controls the air admission. The entire casting is secured over the front of the furnace, which carries the burner and air-regulating cones on a hinged spider, which allows free access to the furnace when desired.

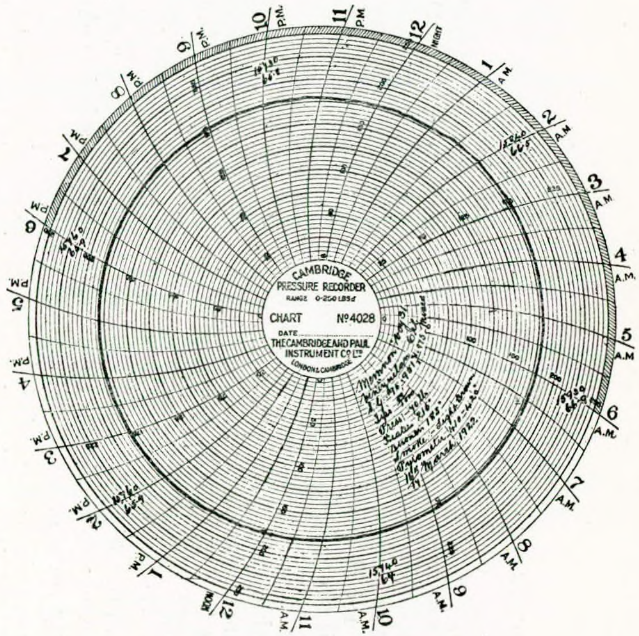
A second type may be mentioned on account of the high efficiency it gives when operating under forced or positive draught. One of these fronts have recently been installed in one of the latest additions to the P. & O. fleet. The air is heated to about 300° F., thereby attaining a higher efficiency.

Steam Pressure Recorder Charts.



Steam Pressure Record when burning Coal.

Fig 5a.



Steam Pressure Record when burning Oil.

Fig 5b.

Note the constant pressure maintained when burning oil with the White Patent Oil Burning System.

Steam is sometimes required for auxiliary purposes on motor ships. Normally the exhaust gases are employed to raise steam, but when in port steam may be raised by means of a small oil installation. Figs 5 (a) and 5 (b) show a steam pressure record when burning oil, and when burning coal. It will be seen that the steam pressure varies from about 150 lbs./sq. in. to 185 lbs./sq. in. when burning coal, whereas when burning oil the pressure is very steady.

Fig. 5 (c) gives an abstract from an engineer's log. It is noticable that the average lbs. of fuel per 1 H.P. hour for all purposes is (voyage No. 1) 0·767 and allowing 14% for auxiliaries 0·659. We may take this result to be good, but in comparison with oil engine practice it is poor, since the average lbs. of fuel consumed per 1 H.P. hour is about 0·4.

With the White system evaporations of over 16½ lbs. of water per lbs. of oil, and boiler efficiencies of 85% are being obtained in daily service.

Among the many ships fitted with the White system are the R.M.S., Majestic, Olympic, Berengaria and Aquitania.

Oil is a dangerous fuel in respect to fire, and the utmost precautions should be taken to subdue an outbreak. Water is useless for quenching oil fires, owing to the fact that oil has a lower specific gravity and will therefore float on the surface of the water. Perhaps the most common method of extinguishing oil fires is by means of a "foam blanket." There are several systems on the market at the present time, all of which use the same principle, i.e., to chemically unite two liquids, thus generating a non-inflammable gas, which smothers the fire. A brief description of the Phomene systems will demonstrate the principle.

Quantities of bicarbonate of soda solution and sulphuric acid are stored in separate tanks. A pipe is led from each tank to a nozzle or spreader, where the two liquids combine, forming carbon-dioxide gas, as given by the following formula:—

$$\mathrm{Na\,HCO_3 + H_2SO_4 = CO_2 + H_2O + Na\,HSO_4}.$$

To prevent the gas from flowing unrestricted there is mixed with the acid solution a patent stabiliser called "Amdyco," which encloses minute bubbles of gas immediately it is generated and thus forms a "blanket" of foam.

The Phomene steam operated engine employs an ejector for bringing the two liquids together and spreading the foam. If the steam is applied direct to the surface of the liquids it con-

ABSTRACT FROM ENGINEERS LOG

VOYAGE Nº	DRAFT LEAVING		TIME HOURS	DISTANCE MILES	AVERAGE SPEED	REVS	SLIP	CONSUMPTION IN TONS DAY	BOILERS	BURNER TIPS	WEATHER	INSTRUCTIONS	AVERAGE I. H. P.	LBS OF FUEL PER I H P/HR FOR ALL PURPOSES	MINUS 14% FOR AUXILARIES.
	FORD	AFT.													
1.	27'-10"	28'-9"	238·5	3424.	14·1	85·4	3.	51	4.	63,73,80	GOOD	OWN DISCRETION	6,205	·767	·659
2.	25'-5	27'-11"	257·1	3395.	13·21	80·8	4.	45·5	3.	63,73,80	"	13 KNOTS	5,009	·847	·728
3.	20'-6"	23'-3"	257·2	3311	12·9	88·7	8.	43	3.	73.	4 DAYS ADVERSE GALES.	3 BOILERS	4,584	·877	·755
4.	24'-3"	THIS 29'-0"	VOYAGE 192·25	LIGHTSHIP 2703	14	88·3.	6.	50	4.	63,73	MODERATE FOR WINTER TIME	4 BOILERS FULL SPEED	6,320	·738	·636

denses and thus weakens the solutions. By employing an ejector the liquids are drawn from their respective tanks and thus no water is condensed inside the tanks. The amount of condensation which occurs in the ejector is known and allowed for in the composition of the solutions. The ejector works well from 50 lbs./sq. in. and upwards, and will throw a jet of foam to a distance of approximately 30ft. The whole unit can be operated by one man. The tanks are of "D" section and bolted together, one of which is lead-lined to prevent corrosion. Each tank is fitted with a handhole cover for inspection purposes and holds 17 gallons, each producing 272 galls. of foam.

A smaller type of marine pattern fire engine is of 10 gallons capacity. This consists of two concentrically placed tanks. The whole unit is mounted upon two trunnions and brackets with floor plate, or if preferred, on small wheels. To operate, it is only necessary to remove the trunnion pin and lower the handle to the ground, thereby uniting the liquids. This type is most useful in motor ships where there is little or no steam. The Company also manufacture several hand-extinguishers.

The Construction of a Three-Throw Crankshaft.

BY "ENTROPY":—W. NICHOLSON (Graduate).

At the present date the modern marine engine has developed to such large proportions that it has become necessary to build the crankshaft in sections. If one attempted to build a shaft in one piece, not only would the cost be very high, but the shaft would be perfectly unwieldly. The main reasons for building the shaft in sections are: ease in fitting and handling, greater reliability, and in case of breakdowns the shaft sections can be renewed or interchanged.

A crankshaft is subject to a very complex system of stresses, such as bending and shear stresses, as well as the pure shear due to torsion. The forces producing these stresses are anything but uniform, so that fluctuating stresses are produced. The webs are in tension and bending for one half of stroke and change over to compression in the other half. If the usual bending and twisting stresses were worked out for each section of the shaft it would be found that the shaft would get heavier from the forward end to the after end, but for interchangability, etc., they are all made similar.

ERRATA.

April Issue, 1926, page 879.

N.B.—Formula should be :—

$$S = \sqrt[3]{\frac{C \times P \times D^2}{3f}} \qquad P = \frac{3f S^3}{C \times D^2}$$

not as printed.

To-day the shafts are built to emperical rules set by the Board of Trade and various classification societies. These formulæ are based on practical experience obtained during recent years.

The Board of Trade formula is:—

"For ordinary condensing engines, with 2 or more cranks."

$$S = 3\sqrt{\frac{C \times P \times D^2}{f}} \qquad P = \frac{3 f S^3}{C \times D^2}$$

where:—S = diam. of shaft in inches.

D^2 = sum of the squares of cylinder diameters in inches.

P = absolute pressure, in lbs./□″, in boilers.

C = length of crank in inches.

f = 1,110 for triple cranks.

Most first-class engine builders and shipowners have the diameters made slightly in excess of Board of Trade or classification requirements, usually between 5% and 12%.

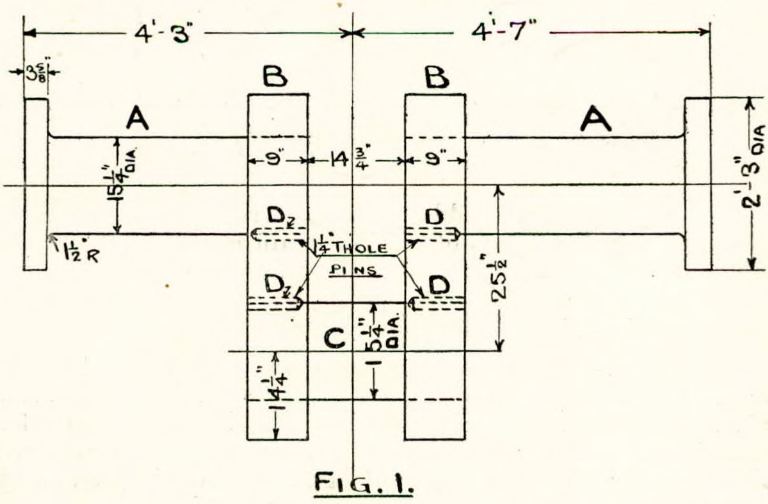


FIG. 1.

Material.—The shaft is usually made of Siemens' Martin ingot steel, this having strong fibrous and tough qualities.

The crankshaft is usually made up of three separate cranks bolted together, one for each engine, H.P., M.P., and L.P.

These are similar, with the exception that the forward end of the forward crank need have no flange, but for interchangability in case of accident it is as well to have this flange. As this is so it will be only necessary to describe the manufacture of one crank.

A typical specification for a crank shaft is: Shaft to be made of Siemens' Martin ingot steel, built in three sections and bolted together with solid flange couplings. Webs to be machined over and neatly milled, large key pins to be securely fitted after webs have been shrunk on body parts and pins.

Each crank is made up of:—

2 journals or body parts A (sketch 1).
2 crank webs B (,,).
1 crank pin C (,,).
4 key pins or tholepins D (,,).

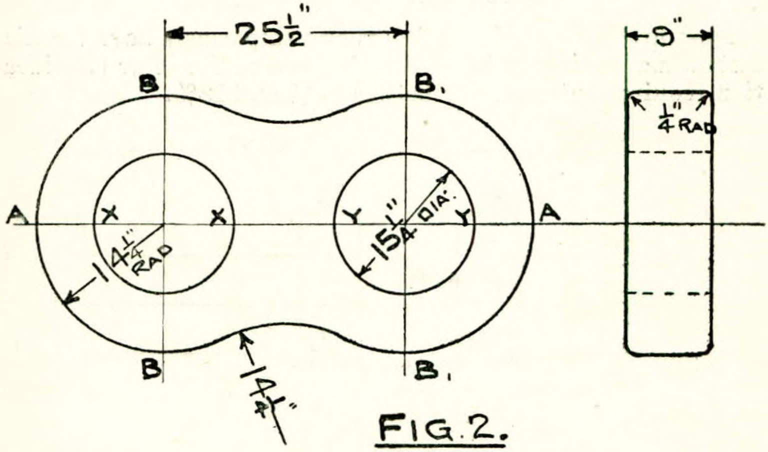


FIG. 2.

The Webs.—The webs are cut from blooms of steel which are sent direct from the steel works in the form of large slabs about $9\frac{1}{2}$in. × 5ft. × 2ft. 8in. These measurements allowing for machining. The blooms are first faced up to the required thickness (9in.) in a planing machine, being held in position by means of the usual stops and clamps, and polished.

The centre lines AA, BB, and B, B, are then marked off at the required centres, $25\frac{1}{2}$in. The holes XX and YY are marked off $15\frac{1}{4}$in. $15\frac{1}{4}/1000$ diameter, the allowance of 1/1000th in. per 1in. diameter is for shrinking on.

The outline of the web is now marked off by means of trammels or templates, usually templates, and the whole of the lines are popped round.

Boring the Holes.—The holes are now bored out, or rather tripanned out by means of a special tool described below.

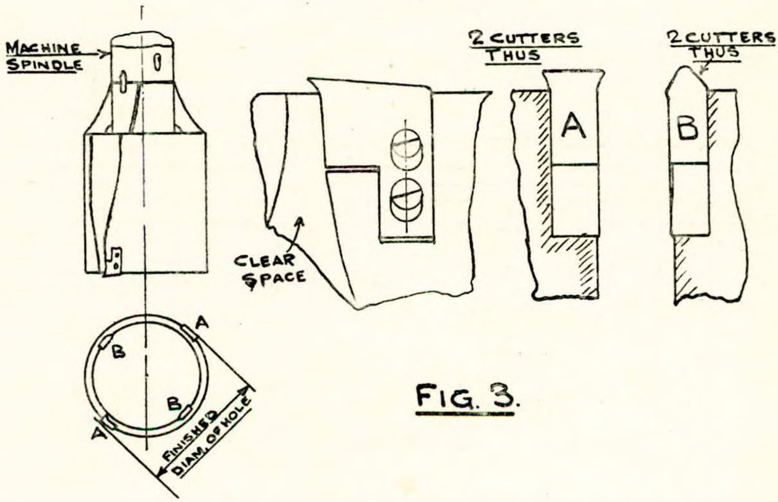


FIG. 3.

The Boring Tool.—The tool is shaped as above, and is made of steel. There are four cutters in it, the two inner ones BB, are slightly in advance of AA (about $\frac{1}{8}$in.), and they rough out the metal. The cutters AA are for finishing off the hole and are set to the exact diameter, adjustment being made by means of packing pieces. The slabs or webs are bored in pairs, thus ensuring exactly the same centres in each pair of webs.

The machined slabs are now brought to the trepanning machine and placed one upon the other so as to coincide all round. They are now clamped and stropped firmly to the machine table. There are two of the above tools, used simultaneously. The spindles to which the tools are attached can be adjusted so as to work at any fixed centres. By this means there is not the chance of boring the holes out of centre, which there would be if each hole was bored separately by means of a boring bar.

The webs on being bored out are checked for the various diameters, centres and profile.

They are now taken singly and sawn all round to within $\frac{1}{8}$in. of pop marks, by means of a narrow band saw. The webs are now ready for milling, the final operation on the webs, before assembling.

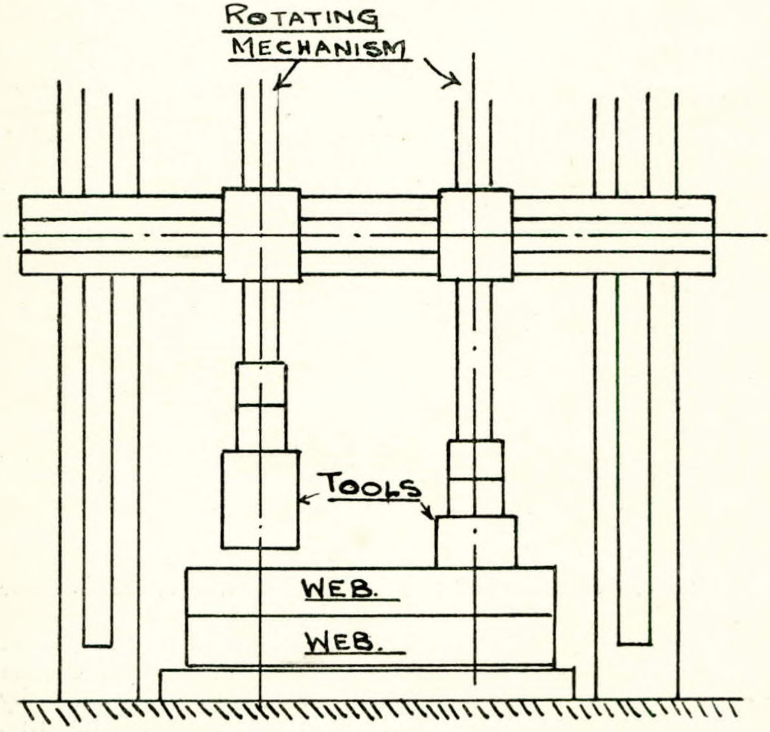


FIG. 4.

The milling machine is of the type in which the table may self-act in two directions at right angles simultaneously. The gears are so arranged that the table will move through the necessary arcs of a circle. The milling cutter revolving in the same vertical plane all the time.

The cutter first mills the part circle ACB, then D.E.F, and finally AD and BF. (See sketch 5).

The milling cutter is built up in sections as in sketch, this enables any thickness of web to be milled. There are two cutters, similar to sketch, placed on the same mandril, as in sketches 6 and 7; this ensures both webs being similar and equal in all respects.

The webs are placed on top of each other as in sketch 7, with the distance pieces between them to allow the milling cutter to radius the webs. These distance pieces have short necks turned on them, which are the exact diameter of the holes in the webs. The webs fitting over these are then central with each other, and on being milled, one is the exact replica of the other. A smooth file is now used to " touch up " the outside of the webs.

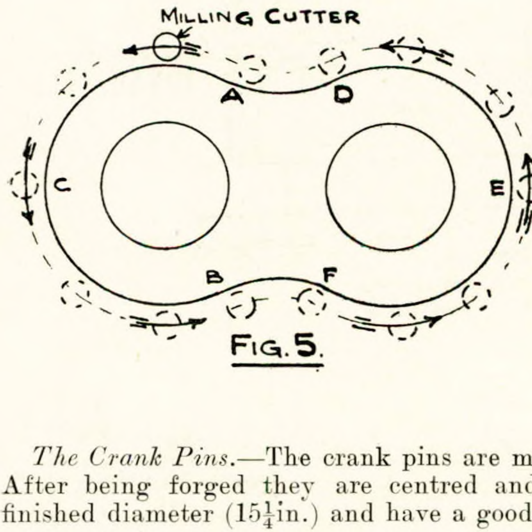


FIG. 5.

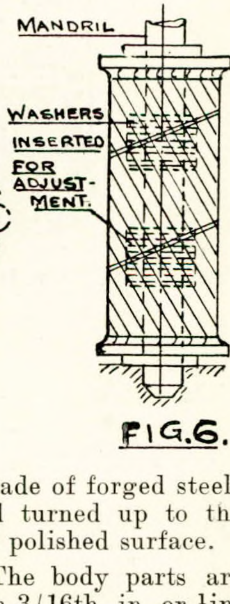


FIG. 6.

The Crank Pins.—The crank pins are made of forged steel. After being forged they are centred and turned up to the finished diameter ($15\frac{1}{4}$in.) and have a good polished surface.

The Crank Body Parts or Journals.—The body parts are forged from steel, and rough turned to with 3/16th. in. or $\frac{1}{8}$in. of finished diameter. The part which is shrunk into the web is turned to the finished diameter ($15\frac{1}{4}$in.) with a good finish for a length of 9in., *i.e.*, the thickness of web. The overall length is finished to correct size, Fig. 8A.

Both body parts are treated thus. Some builders increase the diameter of the pins by about $\frac{1}{2}$in. over the portion gripped by web (Fig. 8B). This is said to overcome any ill-effects due to " nipping " caused by excessive shrinkage. The parts are now ready for assembly and are taken to the " shrinking on " department.

Assembling of Crank Parts.—One hole, that which fits over the body part of each web, is now heated by means of either a gas or oil burner until it has expanded $15\frac{1}{4}$in. and a few thousands of an inch diameter. This is gauged with a point gauge. The few thousands in excess of the pin diameter is necessary because if the hole was just the bare size of the pin it would seize on the cold pin before it was far enough through the web.

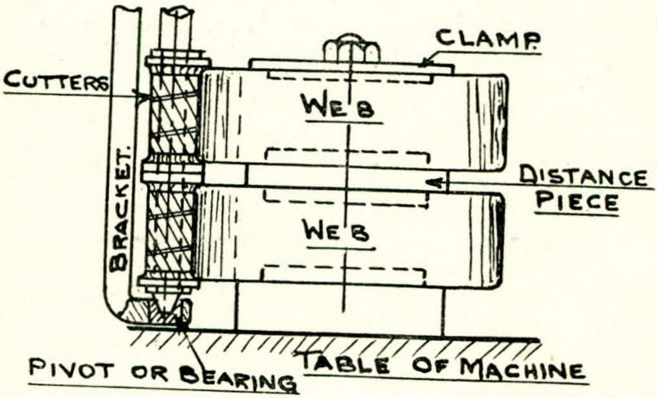


FIG. 7.

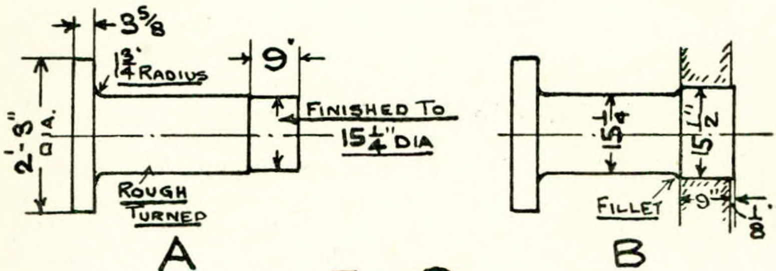


FIG. 8.

The body part is now lowered into the web and is stropped when the end is just flush with the inside of the web, by means of the increase in diameter, which occurs at the commencement of the rough turning. (See sketch 9A).

When the pin is increased in diameter as in Fig. 9B it is sometimes allowed to extend $\frac{1}{8}$in. through web. Both webs and body parts are treated thus and allowed to cool.

When the webs have cooled they are taken to a drilling machine and a $1\frac{1}{4}$in. dia. hole is drilled in both the web and pin, half of the hole being in the web and the other half in the web, as in sketch 10.

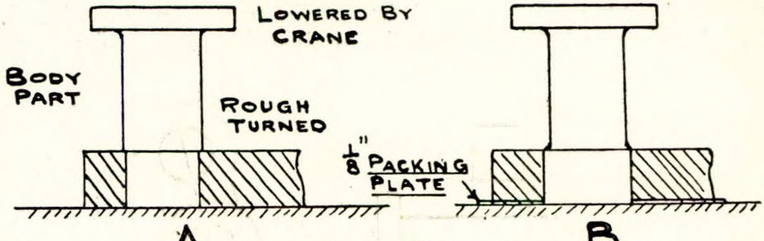


FIG. 9

A thole pin of mild steel is turned a good driving fit in the $1\frac{1}{4}$in. hole, a shank, smaller in diameter than the pin itself, is left on for driving purposes. A small air hole is filed on the side, and the pin driven home with a ram or a 14lb. hammer. The shank is now sawn off and the end of pin filed flush with the web. This is done with the other web and body part.

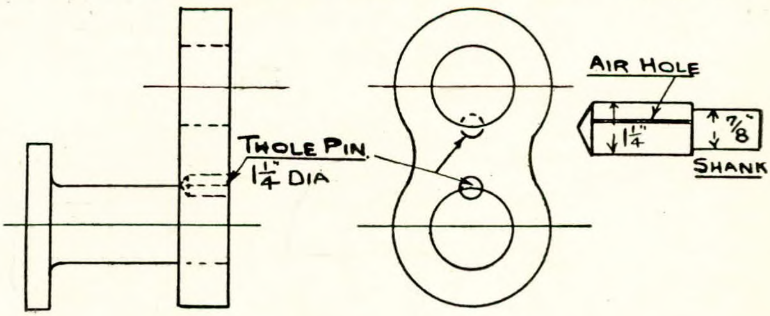


FIG. 10

The crank is now ready for the connecting " link " or crank pin.

Fitting the Crank Pin.—The pair of webs and body parts are propped up by means of supports and stops, as in sketch 11, the correct distance apart. The pin holes are heated simultaneously, so as to expand them to the required diameter. The crank pin is now slipped in, as in sketch, care having been taken to wipe all soot, etc., from the pin holes.

The webs are now allowed to cool, when a hole, shown dotted in sketch, is drilled in each web and in the pin and a thole pin driven home as in the body parts and dressed up.

The complete crank is now put into a lathe and the bearings and flanges turned to the finished dimensions and polished. Care is taken to balance the lathe against the crank webs.

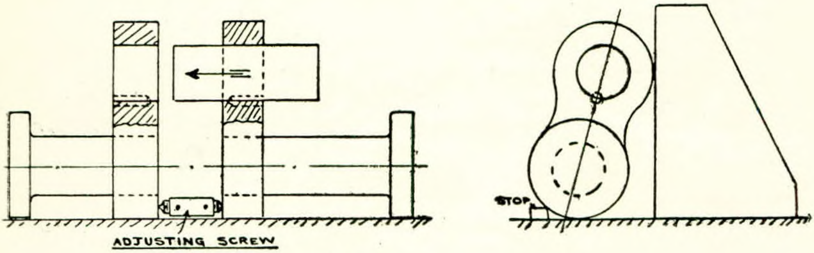


FIG. 11.

Drilling the Flanges.—The drilling of the flanges is carried out with the aid of a jig, which consists of a mild steel disc about 1in. larger in diameter than the flange and about 3in. thick. This is turned up and recessed about ½in. to a diameter

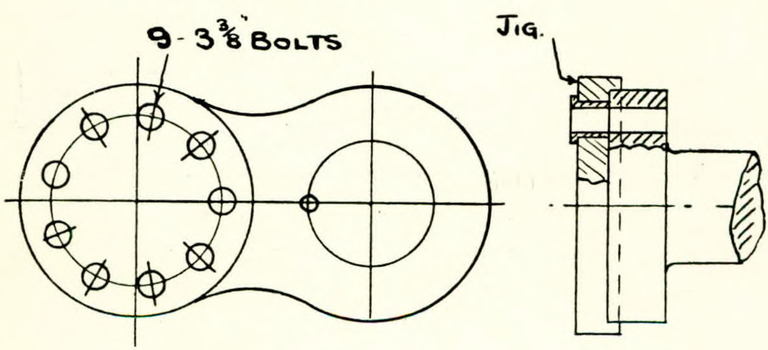


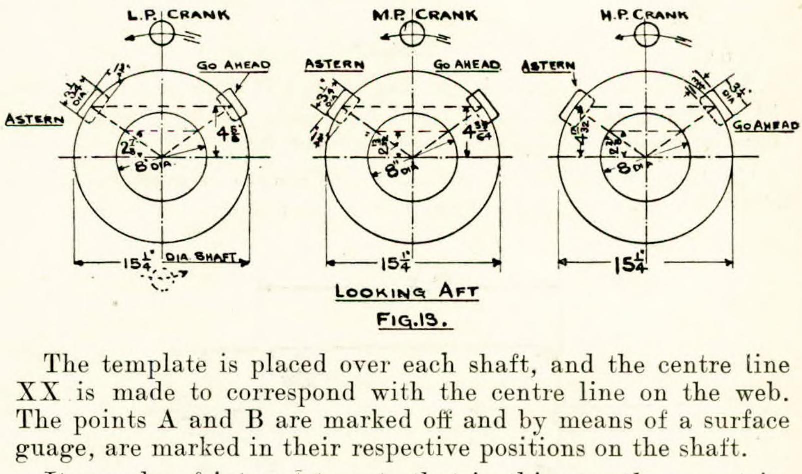
FIG. 12.

equal to that of the flange. This is marked off accurately and bored out to accommodate a hard steel bush, which is interchangable in all the holes in the jig. The internal diameter of the bush is equal to that of the drill to be used. (See sketch 12).

A centre line is marked over one of the holes. The jig is now clamped on to the flange, so that one of the holes lies on a centre line passing through the crank pin as in sketch 12. As there are nine holes and the jig is placed as above on each of the flanges of the shaft, the three cranks may be accurately set at 120° to each other.

The holes are first drilled about $\frac{1}{4}$in. less in diameter than the finished bolt size, by means of the common twist drill, and then bored out to the finished size by means of the " rose bit," and the back of the flange knifed to take the nuts. Sometimes tapered bolts are used, then the holes are rimed out partly and finished off in the erecting bed.

Mark off Eccentric Key Ways.—The drawing office issues a drawing which gives the above information, and from this templates are made to fit over the shaft.



LOOKING AFT

FIG. 13.

The template is placed over each shaft, and the centre line XX is made to correspond with the centre line on the web. The points A and B are marked off and by means of a surface guage, are marked in their respective positions on the shaft.

It may be of interest to note that in this case the eccentrics follow the cranks. This is because the H.P. and M.P. valves are of the piston type, having *inside* admission. The L.P. valve is a patent balance type which requires to follow the crank.

Had they been ordinary " D " valves, which is seldom the case in engines of this size, the eccentrics would have led the cranks, as shown by dotted crank in Fig. 13.

Drilling the Keyways.—The modern practice is now to fit circular keys, as in sketch 15. This means better fitting keys, easily and accurately made. The keyways having been marked off and their centres "popped," a $\frac{1}{2}$in. pilot drill is first used and a hole drilled to about $\frac{1}{2}$in. deeper than the depth of key in shaft. A pin-pointed drill now cuts the hole to within $\frac{1}{4}$in. of its finished depth and a radius drill finishes the hole off with $\frac{1}{4}$in. radius. The $\frac{1}{2}$in. hole is tapped out $\frac{5}{8}$in. (See sketch 16).

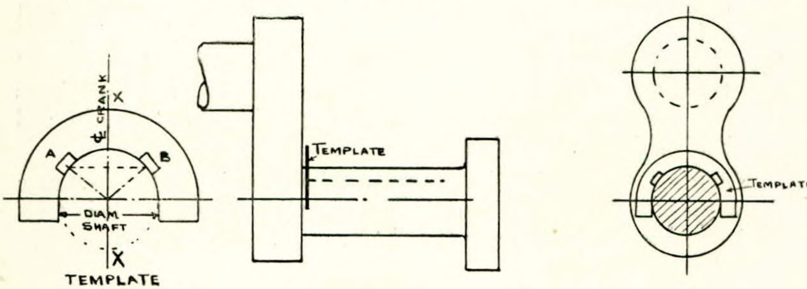
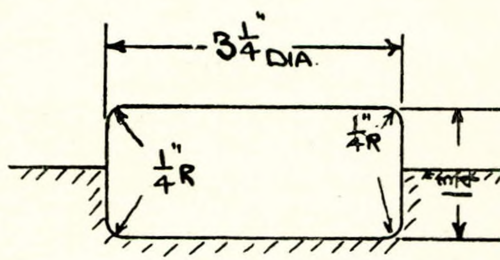


FIG. 14.

The keys are turned up to the correct diameter, *i.e.*, a good fit in the hole. A $\frac{5}{8}$in. tapped hole is in the centre to allow for the insertion of a bar to remove the key.

The larger halves of the eccentric sheaves are drilled in a similar manner and are then ready for fixing on the shaft.



KEY

FIG. 15.

All three cranks having been made and treated as above, are now taken to the erecting shop.

There are six vee blocks or stools, all of the same height, which are used to support the crankshaft. There being a block on either side of each crank. One of the cranks—say the M.P. —is allowed to hang vertically. Then one of its neighbours, H.P., is turned round by means of the crane until it is at 120° to the M.P. crank, three bolts are now fitted temporary and the other holes are rimed out until the holes are such a size that

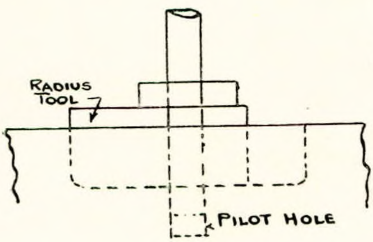


FIG. 16.

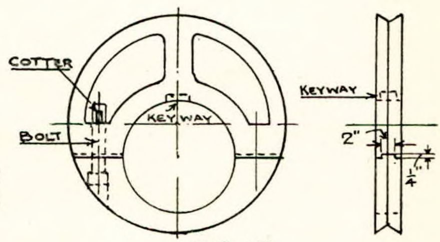


FIG. 17.

the bolts can be knocked in. The three temporary bolts are now properly fitted. This is repeated on the other coupling, the L.P. crank being 120° to M.P. in the opposite direction to the H.P. All bolts are marked, together with their corresponding holes.

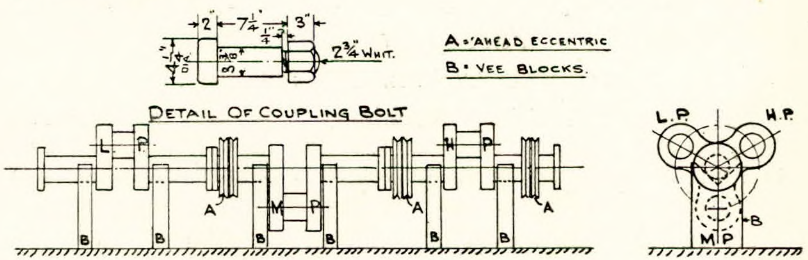
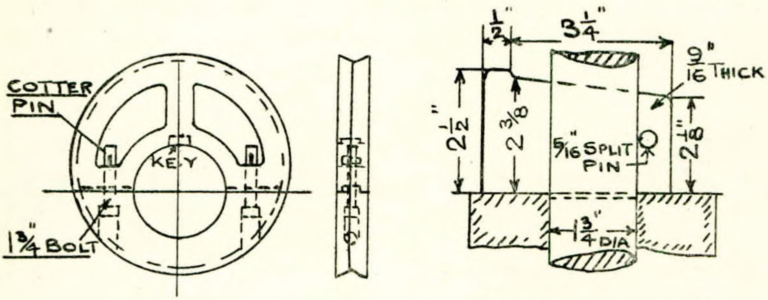


FIG. 18.

Fitting the Eccentric Sheaves.—The eccentric keys are now fitted in their respective keyways on the shaft and secured by means of a ⅝ set screw, countersunk head. The shaft is turned until one pair of the keys are on the top of the shaft.

The larger part of the sheave is now fitted on the key so that it just requires tapping on with a light lead hammer.

The lower portion is now lifted up, the bolts passed through and tightened by means of the coter shown in sketch 19. The position for the 5/16th. in. split pin is marked on the cotter, which is now drilled and replaced. The cotter is made of mild steel, 9/16th. in. thick and fits in the slot provided on the ends of the bolts. This is repeated for each of the three pairs of eccentrics.



DETAIL OF COTTER.

FIG. 19.

The crankshaft is now completed, and may be fitted in the engine bedplate.

Auxiliary Machinery for Cargo and Passenger Ships.

BY "POLLUX."—J. R. MORGAN (Graduate).

The term "Auxiliary Machinery" permits of so much freedom and looseness in its application that it would be well to limit its meaning at the outset by a definition. The term may quite fairly be confined within the following boundary.

By auxiliary machinery is meant any machinery other than the main engines and boilers which is utilised for the efficient running of the ship at sea or for the manipulation of her cargo in port.

A distinction is made in the title between cargo and passenger ships, but for each type of ship there are three further necessary sub-divisions, according as the main engines are reciprocating or rotary steam engines or oil engines. The subject thus falls naturally under the following heads:—

(i.) The auxiliary machinery for vessels having reciprocating steam engines as their main propulsive power: (*a*) Cargo vessels. (*b*) Passenger vessels.

(ii.) The auxiliary machinery for vessels having rotary steam engines as their main propulsive power: (*a*) Cargo vessels. (*b*) Passenger vessels.

(iii.) The auxiliary machinery for vessels having Internal combustion engines as their main propulsive power: (*a*) Cargo vessels. (*b*) Passenger vessels.

Under the first heading it will be sufficient to consider only the absolutely necessary auxiliaries, as quite a number of vessels sail with a bare complement. The better class of cargo vessel will employ more auxiliary machinery than the ordinary tramp steamer, but somewhat less than the type known as the cargo-passenger boats; hence, if the two extremes are described the intermediate type of vessel with its auxiliary machinery may be accorded an appropriate place in the scale. The bare complement of auxiliary machinery for an ordinary reciprocating steam-engined tramp vessel comprises: (i.) Air pump; (ii.) Bilge pumps; (iii.) Feed pumps; (iv.) Circulating pump; (v.) General service pump; (vi) Ballast pump; (vii) Evaporator pump; (viii.) Condenser; (ix.) Evaporator; (x.) Electric light engines; (xi.) winches; (xii.) Steering gear.

The air pump is of the bucket type, usually connected by link gear to one of the crossheads of the main engine, and is thus only working when the main engines are operating. Its function is to draw away the condensate from the condenser and deliver it to the feed water filter, the contained air escaping by a special overflow pipe into the engine room.

The bilge pumps are also connected to the crosshead and driven by means of appropriate link gear. They are usually two in number of the plunger type, and their duty is to keep the bilges clear of water while the ship is afloat.

The main engine feed pumps are similarly connected to the air pump crosshead and are employed while the main engines are running, in pumping the condensate from the feed filter to the boiler. The pumps are mostly two in number, and of the plunger type.

The circulating pump is now usually made an independent unit of the centrifugal type. Earlier designers included it with the main engine pumps, and it was then of necessity a plunger pump. Its duty is to pump a continuous stream of cold sea water through the condenser and out over the side of the vessel. As the head pumped against is low, and the pump deep seated, the centrifugal type performs its duty remarkably well, and is in consequence usually adopted for this purpose.

The general service pump performs several duties. At sea it is used to augment the supply of the main feed pumps to the boiler and thus acts as an auxiliary feed pump. For this purpose it is regulated by a float in the feed filter. When the level of the water in the feed filter drops, the float in falling causes a cock to rotate, and more steam is admitted to the pump with a consequent increase in delivery. When the level rises again the steam supply is once more shut off and the supply of water from auxiliary decreases. In port the pump is employed for feeding the donkey boiler. A pipe line attached to the water end permits of the pump being used to supply water to the deck for wash-deck and sanitary purposes. All pumps which are to be used for boiler feeding must be able to withstand full boiler pressure in the water-end, and should be simplex pumps.

The ballast pump, usually termed the "ballast donkey," is of first importance in the discharging of the water from the ballast tanks. This duty is usually performed in port, while discharging cargo. Its port duty is also to keep the bilges clear and to circulate the auxiliary condenser. It may also be used as a wash-deck pump and sanitary pump. At sea its sole use is as an auxiliary bilge pump. The pump is usually of the duplex type and high-speed pumps are often fitted; the flywheel is geared through rope or belting to a turning gear and worm, and the pump is thus utilised as a turning engine.

The evaporator pump is employed in pumping salt water to the outside of the evaporator coils. It is common practice to drive the pump from link gear connected to the main engine pump links, and to draw the water from the main engine circulating supply.

The condenser employed in the best marine practice is of the surface type, and its function is to condense the exhaust steam from the engine. For this purpose cold sea water is pumped through a number of brass tubes and the exhaust steam brought into contact with their outside surface. At sea the condenser deals only with main engines and auxiliaries. In port the auxiliary exhausts are occasionally passed through the main condenser, if no auxiliary condenser is fitted, and the circulating pump is an independent unit. Although on small engines the condenser is incorporated in the main engine frame, it is becoming more and more popular in the case of reciprocating engines to make the condenser a separate unit, and it is then nearly always supported on columns behind the main engine.

The evaporator is used at sea only, as a rule, and its function is to produce sufficient fresh water to replace the boiler losses. Salt water is put into contact with coils through which live steam is being passed and is accordingly evaporated. The water vapour formed is led by a pipe to the eduction pipe and is condensed with the main exhaust steam. The evaporator coils must always be designed so as to withstand full boiler pressure, and fitted with a safety valve.

The dynamo is now considered as an essential part of the ship's equipment, its function being to provide light for the general uses of the ship and to provide power for the wireless installation. It can obviously be used at sea or in port and its duty is invariably the same.

The winches are of utmost importance in the discharging and loading of a ship's cargo. They are rarely used at sea and afford junior engineers a splendid opportunity of becoming further acquainted with them. Usually the winches exhaust into the atmosphere on the cheaper tramp steamer, steam losses in the donkey boiler being made up with salt water. When an auxiliary condenser is carried, considerable saving to the donkey boiler is gained by exhausting the winches through the condenser and pumping the condensate back to the boiler by the auxiliary feed pump.

The steering engine in this class of vessel is of the usual steam type and is controlled through a hunting gear from the bridge. Its function is to move the rudder in any desired direction, and is thus used whenever the ship needs directing on her course.

This completes the essential auxiliary machinery for any cargo steamer.

The cargo vessel is concerned chiefly with the carrying of goods while the passenger vessel is concerned more with the rate of carrying. Providing the machinery of the cargo vessel is working sufficiently cheaply to give a satisfactory profit on the transport, its main purpose is achieved.

When, however, speed is desired without unduly increasing the costs of freightage, the running costs must be more seriously studied, and the problem becomes more acute. The more efficient the power plant, the less will be the maintenance cost.

Hence the additional machinery employed in passenger ships is in effect to make the machinery more efficient, but the main details already enumerated will always be found and sometimes duplicated.

The auxiliary machinery necessary for a passenger vessel under the first head, which differs from that already mentioned, will be:—Additional feed pumps; two general service pumps; two sanitary pumps; one compressed air fan (double-engined); two centrifugal pumps (one double-engined); auxiliary condenser; two dynamos; fresh water pump; two feed heaters; oil fuel plant; ash expellers; refrigerating plant.

The steam from the L.P. cylinder will, as before, be drawn through the condenser by the air pump and falls into the feed water filter via the hot-well. The main engine feed pumps pump the filtered feed water up to a feed heater at the top of the engine room. The feed heater is usually of the exhaust-steam direct-contact type, and L.P. steam from either the L.P. casing or the exhaust from one or more of the auxiliaries employed. The heated feed water now falls into the suction of the independent feed pumps, which deliver it to the boilers. A live steam heater is employed when the direct contact exhaust heater is not in use. The speed of the independent feed pumps is controlled, as before, by a float in the bottom of the exhaust heater.

One of the centrifugal pumps is used for circulating the main condenser, while the other, the single-engined one, circulates the auxiliary or winch condenser.

The fresh water pump supplies water from tanks on the ship's bottom to a pipe line on deck. This water is for drinking and culinary purposes. Two dynamos are usually employed on passenger vessels, one being kept as a standby machine.

The oil fuel plant consists of pumps and heaters for pumping and warming the oil before forcing it through the nozzles into the furnaces. The ash expellers are used where coal is the fuel and their function is to discharge the ashes from the stokehold over the side or through the bottom of the vessel. One type takes a very similar form to the ordinary steam injector used on loco practice.

The refrigerating gear consists of brine pumps, compressors, condensers, circulating pumps, CO_2 pumps (in the case of CO_2 plant), and evaporators. Its function is to preserve in cold storage food for the passengers or meat if no passengers are being carried, *i.e.*, several cargo-passenger steamers take passengers on the out voyage and return with frozen meat, fruit and dairy produce and no passengers.

If the vessel carries a double set of engines, several of these features may require to be repeated for the efficient working of the plant to suit the nature of the cargo carried. In a single screw job the complement sketched out is as elaborate as one would be likely to meet.

The winches on such a ship are often electrically driven, power being supplied from the dynamos.

The steering gear is of the telemotor type in preference to the usual steam variety.

The trend of modern design is to employ reciprocating Steam engines for low-powered cargo vessels, Internal combustion engines for high-power, high-class and medium speed passenger-cargo vessels, and steam Turbines for fast ocean going liners and cargo vessels. In any case high-power and high-speed cargo vessels fitted with turbines invariably carry passengers, and the difference in the auxiliaries met with on turbine-driven cargo and passenger ships is very little indeed.

Apart from the fact that all the pumps are independent units, there is very little difference in the auxiliaries required for a turbine-driven ship, and those for a high-class reciprocating-engined steamship. Independent air pumps, bilge pumps and feed pumps take the place of the engine-driven pumps of the reciprocating engine, but their function is the same in each case. With this slight difference, turbine-driven ships may well be compared as far as auxiliary machinery goes with what has already been said for high-class reciprocating-engined vessels.

The internal combustion-engined ship, however, differs very considerably from steam-driven ships in both the number and the type of auxiliaries required, and although similar duties have in many cases to be performed by their steam analogies, an entirely different type of auxiliary is employed. The necessary complement for an internal combustion engine-driven cargo vessel is as follows:—

(i.) Two air compressors. (ii.) Three dynamos. (iii.) Bilge pumps. (iv.) Circulating pumps. (v.) Ballast pumps. (vi.) Fuel pumps. (vii.) General service pumps. (viii.) Sanitary pump. (ix.) Air bottles. (x.) Auxiliary boiler. (xi.) Winches. (xii.) Steering gear.

The main air compressor is usually coupled direct to the driving shaft of the main engine and may be of the two, three or four-stage type. It is only working when the main engines are running. Its chief function is to supply air under pressure to an air bottle, the air from there being utilised to blow the liquid fuel into the cylinders, where atomisation and combustion immediately ensues. Marine internal combustion engines are invariably started up on compressed air, the engine running for a few revolutions as a compressed air motor. The starting air is contained in special reservoirs, and the second use of the compressor is to replenish this bottle with air for starting purposes. The second auxiliary compressor is an independent unit, either steam driven or driven by a semi-Diesel engine. Its purpose is to charge the starting air bottles after the engines have been idle for some little time.

In the absence of steam power, the motive power for practically all the auxiliaries is electricity. The power is developed by large oil-engined generators, each of which can supply sufficient current for the general uses of the ship. It is customary to carry at least three such generators, although on some of the smaller cargo vessels only two are carried.

The bilge pumps performs the same duties as their steam analogies, although they differ from them in design. Either two or three-throw plunger pumps are employed, the drive being through gearing from an electric motor. If the pumps are driven from the main engines it is customary to follow steam practice and employ a long plunger type of pump driven by link gear from one of the engine cross heads. In this case the pump is only working when the main engines are working.

When the circulating pumps are independent units they are either of the three-throw plunger type or of the centrifugal type, but in either case they are directly driven by electric motors. The function of the circulating pump is to deliver cold sea water to the cylinder jackets, the supply being drawn from the surrounding sea. It is becoming increasingly popular to cool the cylinders with salt water and the pistons with fresh water. When such a system is adopted the fresh water is cooled in a special surface cooler, very similar in construction to the steam condenser, the cooling water being drawn from the main circulating supply. The circulating as well as the bilge pumps are occasionally driven from the main engines as in steam practice.

The ballast pump is electrically driven through gearing with an electric motor, and performs the same duty as it would on a steamship in pumping out the ballast tanks in port and acting as an auxiliary bilge pump. The fuel pumps are generally driven from the half-speed shaft by means of eccentrics and push rods, the fuel oil being pumped to distributing boxes from whence it is delivered to the fuel valves. In most vessels the fuel pumps deliver the oil to the valves under slight pressure and the injection air forces it into the cylinder, the oil being atomised in passing through the valve. In some cases, however, solid injection is employed, and the fuel pumps then deliver the oil under a very high pressure of several thousand pounds pressure and injected into the cylinder directly through the valves without any injection air. When solid injection is employed the air compressor may be a separate unit and used solely for supplying starting air under pressure to the starting air bottles.

The general service pump is motor driven through gearing and may be used for supplying cooling water, deck-water or for filling the settling tanks for the fuel oil.

The sanitary pump follows the usual type and provides sea water for the deck purposes.

The air bottles are cylindrical steel structures which contain the supply of air for starting the main engines and the electric generators, and for injecting the fuel oil. Their capacity depends upon the size of the engine, most marine plants demanding at least two large bottles about the same size as a marine condenser.

In high-speed engines and a number of marine engines, forced lubrication is employed, the pump being driven by eccentrics and link gear from the main engine. Coolers for the lubricating oil are frequently employed, the cooling water being supplied from the main circulating supply.

A large number of marine oil engine plants include a small vertical boiler of the Cochrane type among the auxiliaries.

Its purpose varies. It may be used for warming the fuel oil in cold climates, or for driving an auxiliary air compressor. In Doxford engines the boiler is used for supplying steam for the heating of the main engines before starting. Owing to the low compression pressure, the temperature normally attained in the engine would be insufficient to effect combustion of the fuel.

The winches are all electrically driven through motors and spur gearing, the power being supplied from one of the Diesel driven generating sets.

The steering engine is sometimes run on compressed air and differs little in its essential parts from the steam steering engine.

All syrens and hooters employ compressed air

The great disadvantages of a large amount of auxiliary machinery is that the power absorbed in driving it is out of all proportion to the work obtained. In this reason it is well to limit the fuel consumption of the auxiliaries to 20 per cent. of that used by the main engines.

As in the case of steam practice the auxiliaries for passenger vessels will include the above features and auxiliaries will be added to meet the increased demands. In the case of twin and multiple screw ships, these auxiliaries may be doubled or trebled.

Superheating in Marine Practice.

By "COLUBA"—A. Brown (Student-Graduate).

Superheating in marine practice has within recent years become more common in this country, but could with advantage be more widely adopted, as the cost of coal is now so high. For a given amount of water a greater volume of steam is obtained by superheating, hence it is readily seen that fuel economy results from superheating.

Superheaters used in marine service are of several types; those most commonly found it is proposed to briefly describe. The steam raised in the boiler is passed through U-shaped tubes which pass in and out of the smoke tubes and meet at a common point called the superheated steam header. The waste gases in the smoke tubes act on the steam already generated in the boiler, causing further rise in temperature, so that, with a constant pressure the volume of steam will increase, or with a constant volume the pressure will rise. The following goes to prove the above statement when a rough test was made with a trawler's winch which was set to work with saturated steam for 20 minutes, the water evaporated in the period was found to be 5 inches—read from the boiler gauge glass. In the second part of the test the boiler was refilled to the same water level and to the same boiler pressure, but superheated steam was used, doing the same work for 20 minutes; the reading in this case was found to be 3 inches of water evaporated from the boiler. The boiler feed check valves in each test were closed. Te saturated steam passes through the boiler stop valve, and in some cases also through a reducing valve. The reducing valve is fitted according to the view entertained by the superintendent.

A stop valve chest is fitted on the top of the boiler to give a direct outlet of saturated steam to the engine when necessary or a mixture of saturated and superheated steam, or solely superheated steam may be used by adjustment. All boiler mountings and steam pipes used in conjunction with superheated steam are made of special quality steel.

The use of superheated steam has several undoubted advantages over saturated steam, which result in considerable economy in the fuel bill, as there is a greater volume of steam for a constant pressure. Smaller boilers may be fitted in comparison with those required for ordinary steam, owing to the fact that for a given grate surface a larger volume of steam is obtained by superheating.

In reciprocating engines the loss of efficiency due to condensation in the steam pipes and cylinders is reduced to a minimum, with the use of superheated steam, owing to the steam being in a drier state when entering steam pipes and cylinders. The chance of damage to cylinders and cylinder covers due to an accumulation of water is reduced, as a smaller quantity of water is in the steam, and there is less leakage of water past valves and glands, while there is practically no danger to chests and steam pipes due to water hammer.

The stripping of blades in turbines has often been caused by water collecting in the casing, due to condensation, therefore the drier the steam used in turbines the lesser the chances of breakdown from stripped rotors. Superheated steam has another advantage as it tends to reduce erosion in turbine blades.

With deck machinery, winches and windlasses, condensation in steam pipes is great, due to the lengths and exposure of the pipeline, and by superheating, dry steam is delivered to the deck machinery.

Faults are to be found in most things and superheating is not lacking. The first consideration which arises before one is to obtain a good reliable make of superheater, proved to withstand the severe temperatures to which the tubes are exposed. Occasionally leakage is found at the superheated steam header, and to cut out one or more of the superheating elements while at sea is then necessary. This temporary repair involves time, and it is a somewhat disagreeable job for the engine-room staff. All boilers prime more or less, if they prime heavily a residue of boiler water impurities may be deposited on the superheating tubes, which will more or less affect them detrimentally, as if the temperature in the tubes becomes excessive they will burst.

One great difficulty with reciprocating engines is to lubricate the working parts, such as valves, valve faces, pistons, piston rods, etc., this is due to the dry state of the superheated steam, the high temperature burning up the ordinary cylinder oils. This difficulty is overcome by using special high temperature mineral oils, manufactured by various oil companies, which are said to allow suitable lubrication for valves, pistons, etc. By using superheated steam without proper lubrication, valve faces are scored and cylinder walls are fired up, so it is most essential that a good quality of lubricating oil is used. By switching the engines on to saturated steam frequently, this prevents much wear and tear. Another method is to open the mixing valve occasionally, to give the engines portions of superheated and of saturated steam. The working surfaces in reciprocating engines show no extra wear if properly attended to. The piston rings are more easily broken and piston valves should be opened up at shorter intervals, as the springs become dead, due to becoming choked up with the residue of burned oil. Soft packing does not stand up against the high temperatures of superheated steam and a metallic patent packing is usually employed.

Although turbines are usually driven by superheated steam is has its disadvantages, and breakdowns are caused by unequal expansion of turbine blades due to excessive expansion with high temperatures. Experience, however, with high pressure and temperature of steam has led to the earlier difficulties being overcome. It is usual practice to admit low pressure steam, from 80 to 100 lbs. per square inch, in the case of an astern turbine reaction blading, the drop in pressure may be dealt with by the throttle valve. With a velocity compounded impulse turbine however the risk of stripping blades is not so great and the present practice is to make the astern turbine of this type.

The auxiliary machinery requires to be specially constructed of steel to meet the conditions imposed by the superheated steam, which is most searching at joints, and plays havoc with the working parts. The auxiliary machinery is often fitted with metallic packing for this reason. An alternative method is to drive auxiliaries by saturated steam. The cargo winches are usually of a rough finish and insufficient allowance is made for cylinder lubrication; it may be added that deck machinery in small vessels in not as a rule well looked after, and if superheated steam is to be used under these conditions, the working surfaces would soon become scored, and as a result become more inefficient machines.

When the method of superheating is done by passing the U elements into the boiler tubes, some arrangement has to be fitted to clean the tubes, as the heating surfaces would soon be covered with soot—a bad conductor of heat. The diamond blower is often used, this apparatus is fitted in the combustion chamber and blows at intervals boiler steam through the flues, cleaning both superheating and smoke tubes. Another method is to use a flexible pipe joined to the superheated steam header and directed to blow dry steam through the flues. With superheating installation forced draught is commonly employed, if superheating is done by the waste gases the temperature of the funnel gases will be reduced, this in turn renders less heat available for the air heating tubes in the forced draught system, as in the case of Howdens' forced draught system.

There are dangers with superheating of steam, for example, should the engine stop valve be suddenly closed, a volume of steam would be imprisoned in the superheating tubes, and the pressure would rise along with the temperature and would probably cause an explosion, for this reason, reliable safety valves must be fitted to the superheater. In Yarrow water tube boilers the superheating tubes are in one side of the boiler, and the above difficulty is overcome, should the superheated steam be imprisoned, the heat and flame being deflected to the other side of the boiler and then pass on to the funnel.

While raising steam, the superheating tubes are exposed to the impact of heat and flame and provision is generally made to protect the tubes, as otherwise little or no steam is then passing through.

An instance has been stated, where three boilers were fitted athwartships and the superheating system installed, that while at sea the centre boiler gave trouble owing to difficulty experienced in keeping the water in the gauge glass at a uniform level. The feed check valves were adjusted several times, but it was impossible to regulate the feed, as at one time the glass would be full of water and the next time empty. It was found that by cutting out the superheating system in the centre boiler and using saturated steam, the water level in the gauge glass was no longer erratic, the wing boilers worked without trouble when using superheated steam. The cause was not stated and it is a problem difficult to solve without full reliable data.

The following table shows the advantage of using superheated steam in comparison with saturated steam in reciprocating and turbine engines, all of which develop the same I.H.P.

	2-SHAFT. Quadruple Engine.		4-SHAFT SERIES. Direct Turbine.	
	Saturated.	Superheated	Saturated	Superheated
I.H.P.	21,650	21,650	21,650	21,650
Working Pressure, lbs.	210	210	200	200
Superheated °Fahr.	Nil	200	Nil	100
Steam used per H.P. hour, main engines, lbs.	12·71	10·4	11·86	10·9
Equivalent coal used in lbs. per hr.	31,800	27,200	30,200	28.200
Boilers. No. off	6DE;4SE	6DE:3SE	6DE:4SE	6DE:3SE
Heating surface of boiler, sq. ft....	52,000	48,750	52,000	48,750
Grate area ,, ,, ,,	1,232	1,155	1,232	1,155
Draught	Howden's	Howden's	Howden's	Howden's
Coal used per day, in tons ...	341	·292	·324	302
Gain in dead weight, tons... ...	—	457	—	241
Cubic capacity gained in cubic ft.	—	21,200	—	6,510

About the year 1860 superheating was frequently used, but was abandoned mainly because of the difficulty in regard to lubrication. The importance of taking means to avoid initial condensation was less generally understood in those days than it is now, and with the lubricants at present in use the old objection to superheating have little force.

—o—

Notes.

The following interesting letter has been received from Mr. J. B. Russell (Member) :—

In a single paper it is difficult to give complete details of a subject so comprehensive as salvage, and I agree with Mr. H. G. Dixon that a further paper from Sir Fred W. Young would be of great interest to members. His article on "Salvage Work" contained in March issue of the magazine made a special appeal to me on account of my having served for three years as Engr. Sub-Lieut. and Engr.-Lieut., R.N.R., respectively, on *Racer*, the salvage ship whose replica is depicted on page 745, from the date of her commissioning. A few particulars of this ship may not be out of place as casting a light on war-time's "peaceful" activities.

Racer was built about sixty years ago as a sloop and, among other duties, took part, I understand, in the bombardment of Alexandria. She afterwards became attached to Osborne College, Dartmouth, as a training-ship for cadets, but before being fitted out for salvage work was employed as a coal hulk! Being of wood, she was eminently suited to salvage conditions and her possibilities were regarded with such favour that she was converted, and early in 1917 proceeded to the south of Ireland fully equipped with salvage plant and repairing appliances as detailed on page 744.

The portable salvage pumps comprised a total pumping capacity of 3,500 tons per hour. All were centrifugal, including steam and motor driven pumps and electrically driven submersibles. The motive power for the submersible pumps was supplied by a 150 K.W. A.C. generator, driven by a compound steam engine of 379 B.H.P. Portable cables were connected from engine-room switchboard to pump starters on deck, thence to pumps. Alternatively, power could be supplied from a portable generator driven by a six-cylinder Thornycroft engine.

The duties of the staff consisted of pumping out and patching disabled ships, these afterwards proceeding to dock, under their own steam when possible. At times only pumping was necessary, pumps being in that case placed on board in charge of salvage party and kept running during the passage. In one instance only were lifting lighters employed—by means of two lighters and four nine-inch wires the raising and beaching of a German submarine from fifteen fathoms was successfully carried out in the method indicated on page 740.

During the first fifteen months of her career, *Racer*, in addition to other work around the United Kingdom, was wholly or partly responsible for the docking of ten large disabled ships and it will be understood that the keeping of an accurate technical record was a matter of extreme difficulty under the busy circumstances, especially as the commissioned officers on board were R.N.R., ex-Merchant Service, with little or no previous experience of salvage work and machinery. It was, however, an enjoyable and interesting commission, the credit for which being due to the perfect harmony and accord which always existed, not only on board, but also between the ship's officers and the Head of Salvage Section, at that time Engineer-Captain H. R. Teed, R.N., now retired.

I am, therefore, indebted to Sir Fred W. Young for recalling to me a most pleasant and instructive period of service.

———o———

Royal Navy Engineer Officers.

The following historical notes are of considerable interest at the present time:—

ROYAL NAVY HISTORY OF THE ENGINEERING BRANCH, 1902-1925.

1902.—The new scheme of training (generally known as the Selborne scheme). Under this scheme the officers required for the Executive, Engineer and Marine Branches of the Service, in short those officers essential for fighting a ship, had a common entry and common training until such time as they would specialise in their respective branches. (See Note I.).

1903.—First term of cadets, aged 12-13 years, who had been selected for the Service under the conditions of the new scheme, entered the R.N.C., Osborne.

1903.—Statement of Admiralty policy presented to Parliament. Signed by Lord Gawder.

A Committee under the presidency of Admiral Douglas ordered to report:—

(*a*) Whether any necessity exists for distinct classification of such officers who had entered the new scheme.

(*b*) Whether specialisation for a period of their career *only* is necessary.

(*c*) How best to provide for filling efficiently the higher scientific appointments open to Engineer Officers.

Committee reported that as regards (*a*) and (*b*) there was no need for a final division into three branches, and that specialisation for a period only is necessary, as opposed to permanent classification into separate lists. Admiralty comments that "There can be no question of the great advantage to the efficiency of the Service that this removal of differences will entail."

1905 to 1911.—Although many details of the training of new scheme officers were constantly being altered and improved as the result of experience, the fundamental basis of the scheme remained unchanged. These principles were:—

(*a*) A common entry.

(*b*) Common training until specialisation into the various branches of the Service occurs, viz., (G), (T), (H), (E), etc.

(c) All specialists to be on an equal footing.

(d) Specialist officers to revert to general service on being promoted to the rank of Commander, except in the case of a few officers (not exceeding 10% of the total number of Engineer Officers) who would volunteer to devote themselves for their whole service career to engineering, thus fitting themselves for the higher Admiralty and Dockyard posts, being compensated for the loss of military command by increased pay and prospects.

In 1907 a second Committee presided over by Admiral Douglas reported on the condition of Service and duties of the Old Type Engineer Officers (Keyham trained) and made *recommendations* regarding their position in respect to the new scheme officers who would eventually serve under them.

1911.—First term of new scheme officers promoted to rank of Sub-Lieutenant. All these officers received the same commission as had been issued to all Executive Officers. (See Note II.).

1912.—Volunteers to specialise in engineering were called for from the first two terms of the new scheme, the first specialist course being due to commence in October, 1913:—

1912.—Mr. Winston Churchill, First Lord of the Admiralty, stated in the introduction to the Naval Estimates, that the officers who volunteered for engineering would remain members of the military branch of the Navy, being placed on an equal footing in all respects to officers who volunteered in navigation. Subsequently K.R. and A.1, Article 326 was amended in 1914 to give effect to the above and also to the conditions of service offered by Admiralty letter C.W. 8596, dated May, 1912, to intending volunteers in engineering. (See Note III.).

NOTE I.—New scheme introduced:—

(a) Owing to lack of co-ordination and general friction between the Executive and Engineering Branches which had been found to impair the efficiency and discipline of the Service.

(b) To man the Executive and Engineering Branches by officers drawn from the same class of society.

(c) To give all officers of both branches equal opportunities and equal status.

(d) To ensure that whilst specialist officers had a complete knowledge of their own speciality yet they would all have a general knowledge of the duties and capabilities of other branches.

NOTE II.—Commissions signed by H.M. The King issued to Executive Officers differ materially from those issued to officers of non-military branches. The former Commission orders officers "to take charge and command," the latter type orders the officer "to discharge the duty of, and to be obedient to such as command" each in the rank to which an officer belongs. It is interesting to note that Executive Commissions have been issued to all (E) Officers until the present time and this indicates that even after the First Lord's statement in 1920-21 predicting final separation of these two branches no intention existed to alter the status of (E) Specialist Officers.

1915.—The whole of the Engineering Branch made part of the Military Branch of the Navy. (See Note IV.).

1916.—Admiralty issue special orders regarding officers who have specialised in engineering. It is stated that:—

(*a*) It is to be clearly understood that officers after specialisation in engineering, retain the same status and are regarded as in the same position as other specialist officers.

(*b*) Lieutenants appointed for (E) duties should not be called upon to perform ship duties to such an extent as to interfere with their engineroom duties.

(*c*) As a wartime measure only, Lieutenants (E) are not to assume command so long as there is a commissioned officer in the ship qualified to succeed in command.

The above is not applicable to Lieutenants (E) serving in submarines, who will assume command if the officers senior to them are disabled.

1918, Dec. M.O. 4047/18.—As the result of a Committee, presided over by Mr. McKenna, consisting of Lord Jellicoe and Sir George Goodwin (then Engineer-in-Chief of the Fleet), it was decided that:—

(*a*) If an officer specialised in engineering as a Sub-Lieutenant without first obtaining an upper deck watchkeeping certificate, he would forego all future right of reversion to deck duties and of military command.

(*b*) If an officer specialised after obtaining an upper deck watchkeeping certificate he would retain his right to military command until he reached the seniority of between $7\frac{1}{2}$ and 9 years, when he would have to elect whether he would exercise his right of reversion to the upper deck or remain as an (E) officer for the remainder of his service career, giving up the right of military command, but retaining his military status. These decisions were embodied in revised conditions of specialisation published in the Order quoted above.

NOTE III.—Admiralty Letter C.W. 8394 points out that:—

(a) Officers specialising in engineering will return to the upper deck on attaining the rank of Commander unless they wish to continue as (E) Specialists in the higher ranks.

(b) Selection for the Submarine Service will to a great extent be made from officers qualified in (E).

(c) The rates of pay for engineering are higher than other Specialist Branches.

(d) The prospects of promotion for (E) Officers are as good as for officers who have specialised in other branches.

NOTE IV.—The Military Branch to consist of the Executive and Engineer Branch, i.e., those officers who are essential for fighting a ship. The term "Military Command" is used in the sense of a command of a ship as a whole and is distinct from "Military Status," which is that of an officer who performs military duties.

1919, March.—Officers who had specialised in engineering prior to the issue of M.O. 4047/18 were given the following alternatives:—

(*a*) To remain as they were. In which case they could not expect to receive engineering appointments continuously. They would also be judged for promotion to the rank of Commander and Captain in competition with deck officers generally and not on their engineering abilities, as would be the case if they accepted the regulations issued in M.O. 4047/18.

(*b*) To accept the application to them of the new regulations in M.O. 4047/18.

(*c*) To revert to deck duties forthwith. (See Note V.).

1920.—The First Lord, in the statement introducing the 1920-21 estimates, stated that it was considered that final separation between the officers of the Executive and Engineering Branches was essential. He stated that "There is a definite distinction both as regards knowledge and capabilities between those who are trained in the science of naval war and strategical and tactical method of fighting, and those who are to deal with the upkeep and maintenance of engineering and mechanical appliances which are necessitated by the complex machinery and weapons of war." He emphasised the absolute necessity for full co-operation and sympathy between the officers of the two branches, and stated that it was believed that this condition could be obtained by common entry and training in the initial stages of an officer's career. In order that a due proportion of officers of ability should be attracted to the engineering branch, the following decisions had been made and promulgated.

(*a*) The duties of the Engineer-in-Chief were to be extended, and he would be in future held responsible for advice on all matters in connection with the engineering policy and the instruction and training of the personnel of the Engineering Branch.

NOTE V.—Alternative A entails being judged in comparison with other Upper Deck Officers not on the (E) Officer's whole career, but purely on the short period he remains on the upper deck, by a Selection Board composed entirely of Upper Deck Officers. Those conditions in practice would entirely eliminate any chance of future promotion beyond the rank of Lieutenant-Commander.

Alternative B subject only to the possible exercise of the rights of revision in the limited period named, entails the eventual surrender of the right of military command. This was contrary both to the letter and spirit of the regulations under which the officers concerned specialised.

Alternative C virtually entailed the closing of the officers' career since most officers were too old to specialise in other branches of the Service, and it was considered probable that officers who accepted (c) would therefore be "axed."

The majority of the officers were naturally unwilling to accept any of those alternatives allowed and were finally doomed to have accepted Alternative B by default.

(*b*) When (E) officers became available, they were to be considered with deck officers for appointment as Admiral Superintendent of Dockyards. It was also stated that no (E) officer in future would have the right to revert to the upper deck, and that it was intended to set up a Committee to consider the question of transferring the responsibility for the upkeep and maintenance of the electrical machinery from the (T) officer to the Engineer Officer, thus apart from other considerations opening up further positions to officers who elect to specialise in engineering.

1921.—The First Lord stated in the statement introducing the 1921-22 estimates, that the policy inaugurated in 1920 had been further developed, and to this end the following decisions had been made :—

(*a*) To transfer the electrical installation of ships from the Torpedo Branch to the Engineer Branch.

(*b*) That in future officers who volunteered to specialise in (E) would do so earlier than had previously been the case, and that they would specialise on being rated midshipmen. It was considered that the period of common training at Dartmouth and as cadets at sea was sufficient to give common understanding of the ideals and discipline of the Service. The Committee, forecasted in the 1920-21 estimates, was formed under the presidency of Admiral Tudor and reported during this year, making recommendations that the pay and prospects of Engineer Officers should be improved in order that sufficient candidates of the right type should be attracted to this branch of the Service. (See Note VII.).

1921 to 1925.—In accordance with the foregoing policy a number of midshipmen drawn both from Dartmouth and Public Schools, have elected to specialise in engineering. Latterly the numbers of volunteers from Dartmouth trained

NOTE VI.—It will be observed that Specialist Officers, so far as the Engineer Officers are concerned, were then no longer expected to have a general knowledge of the duties and capabilities of other branches. Similarly the amount of time devoted to engineering instruction for other Executive Officers was reduced to a negligible quantity, with the result that there is gradually creeping into the Service a body of officers who have little conception of the duties and responsibilities of Engineer Officers.

NOTE VII.—The Committee, whose terms of reference related solely to the question of training of the future Engineer Officer, is Mechanical and Electrical Engineering, took a large amount of evidence from outside engineering opinion. It recommended:—

(a) Common entry for all officers of the Military Branch.
(b) Common training until officers were rated Midshipmen.
(c) Course of instruction to last four years, of which $3\frac{3}{4}$ to be spent at Keyham and $\frac{1}{4}$ year in Vernon.
(d) (E) Officers who passed the advanced Electrical Engineering Course to be eligible for the higher posts in the Electrical Engineers' Department in the Dockyards and at the Admiralty.

officers have been very small, and therefore it has been necessary to draw more and more from Public School entries. (See Note VIII.).

1925, Nov.—A.F.O. 3241/25 issued. Engineer Officers, both old type and new scheme included in the category "Engineer Officers." The term Military Branch abolished and the officers will be divided into a number of categories, of which only the Executive Officers will be allowed to assume military command. All (E) officers to be definitely regarded as eligible for engineering appointments only and not as having the qualifications for carrying out the duties of Executive Officers. As a corollary, they will be considered for promotion to Commander (E) in competition with Engineer Officers, and not in competition with Executive Officers. All officers qualifying or employed on engineering duties to be shown on separate lists in the Navy List, and are to wear the purple distinction cloth worn by other Engineer Officers. A more distinctive shade of purple is to be used. (See Note IX.).

1925, Dec.—The first term of Engineer Officers who have been trained in mechanical and electrical engineering under the policy inaugurated in 1921, completed their course of instruction. Conditions under which these officers will be allowed to specialise in electricity, if they so desire, have not yet been promulgated, it is therefore very doubtful if any of the first term of these officers will be allowed to specialise in electricity. (See Note X.).

Notes relating to the Status of Engineer Officers in the Royal Navy.

The subject is one in which the best interests of the Service must be uppermost. There are two standards of consideration:—

1. The Army R.E. Officer. He is a technical officer fully trained in all military matters as well as his speciality, yet in the field from Subaltern to Commander-in-Chief he takes com-

---

Note VIII.—The objection to drawing the bulk of the officers who volunteer to specialise in the Engineering Branch from Public Schools is that the advantages of common entry and training obtained by Dartmouth volunteers are sacrificed.

One E.R.A. Apprentice is allowed to pass on from the Fishgard to the Royal Naval Engineering College at Keyham each year.

Note IX.—The effect of this order is to place the officers of the Engineer Branch in exactly the same position as they were in 1902 previous to the introduction of the new scheme.

Note X.—The transferring of the electrical equipment from the Torpedo Branch to the Engineering Branch as foreshadowed in 1921 has not yet taken place, and it appears probable that such a transference will not now be effected.

mand of Artillery, Engineers, Cavalry, Infantry and Dragoons, according to seniority in the *Army*.

II. The Navy.—Can the same condition apply? Now I think in order to maintain full control over your staff technically, a *full* practical training in details of technique as well as theory is essential, otherwise one gets somewhat too dependable on your Subordinate, which is wrong. Can he attain that and get a full, and satisfying to the public, capability of handling a Naval ship, or a fleet, of any size under any conditions of service with considerable upper deck experience. I am not prepared to say that I would trust it to the majority, but to say 10%, if proper arrangements for alternate experience were given and at 30 say a distinct separation to upper deck, I would expect, by careful selection, to get satisfactory results. But if there is any doubt—*Service* must not be left in the least inefficient, even for the person. The *spirit of sacrifice* for Service is the higher ideal of the officer here. But to keep on solid ground I will state as follows:—

(1) It has been recognised and urged by several officers of weight and standing, who have considered the question since the introduction of the Engineering Branch in 1837, that the duties of the Engineer Officers are largely identical with those of the Deck Officer.

(2) Among the duties considered appropriate to the Engineer Officer, which would automatically have devolved on him, had the Selborne-Fisher Scheme of 1902 been allowed to develop are:—

(*a*) Administration of the discipline of the department under the captain of the ship, and entirely if in command of other establishment.

(*b*) Membership of Court Martial.

(*c*) The right, if Senior Officer of a Court of Inquiry, to act as President of the Court.

(*d*) The right to be in command of technical establishments and schools.

(*e*) The right to be considered eligible for Superintendents of Dockyards and contract-built ships.

(*f*) The right to be considered eligible for a seat on the Board of Admiralty.

These points I consider essential and sound.

At present, the Senior Engineer (*i.e.*, the officer next below the Engineer Commander) deals with discipline under the Commander. The whole should be under the Senior Engineer *Officer* of the ship responsible only to the Captain.

Three other points I would suggest:—

As the Engineer Officer is to all intents as essential to the fighting machine as the Deck Officer and has, in spite of the denial of administrative powers of discipline, to assume that power whenever he is in the department and then on all occasions. Accident to ship—engagement with enemy, or at any time to control his men; he should be meted the same courtesies as apply to the upper deck.

I. To be piped up the side, rank for rank, with the Upper Deck Officers.

II. To take precedency in all places, except in command of ship, with the Upper Deck Officer, *i.e.*, as Senior N.O., where no actual officer of equal or higher rank in command is present to represent the Navy.

III. That no distinction mark be worn—it is an invidious distinction in his case as an Executive Officer. The Gunnery Officer and the Torpedo Officer and Navigator are not so decorated or marked. All three technical heads, the first two doing practically no upper deck duties as watchkeepers for years. Why place a distinctive mark on one without placing it on the others?

(3) The idea now in force that officers cannot carry out the duties of high command at sea and at the same time be specialists in engineering may possibly be accepted as I have just stated, but this does not in any way affect the fact that the duties above mentioned are legitimately amongst the duties of Engineer Officers, nor does it make it less essential that Deck and Engineer Officers should be entered from similar sources.

(4) The "*Common Entry*" system is seriously jeopardised by the recent order, and in fact the abolition of the "Common Entry" is quite seriously advanced by a certain school of thought under the mistaken idea that the Engineer Officer entering from a lower social standing will be content to take a secondary place all through their careers. *Nothing could be further from the teaching of all history*, and particularly of the British race.

(5) In 1915 the old style Engineer Officer was recognised as part of the Military Branch and given the Executive "*Curl*," while retaining the distinctive purple between the stripes. In 1919 the "Curl" was given to all officers (medical and accountant, etc.) thus in part reducing the effective recognition of the Engineer Officer as one of the two branches essential to the fighting of the ship—Executive and Engineer.

(6) Now in 1925 the New Scheme Engineer or (E) Officer, already in 1920 rendered ineligible to succeed to command of a sea-going ship, is, by the new Order informed that:—

(*a*) The Military Branch which linked together the Deck Officer and Engineer Officer as the two indispensable for the working and fighting of the ship, is abolished.

(*b*) He must wear a distinguishing mark on his uniform, which groups him with those officers not indispensable for the working of the ship, and is contrary to the uniform regulations under which he volunteered.

(7) The logical result of the new Order would therefore appear to be that the rights mentioned in para. 2, which would have come into operation in due course, are now precluded, and all the promise and inducements to volunteering for these officers who have already volunteered for (E), will come to nothing.

(8) The whole aspect of engineering in the Service in its most complete sense needs close and unbiassed consideration. The institution of the Selborne-Fisher Scheme was not only to improve the engineroom department—it recognised that the efficiency of the Service, its maintenance, and its operation in war, depended fundamentally on a proper appreciation of engineering.

(9) In 1922 the Admiralty Order (No. 3333) foreshadowed the transfer of the electrical power and machines of the ship to the engineering department. This was logical and could and would have led ultimately to increased efficiency and economy by centralising workshops and staff.

By the new Order a separate branch of Electrical Engineers is to be formed, who will serve afloat as juniors only, presumably under the Torpedo Officer to whom they will act as civil or technical advisers. This scheme can only lead to unsatisfactory results, it will not help collaboration amongst officers and men, and will add greatly to the cost of maintenance of the Fleet.

(10) The war showed that certain problems which are engineering problems, viz., guns, torpedoes, mines, searchlights, departments in which the higher skilled and experienced engineer had an inadequate field of control and experiment, were inferior to those of the enemy.

(11) On the other hand the propulsion of our ships and reliability for service were greatly superior to the enemy, and met far greater demands, and it is to be noted that the German High Naval Authority treated his engineers as men of an inferior status, in much the same way as the logical result of the new Orders would lead to a domination over ours. It will also be remembered *that the break up of morale and discipline* in the German Fleet started in the higher ranks of the engineroom personnel. It is further most important to remember that mechanics are notoriously men difficult to handle, not amenable to the type of discipline usual to parade ground or quarter deck. They can only be well handled by the best type of Engineer Officer—*quick in judgment and decision, both in handling of men and machinery—a master of his profession to whom they can look for sympathy and a thorough appreciation.* These men are British, they have the Britishers innate sense of fair play—their discipline is not that of the barrack square of old time—it is that of their work and their workshop, and they can only be kept in the right way by the right type of officer.

It will not help the morale and discipline of these men to see their officers getting anything but a square deal.

From "The Times," March 24th :—

NAVAL ENGINEERS.

Sir,—The deputation of distinguished engineers who, as the chosen representatives of our great engineering institutions, waited upon the First Lord of the Admiralty to protest against the Fleet Order of last November, have done well to publish their memorandum. It is evident that neither Mr. Bridgeman nor the Board have any true idea of the bitter feelings of injustice their action has engendered, and if the battle for status has to be fought over again it is right the facts should be widely known. For Mr. Bridgeman to suggest there is nothing derogatory to the position of the engineer officers in the deprivation they have suffered convinces no one. The older officers who had to fight long and hard for adequate recognition are in no doubt about the matter, while the younger officers have lost far more than they have. But in these days, when it is essential that the engineering branch of the Navy should be at its highest efficieincy, surely it would have been wiser to strengthen its hands and not to weaken them.

In your issue of March 12th, in the next column to that in which you published a part of the memorandum, you gave an account of the visit of his Majesty the King to the Headquarters of the Royal Engineers at Chatham. That signal honour was paid to a corps whose importance to the Army is not one whit greater than the importance of the engineers to the Navy. But whoever heard of the engineering *personnel* of the Army being treated in the same way as the engineers of the Navy? When have they been driven to ask to be given executive authority or to be endowed with disciplinary powers?

Probably few of your readers are familiar with the story of the rise of the engineering corps of the Navy and the undying antipathy it has had to struggle against. The treatment of the naval engineering *personnel* question was once described in your columns by Sir Edward Reed as a blot on naval administration, and a blot apparently it is to remain. You may search the records right back to the days when the little steam sloops, the *Dee* and *Rhadamanthus*, were used to blockade the Dutch coast, but you will find no single instance where the question has been dealt with on its merits in a broad, wise, and statesmanlike manner. Yet, for all that, the records contain no such piece of folly as the order of last November.

There could be only one justification for the reversal of the decrees which conferred military status on engineer officers. If the order of November was calculated to assist the engineering branch to attain a higher standard in the performance of its duties, there might have been reason in its promulgation, but even Mr. Bridgeman has not suggested it will result in that.

Yours faithfully,

EDGAR C. SMITH, Engr. Captain, R.N. (retired).

Riddleswood, Purley.

The following letters are from "The Times" of April 6th and 9th respectively:—

Sir,—In the penultimate sentence of your article of March 25th on the status of engineer officers you ask, What harm could be done to the Navy by recognising engineer officers as part of the military organisation of the Fleet? May I be permitted to draw attention to certain aspects of the question which as yet do not appear to have received any notice, and ask instead what harm, great and fundamental, may be done not only to the Navy, but to the nation as a whole, if this question is not settled once for all while there is yet time?

You rightly draw attention to the force of sentiment, but, so far, the question raised seems to relate solely to the breaking of promises as they affect engineer officers individually. Is not this a somewhat limited point of view? If the Navy will benefit by the drawing of a hard-and-fast line between the Executive and Engineer Branches and the reversion to the state of affairs of bygone years, then the feelings of the individual must not be considered unduly. But will the Navy benefit by such a reversion, or will instead a lasting blow to efficiency be delivered?

All who have had any contact with the Navy in the past are aware of the feeling of wrong which existed, and the internecine squabbling which took place before the introduction of the Selborne Scheme and the granting of military rank to engineer officers. All this must start again in a form still more acute. What must be the effect? We have given up the preponderance of sea power which the people of this race have instinctively felt essential to their safety; we are still scattered over the face of the earth, and, as far as we can see, the efficiency of whatsoever fleet we may have will for many a long year be the ultimate means of assuring the food supply of these islands, and the mutual safety of the nations which comprise the Empire. We are now in a period of comparative quiet, and, having given the undertakings we have done, the whole question of the Navy resolves itself into maintaining the highest possible standard of efficiency and making the organisation such that the fullest advantage may be taken of the advance of scientific and engineering knowledge to produce the best weapon, together with a close co-ordination to allow that weapon to be used in the most effective manner should the need unhappily arise.

Can this possibly be done in a house which is divided against itself, and the house is divided as long as feelings of wrong are harboured and the sense exists, even if it does not find expression, that one section of the Navy is primarily concerned with the maintenance of its own position of complete power, a quite unnecessary attitude as engineers as such can never command fleets; they have too much to do already and their job will be one of increasing complexity. The wielding of the weapon must always rest with the executive officer of high rank who has spent a lifetime being prepared and preparing himself for this purpose, but will the type of mind best calculated to produce and maintain the most effective mechanism for him to wield be attracted to and be developed in the Engineering Branch under these conditions?

There are other aspects such as the higher posts which should be open to, and in some cases the sole right of, the engineer officer (Admiral Superintendents of the Royal Dockyards, for instance) and representation on the War Staff, where his duty should be not only to initiate developments of the mechanism generally, but to use his special training to endeavour to develop the ideas and produce a weapon in accordance with the desires of the representatives of those who will use it. These questions, however, are closely interwoven with the broader one of defence as a whole.

It is strange to reflect that so much may hang on a strip of purple cloth, but such it is; the stripe is the symbol of what lies underneath and may be taken as the warning of the issues involved. Now is the time to decide what the future is to be. We may rest assured that the Navy will always be relatively efficient, but were we as ready as we might have been in August, 1914, had we had that close co-ordination during the previous 20 years, and can we be as ready without it as we might be if the necessity should arise again?

Just when the Fleet Order was issued attention was called by the Admiralty, through the Commander-in-Chief, Portsmouth, to the sowing of subversive propaganda on the Lower Deck aimed at dividing the men from their officers. Is it not ironical that at such a moment the Admiralty itself should issue an order which tends to divide the officers themselves and keep them divided through the years? How can that needful fraternity between officers and men be maintained at its highest pitch when the men see, as they must see, the cleavage among the officers themselves? The Golden Age of the Navy was that of Nelson and his Band of Brothers. Are we to throw this away or are we to make the modern Navy, so different and yet capable of being so like, again a Band of Brothers? Is this necessary for the Empire as a whole, and will its existence prove detrimental to the interests of any group within the Navy itself, all branches of which now draw their *personnel* from similar sources?

Yours faithfully,

G. H. TURRALL,

Engineer Lieutenant-Commander,
R.N. (retired).

Sir,—Lord Fisher was a man of vision who realised the prominent part engineering must play in the Navy of the future. Facing the facts, he endeavoured to include engineering in the military and executive branch of the Service. All officers were to have some engineering training and those who took up engineering permanently were to be as military and executive as those who undertook deck duties. It was, however, found impracticable to combine engineering and seamanship in one officer owing to the encyclopædic nature of the science of engineering; but under the principle of common entry his ideal of uniting the engineering and executive interests was shaping successfully until the present Board of Admiralty, which does not share his forward view, undid his good work by the issue of its reactionary edict of last November.

In envisaging the situation and taking future precautions against such another set-back, it must be realised that these periodical upheavals are produced by a radical falsity in the constitution of our modern Navy. Hide-bound as it is by tradition and the natural conservatism of the military mind, it is not elastic enough to accommodate itself to modern technical progress. The organisation of the Admiralty is obsolete and being a relic of sailing ship days it readily lends itself to a retrograde policy. The tradition of the Navy, which has inspired such historic deeds of glory, now blinds the eyes of some executive officers in high places. They have not been scientifically trained and their mentality being of a past generation, they cannot readily assimilate the scientific ideal. They will not admit that engineer officers must challenge the supremacy of the deck officers and refuse to be dominated by a non-technical branch.

Science has made such rapid developments that the present engineer officer is immeasurably more important than he was even 25 years ago. The warship of to-day is full of highly scientific and complicated machinery, for which the engineer officer is solely responsible. Its effective maintenance and administration require not only the highest technical qualifications, but the exercise of the executive qualities of command, initiative, rapid decision, and resource, especially in action.

It is just this fact which the present Board of Admiralty refuses to recognise. The Fleet Order of last November is an effort to maintain the authority and prestige of the deck officer, even over those officers who enter Dartmouth with him, and subsequently volunteer for engineering. This traditional state of mind produces repressive schemes which aim at subordinating the engineer branch. It should be noted that the animus displayed against naval engineers extends even to the E.R. artificers, who have been degraded in like manner to their officers—the change in their uniform symbolising the lower status to which they have been relegated.

The attack on the engineering branch made by this Fleet Order has united engineers throughout the country. They will not rest content until they have secured the reinstatement of naval engineers in their former military and executive position. This time the gain must be consolidated. To guard against similar reversions and ensure that naval engineers shall henceforth obtain the recognition to which they are entitled, it is essential that the precaution be taken of stipulating that a representative of the engineering branch be placed on the Board of Admiralty, and that the technical viewpoint shall receive due consideration in the determination of future policy. Until this is granted the status of the engineer officer will never be assured.

Yours faithfully,

J. W. HAM.

Ashton Lodge, Bassett, Southampton.

April 7th.

From "The Times," April 13th:—

A QUESTION TO THE SEA LORDS.

Sir,—In your issue of March 31st, Engineer Rear-Admiral Sheen puts clearly the position of naval engineer officers as affected by the last Fleet Order, and indicates how the engineering branch is lowered in status by it. Outside the Service the question is confused by the term "military status" applied to naval *personnel*. Why military? The word executive or combatant is sufficient to cover all branches except the few Civil Departments of the Fleet.

In 1902 a great advance was made by the introduction of common entry and universal preliminary training at Osborne and Dartmouth. The special training in gunnery, torpedo, navigation, and engineering came afterwards, but the common entry produced good fellowship which had not existed before. The status of the new engineer officers was distinctly raised in accordance with the increased importance of his duties. Why the recent change was made, and what defect, if any, it was intended to remove, I have not found in answers by civilian members of the Admiralty. If one of the Sea Lords would tell us, the general public would be satisfied. The purple stripe is an insignificant detail.

Yours, &c.,

S. EARDLEY-WILMOT, Rear-Admiral (retired).

Hotel du Louvre, Monte Carlo,
April 9th.

From "The Times," April 27th, 1926:—

The First Lord of the Admiralty, in reply to a question, and a supplementary, put to him in the House of Commons last week, on the question of Withdrawal of Military Status from Naval Engineers, replied, "I am always ready to listen to any representations made by Engineer officers, and perhaps the hon. member will tell me what power it is that they have lost which they enjoyed before the Fleet Order to which reference was made was passed." What engineers throughout the country would like to know is, did the First Lord hear any representatives of the Engineering Branch before promulgating the Fleet Order referred to, or was he guided solely by the Board of Admiralty, which has no engineering representative on it? I would like to put a definite question to the First Lord. Does he consider that no power has been lost? If he does so consider, why was the Fleet Order referred to promulgated?

Engineer Captain J. H. H. IRELAND.

3, Sussex Terrace, Southsea.

From "The Times," April 28th, 1926:—

Sir,—Mr. Bridgeman, in answer to a question asked in the House of Commons by Mr. Basil Peto on April 21, said:—

I am always ready to listen to any representations made by Engineer Officers, and perhaps the hon. Member will tell me what power it is they have lost which they enjoyed before the Fleet Order to which reference is made was passed.

As the Speaker intervened and did not permit Mr. Peto to answer, I should like to give the following reply to Mr. Bridgeman's query.

Executive rank for (E) officers, which has now been lost, carries with it:—

(1) Power of departmental command on board ship.

(2) Control of divisional work and charge of Messes for Engine Room ratings.

(3) Equal status with Gunnery, Navigating and Torpedo officers on board ship and ashore. Respect of subordinates and their readiness to obey.

(4) Eligibility to sit on Courts-martial and to preside over Courts of Enquiry, especially where technical offences are concerned.

(5) Command of technical establishments and schools ashore.

(6) Eligibility for higher shore appointments, such as Superintendents of Dockyards and of contract built ships.

(7) Eligibility for seat on Board of Admiralty on reaching the rank of Admiral (E).

(8) Right to sit on all Admiralty Committees dealing with proposals and policy regarding Engineering material and *personnel*.

(9) Charge of all technical work and sole responsibility to the Commanding Officer of the vessel.

(10) Share in honours (Military Division), salutes, ceremonies, civil and foreign functions.

Mr. Bridgeman asserts his readiness to listen to any representations made by engineer officers, but as First Lord of the Admiralty he is surely aware that it is a punishable offence for naval officers to combine and send a representative to him in protest against the Order. The regulations only allow officers to make individual protests through their commanding officers, and this has already been done.

Yours faithfully,

CHARLES C. SHEEN,

Engineer-Rear-Admiral (retired).

Pyrford, Surrey, April 26.

BOILER EXPLOSIONS ACTS, REPORT NO. 2743.—This refers to an explosion which took place in the boiler of the fish carrier *Gael*, January 21st, 1926, when in Loch Fyne. No one was killed; the engineer received a shock and one man was scalded. The boiler was 10ft. diam. x 9ft. long with two furnaces, 3ft. diam., each having a separate combustion chamber. It was built in 1903. The shell was composed of two steel plates extending the full length, the longitudinal seams being double riveted, with double butt straps. The end plates were flanged to connect the shell plates and the furnaces, with a manhole door on the lower part of the front plate. The steam pressure was 130lbs. In September, 1910, the boiler was overhauled, when the furnace bottoms and other parts were made good by welding where corroded. In April, 1920 a further overhaul and reinforcement of reduced parts followed, when the boiler was tested by hydraulic pressure. In 1921 another overhaul of a similar nature was made, and again in 1923, when the flange of the manhole was reinforced by welding. The cause of the explosion was due to corrosion of the front shell plate around the manhole; a part of the plate was blown out making a hole about $1\frac{1}{2}$in. x $\frac{3}{4}$in. through which the water escaped. From the evidence it appeared that the boiler had not been thoroughly and periodically examined by a competent engineer and although repairs had been carried out from time to time with a good deal of expenditure, the part that gave out had been overlooked. A new boiler was fitted. These Reports are valuable as lessons.

BRITISH ENGINEERING STANDARDS COMMITTEE.—An important matter under discussion in connection with screw threads in the possibility and feasibility of adopting a thread which will be a compromise between the Whitworth and the Sellers. It is felt that the adoption of such a thread would be a gain both to this country and to America, if not to the world at large. An invitation to the B.E.S.A. to attend an Anglo-American Conference in New York on this subject has been received from the American Engineering Standards Committee. The pitches of the two standards agree except in two sizes, namely, $\frac{1}{2}$in. and 3in. diameter. The angles differ by 5° and the other principal difference is the rounded top and bottom in the Whitworth as against the flat top and bottom in the Sellers thread. The importance of possible unification between the two so as to make an international thread is obvious. By unification an enormous number of threaded parts of the same kind, bolts, nuts, screws, etc., would then become interchangeable on an international scale, an undoubted advantage all round.

Thomas Gray Memorial Trust Prize for an Improvement in the Science or Practice of Navigation.—Under the terms of the Thomas Gray Memorial Trust the Council of the Royal Society of Arts offer a prize of £50 to any person who may bring to their notice a valuable improvement in the science or practice of navigation proposed or invented by himself in the year 1926 or in the years 1921-5 inclusive. Preference will be given to an invention of 1926. In the event of more than one such improvement being approved, the Council reserve the right of dividing into two or more prizes at their discretion. Competitors must forward their proofs of claim on or before December 31st, 1926, to the Secretary, G. K. Menzies, Royal Society of Arts, John Street, Adelphi, London, W.C.2.

In "Engineering and Boiler House Review" for March, there is an illustrated descriptive article on a new integral hydraulic propeller forcer, for quickly starting a ship's propeller, when such an event falls due to be dealt with, in the course of overhauling or of necessity arising. The apparatus consists of a ram of non-corrosive material, situated in a recess bored in the forward face of the boss. The apparatus requires about 1,000 lbs. pressure by a pump applied to a ram which acts on the boss and slides it off. The object of the apparatus is to save the labour and fittings usually employed to remove the propeller in dry dock.

Titanic Engineering Staff Memorial Fund.—The Committee acknowledge with thanks a donation from F. W. Smith, M.2334 (Singapore, whence he is soon retiring), £1 11s. 6d. The amount received by donations since January 31st, when our year ended, is £10 19s. 1d.

Election of Members.

List of those elected at Council Meeting on April 19th, 1926.

Members.

Howard Denovan Adam, Oakcroft, Chalk Hill Road, Wembley Park, Middlesex.
George Frederick Aris, *c/o* A. B. Aris, Esq., Belvidere House, Shrewsbury.
George Blackler, Blakemore, Totnes, Devon.
John Cowley, 14, Beaumont Terrace, Spennymoor, Durham.
Allan Hunter Doeg, 37, Leicester Road, Wanstead, E.11.
George Edward Hendrie, 9, Oakfield Avenue, Hillhead, Glasgow.
John Anderson Hunter, 5, Edenpark Road, Birkenhead.
Wilfred Augustus Jaques, 91, Brownlow Road, Horwich, Lancs.
James Ramsay, 34, Brougham Street, Greenock, N.B.
Thomas Niven Rennie, *c/o* Shanghai Dock and Eng. Co., Ltd., Shanghai, China.
Andrew Grieve Stuart, *c/o* Messrs. Butterfield & Swire, Shanghai.
John Toomne Roberts, Engr.-Lieut., R.N., H.M.S. *Vampire*, Mediterranean Fleet, *c/o* G.P.O., London.

Associate-Members.

Thomas Craig English, 70, Rugby Road, Belfast.
Ferdinand Robert William Runge, 40, Ashburnham Grove, Greenwich, S.E.10.

Associate.

Thomas Heddon Hancock, 5, Argyle Place, Clifton, Bristol.

Graduates.

James Tod Carnaghan, *c/o* Fletcher, 2, Wellington Street, Greenock, Scotland.
Robert Marshall Knox, 3, Lothair Avenue, Belfast.

Transferred from Associate-Member to Member.

Arnold James Curtis, 301, High Street, Sheerness.

John H. Albertini, 50, Killieser Avenue, Streatham, S.W.2, elected an Associate on the 12th January, 1926, confirmed 31st March.