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"Notes on the Lentz Standard Marine Engine as Fitted to Ships of the Koninklyke Paketvaart Maatschappy."

BY MR. W. J. MULLER,

READ

Tuesday, May 7, 1929, *at* 6.30 *p.m.*

CHAIRMAN: Mr. R. T. WILSON (Chairman of Council).

The CHAIRMAN: I have much pleasure in introducing to you Mr. Muller, Chief Superintendent Engineer of the Dutch Royal Packet Line, who has come over from Amsterdam to read his paper on the Lentz standard marine engine, which he has very kindly prepared at the request of the Council.

I am sure you will all be very much interested in the subject matter of his paper, as the Lentz engine may claim the distinction of being the best known of the various new types of marine reciprocating steam engine which have been developed in recent years. Mr. Muller's account of the engine and its service performance in the ships of his Company will no doubt have been eagerly awaited by all who are present and by many of our members who are not privileged to be here this evening.

I will now ask Mr. Muller to read his paper.

In response to a request from the Council of this Institute to read a paper on the Lentz standard marine engine, I have thought that it might be of interest to give a few results from practical experience with this new type of engine, which has only been developed in the last seven or eight years, and of which a fairly large number has been installed on board ships of the Koninklyke Paketvaart Maatschappy of Amsterdam. Before doing so I want to say something about the principal reasons which have led to an experiment by the K.P.M. with the Lentz engine on such a comparatively large scale.

In 1924 the board of directors of the K.P.M. decided to enlarge their fleet plying in the Dutch East-Indian Archipelago with a large number of vessels of different size and speed. It was obvious that, on doing so, there would be an advantage in dividing the vessels into certain classes of uniform ships and therefore to standardise the ships and the machinery equipment as far as possible. Besides a number of other ships with different types of engines, 23 steamships, one twin screw passenger steamer included, with 24 steam engines in all, were to be built, according to the programme of 1924, in the course of five years.

Now in the beginning of 1924 we had an opportunity personally to make a trip in the steamer *Bilbao* of the Oldenburg-Portuguese Shipping Co. of Hamburg, which vessel must be regarded as being the first ship equipped with a Lentz standard marine engine. As a result of this trip, of the performances of the main engine and of the good results as regards coal consumption and costs for upkeep and repairs, we have then more closely considered the application of the Lentz standard marine engine on a number of K.P.M. vessels, as the following principal advantages could be obtained by doing so:

1. Superheated steam could be introduced with less risk than if ordinary slide-valve engines were fitted, the K.P.M. having installed no superheated steam engines previously.

2. Standardisation of the engines (which would affect the manufacturing cost as well as the cost for upkeep and the number of spare parts) would be easier when starting with a new type of engine than if ordinary slide-valve engines, the design of which is dependent on the ideas of the various engineering works, were to be installed.

3. There would be a saving even if compared with ordinary superheated steam engines fitted with slide valves, according to the results of the *Bilbao* and to the expectation of the designers.

Furthermore, the *Bilbao* engine had shown that manœuvring was remarkably simple, and took very little time even without the aid of a steam driven reversing engine. Last, but not least, the general design of the Lentz engine, besides being simple, showed its suitability for totally enclosing the running gear for the purpose of introducing forced lubrication, in order to diminish the wear and therefore lower the costs for upkeep and repairs, which are comparatively high in the East Indies as compared with Europe.

With regard to the three principal advantages mentioned above, I feel obliged to give an explanation so far as the first is concerned. It will be understood that with the risks which may be run by the application of superheated steam, only the risks in connection with the *boilers* are meant, and although enough experience had been collected by shipping companies who had installed superheated steam engines and Scotch boilers, the number of ships fitted with reciprocating superheated steam engines and water-tube boilers was, and is still, comparatively small. The K.P.M., having decided in 1919 for various reasons, which cannot be dealt with in this paper, to instal water-tube boilers in all the steamships to be built in future instead of the old Scotch boilers, we were compelled to consider more particularly the consequences of the introduction of superheated steam with regard to the boilers, as these would have to deal with feed water containing far more lubricating oil than is necessary for saturated steam engines. In this respect the Lentz engine with poppet-valves possessed some positive advantages over the slide-valve reciprocating engine, and thus it was decided in 1924 that five ships, to be followed later on by eighteen more ships, were to be installed with Lentz standard marine engines. For this purpose the K.P.M. bought the patent rights for the application of this type of engine on the Company's own ships from Messrs. W. Salge & Co., Berlin, owners of the Lentz patent rights as far as the Lentz standard marine engine is concerned, in order to be free to have the engines built by any engine maker in Holland.

The Lentz standard marine engine has been made in six standard sizes, ranging from 400 i.h.p. to 3,700 i.h.p., of which the principal particulars are given in table I. From this it may be seen that the ratio of the H.P. and L.P. cylinder volumes is about 1:4·6, and the total expansion of the steam in both the cylinders varies from 15·3 to 11, the clearance volumes of the cylinders not being considered, depending on the admission of the steam in the H.P. cylinder, which may be varied from 30-42% of the stroke.

TABLE I.

Size	Dimensions.	Admission of the steam in H.P. cyl.	I.H.P.	Revs. per min.	*Estimated steam consumption per I.H.P. per hour.
7	2 × 325 × 700 mm. dia. / 700 mm. stroke.	30-42%	400-1,000	70-140	4·2-4·42 kg. (9·26-9·74 lb.)
8	2 × 370 × 800 mm. dia. / 800 mm. stroke.	30-42%	550-1,400	70-130	4·2-4·42 kg. (9·26-9·74 lb.)
9	2 × 420 × 900 mm. dia. / 900 mm. stroke.	30-42%	800-1,900	70-120	4·16-4·38 kg. (9·17-9·65 lb.)
10	2 × 465 × 1,000 mm. dia. / 1,000 mm. stroke.	30-42%	1,100-2,300	70-110	4·16-4·38 kg. (9·17-9·65 lb.)
11	2 × 510 × 1,100 mm. dia. / 1,100 mm. stroke.	30-42%	1,450-3,100	70-110	4·12-4·34 kg. (9·08-9·56 lb.)
12	2 × 560 × 1,200 mm. dia. / 1,200 mm. stroke.	30-42%	1,900-3,700	70-100	4·09-4·3 kg. (9·02-9·48 lb.)

*Assuming { 14·5 kg./cm^2 = 206·2 lb./sq″ boiler pressure.
325° C = 617° F steam temperature, and
90-92% vacuum.

I will now try to give a brief description of the general design. The Lentz standard marine engine consists of two entirely separated halves, each forming a complete and self-contained two-cylinder two-crank compound steam engine, which halves are interconnected only by the crankshaft. The two H.P. cylinders are placed in the centre, one L.P. cylinder is placed forward and one aft. The steam after having passed the main stop valve is divided into *four* flows, two for the forward engine-half (one for top-side and one for bottom-side of the cylinders) and two in a similar way for the aft engine-half.

The steam passages are formed by ducts, which are placed so that the steam always passes in the same direction.

For steam distribution there are altogether twelve independent valves, i.e., three for top-side and three for bottom-side, for each engine-half:

the H.P. inlet valves (A),
the H.P. exhaust; also L.P. inlet valves (B),
the L.P. exhaust valves (C).

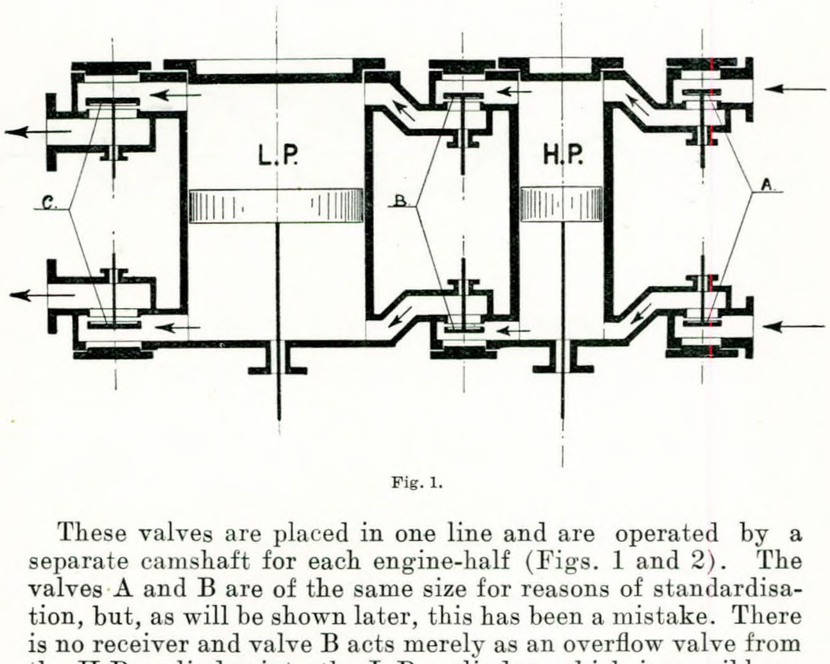


Fig. 1.

These valves are placed in one line and are operated by a separate camshaft for each engine-half (Figs. 1 and 2). The valves A and B are of the same size for reasons of standardisation, but, as will be shown later, this has been a mistake. There is no receiver and valve B acts merely as an overflow valve from the H.P. cylinder into the L.P. cylinder, which is possible as the two cranks belonging to the same engine-half are placed at 180°, so that the exhaust of the H.P. cylinder, top-side, may coincide with the admission of steam to the L.P. cylinder, top-side, and similarly for the bottom-side.

As mentioned before, the cranks of each engine-half are placed opposite each other, whereas the cranks of one engine-half are placed at right angles with regard to the other engine half, so as to afford regular working and certainty of manœuvring, but as a consequence the system is not balanced, either statically or dynamically. It is, however, possible to fit counterweights to the crank webs, which has been done in the largest size (No. 12) only.

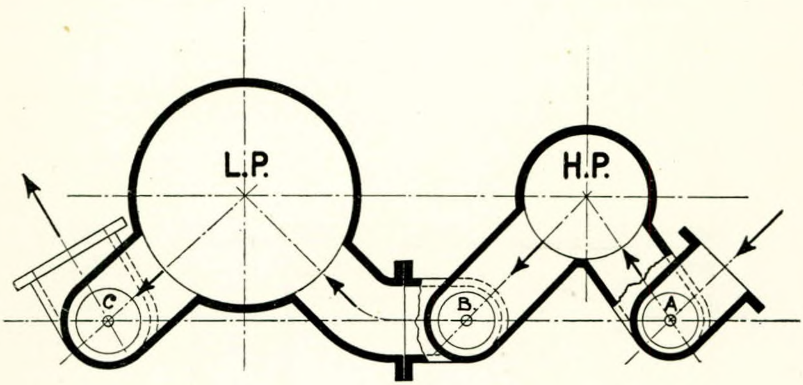


Fig. 2

Fig. 3 gives a section of the H.P. cylinder (1) with valve chests (2) and valves (3), and also shows the position of the camshaft (4) and cams (5). The valves are placed in valve cages (6), fitted in the casting with two seats and kept to its place by the valve chest covers (7) and by bolts (8), to ensure perfect tightening. The valves are of the balanced double-beat type and are held down to the seatings by means of separate spindles (9) provided with springs (10). The valve spindles are actuated by separate tappets with rollers, also called *compensators*, and by this arrangement correct alignment of the valve mechanism is ensured. The compensators also serve to eliminate faults in the adjusting of the valve gear, caused by the rise of temperature of the engine when running. (Fig. 4).

The valves are made of high grade cast iron (Perlit) annealed to a temperature of about 400° C. (752° F.). The grooved valve-spindles are of stainless steel, ground into cast iron liners and fitted in the usual way without any packing or stuffing box. The cams and rollers are of case-hardened steel. The compensator works in a bronze bush and is provided with a weak spring so as to keep the roller off the cam during the period when the cam does not operate the valve. As regards the oscillating camshafts, there is one for each engine-half, working in roller bearings and each operating three top valves and three bottom valves.

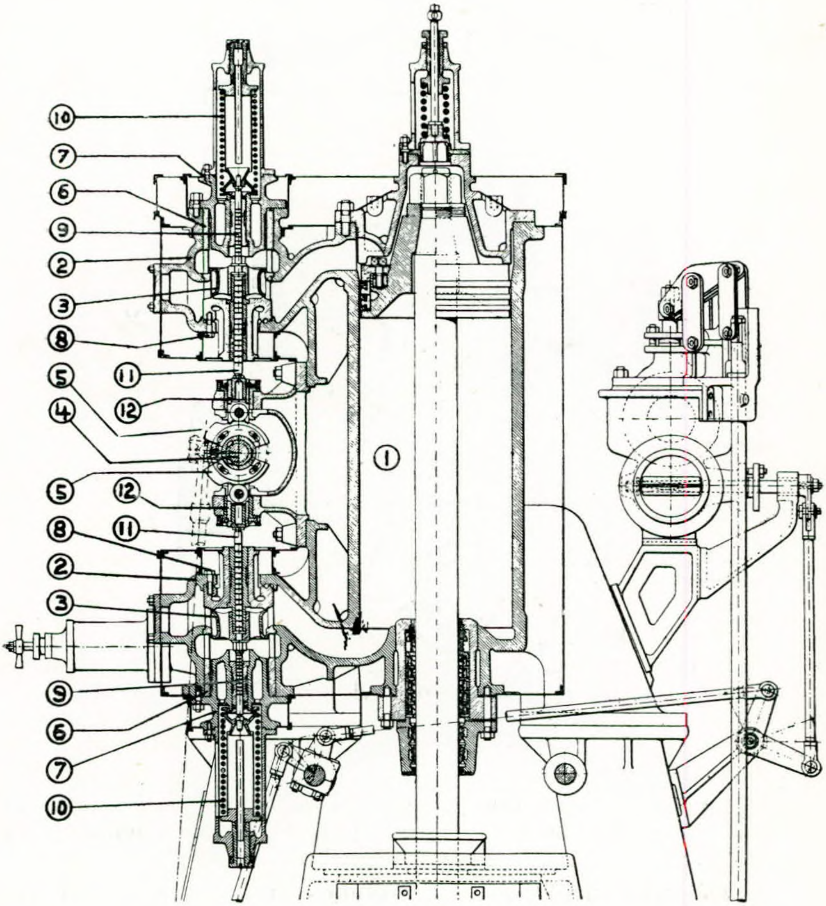


Fig. 3

The link motion is of the Klug type and has much resemblance to the Hackworth link motion, which is perhaps better known in this country. The latter has been fitted to the engine of the SS. *Bilbao*. For reasons of practical design the Hack-

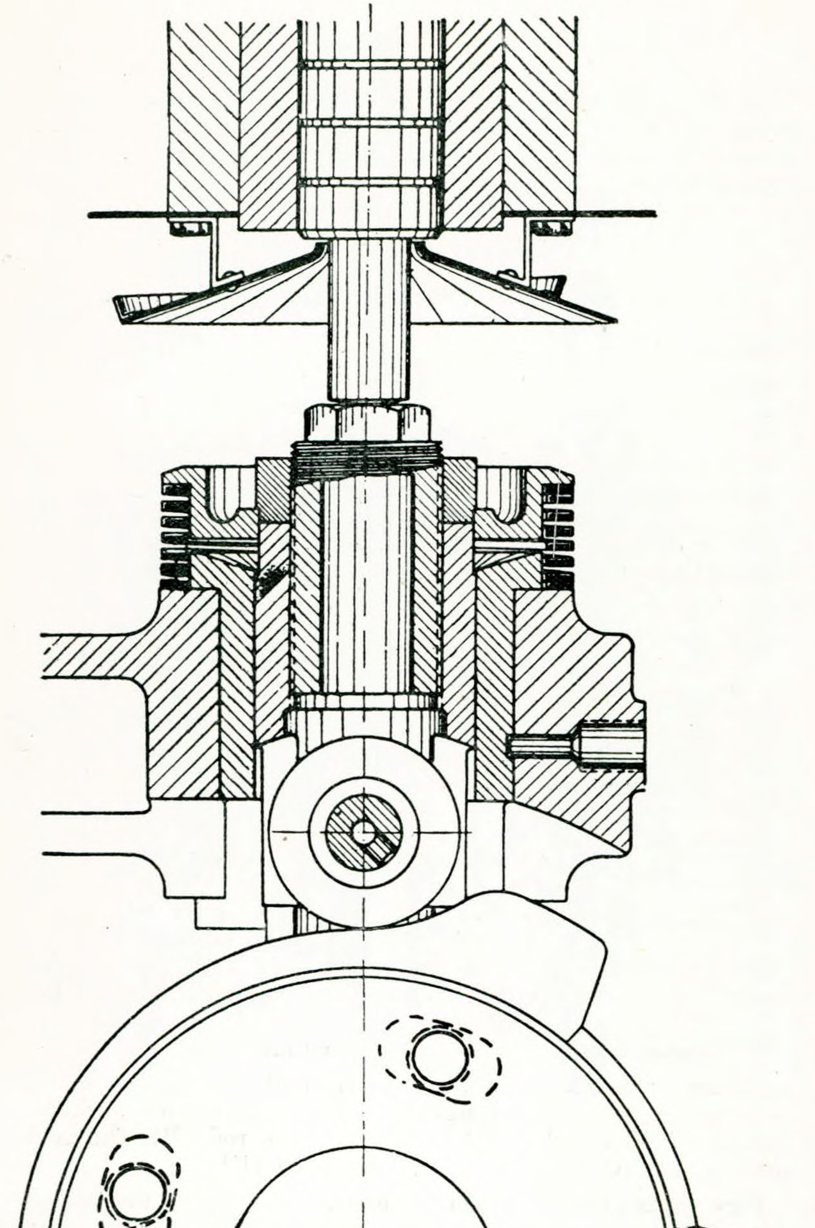


Fig. 4

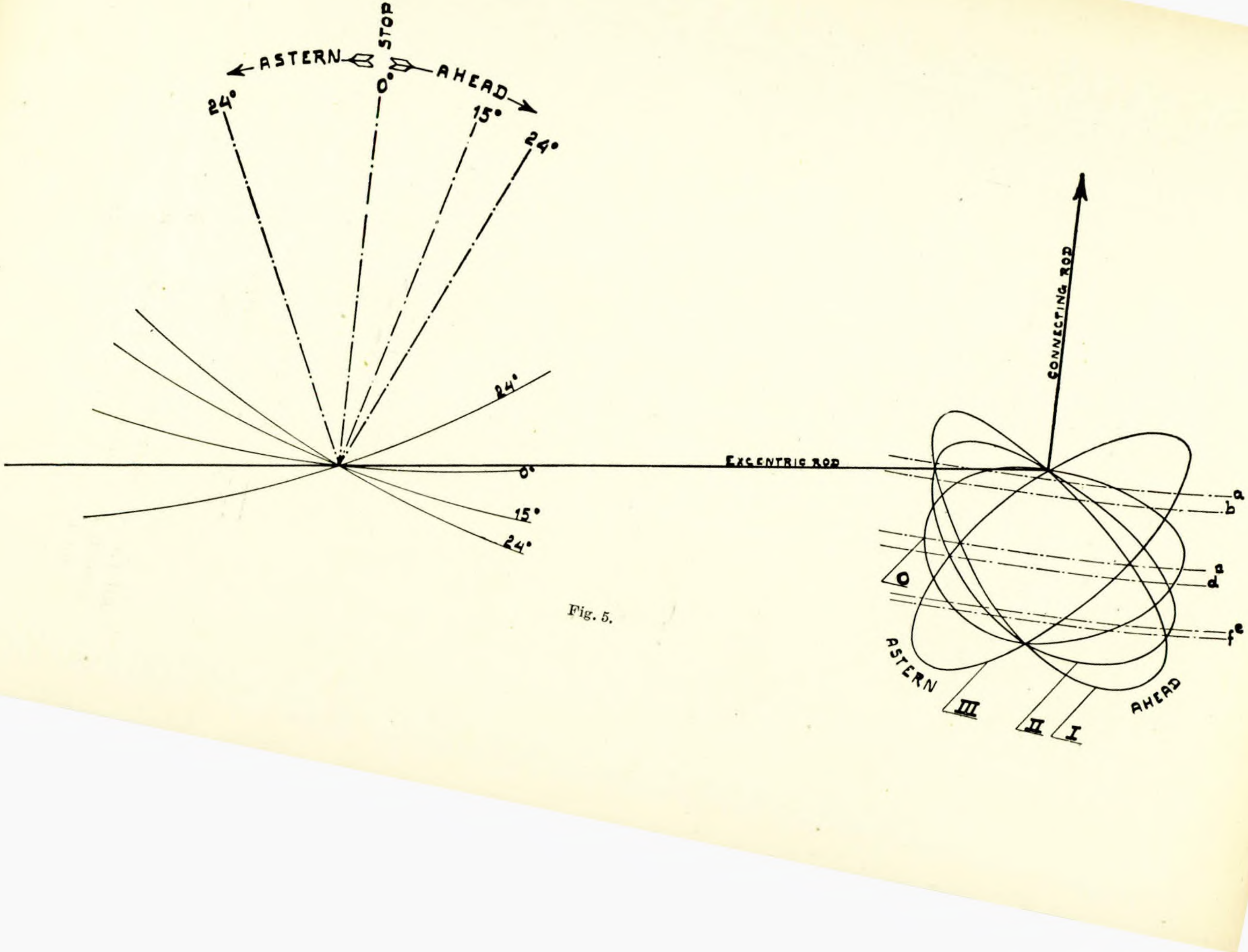
worth motion has now been replaced by the Klug motion, although the former has some advantages as regards equal steam distribution for top and bottom sides.

Fig. 5 shows the curves of the "Klug" gear for different positions of the link motion; curve *O* shows the movement of the gear in the central (stop) position, curve I for manœuvring full speed ahead (gear at + 24°), curve II for normal speed ahead (gear linked up at + 15°), curve III for manœuvring full speed astern (gear at − 24°). The intersections of these curves with the lines a, b, c, d, e and f give the points in which the cams are just beginning or finishing to lift respectively: H.P. inlet valve top-side (a), H.P. exhaust valve bottom-side and L.P. inlet valve bottom-side (b), L.P. exhaust valve bottom-side (c), L.P. exhaust valve top-side (d), H.P. inlet valve bottom-side (e), H.P exhaust valve top-side and L.P. inlet valve top-side (f). As may be seen from this diagram, in the stop position of the gear the cams still lift the valves, although very little, unlike Diesel engine gears, in which no valves are lifted in the stop position of the gear. An advantage of this gear, which is worked easily by hand, even for the biggest size of engine yet made, is that it is not necessary to shut off the steam when manœuvring from full speed ahead to full speed astern, and recent trials with a 1,600 I.H.P. engine running at 100 r.p.m. and giving the ship a speed of about 10 knots, have proved that it is possible under such circumstances to reverse the engine actually from full speed ahead to full speed astern in about six seconds.

The diagrams given in Fig. 6 show the lift of the valves of a No. 8 standard engine during the stroke of the pistons for three different positions of the reversing gear, viz., notched up (at + 15°) for normal speed ahead, in the stop position (0°) and for manœuvring full speed astern (− 24°). As will be seen, the way in which the valves are lifted is not the same for top and bottom valves, which of course must affect the form of the indicator diagrams, as will be shown later on.

Figure 7 gives a vertical section through the whole engine, showing the complete arrangement of the link motion with the manœuvring handwheel (A), the eccentric rod (B), the connecting rods (C and D), and the camshaft (E).

Figure 8 is partially a section through the engine, partially a side view, showing the position of the cylinders, valves, camshafts and the manœuvring panel with manœuvring handwheel



ASTERN
STOP
AHEAD
24°
0°
15°
24°
24°
0°
15°
24°
EXCENTRIC ROD
CONNECTING ROD
a
b
c
d
e
f
O
ASTERN
III
II
I
AHEAD

Fig. 5.

(A), telegraph (F), main stop-valve handwheel (G), speed-meter (H), direction indicator (I), link motion indicator (K), throttle valve (L), the pressure and temperature gauges (M)

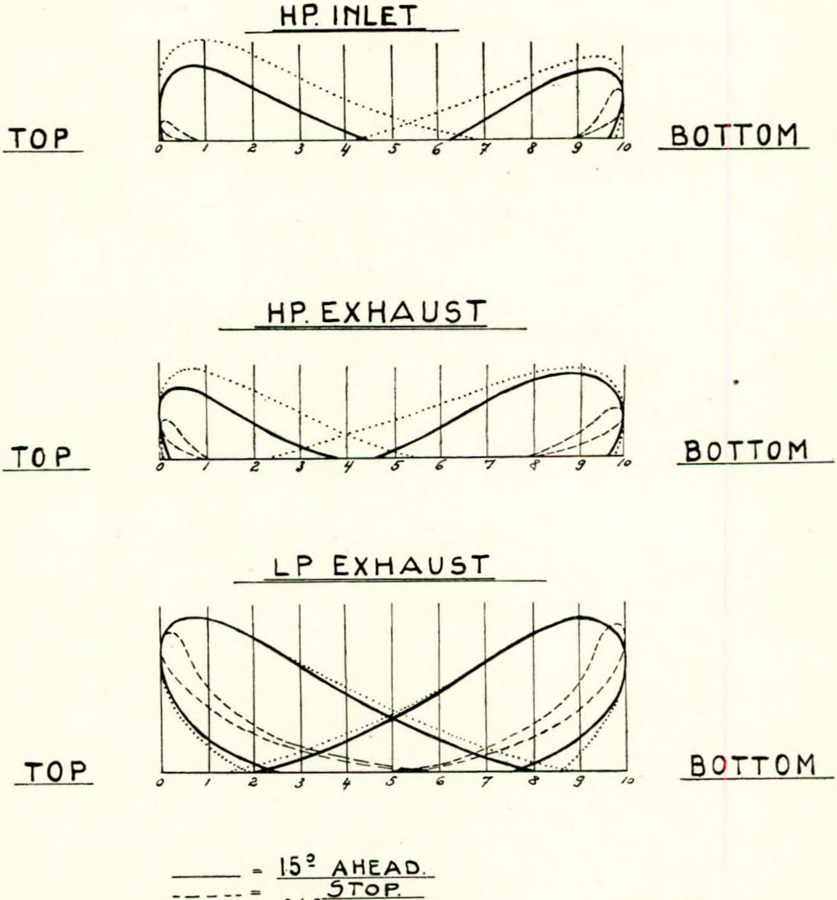


Fig. 6.

and the cylinder lubricators (N). From this view may also be seen how the engine has been enclosed, leaving open only the part directly under the cylinders, in order to make the piston rods and bottom valve springs and covers accessible.

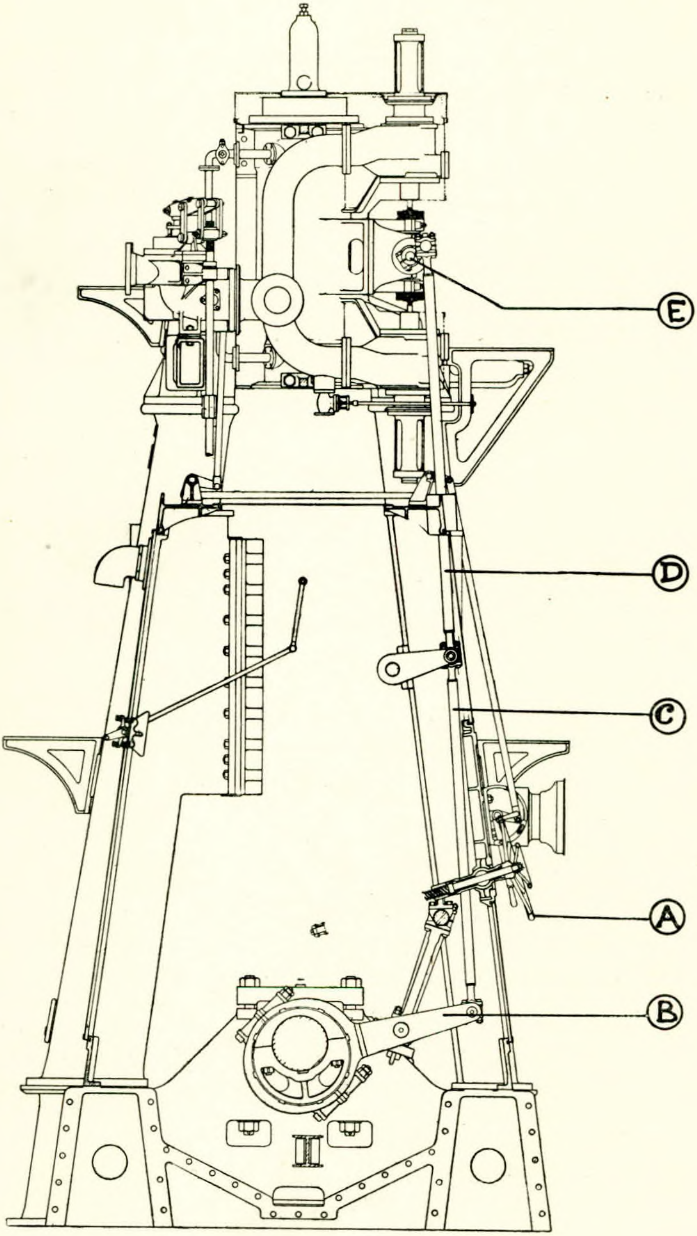


Fig. 7.

Figure 9 gives a top view of the cylinders (left side) with the main stop valve (O) and the live steam pipes (P) from the

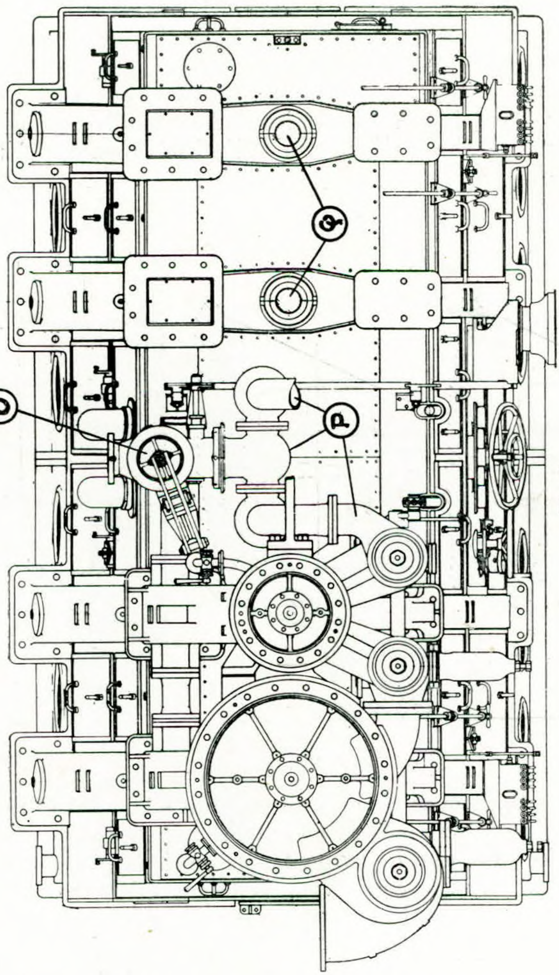


Fig. 9

stop valve to the H.P. inlet valves; and also, on the right side, a view on top of the engine casing showing the openings (Q) through which the piston rods pass.

About the general design of the engine there is not much more to be said, but I should like to refer briefly to the piston rod stuffing boxes, the h.p. piston rings and the system of cylinder lubrication, three details which deserve special attention when superheated steam is used. As a matter of fact, the only important trouble experienced with the first Lentz standard engines on board K.P.M. ships has been the rapid wear of piston rings, causing leakage of steam and therefore also a high steam-consumption. Figure 10 shows the type of rings originally fitted in the first ships, being ordinary Ramsbottom piston rings of the well known "limited pressure" type (a),

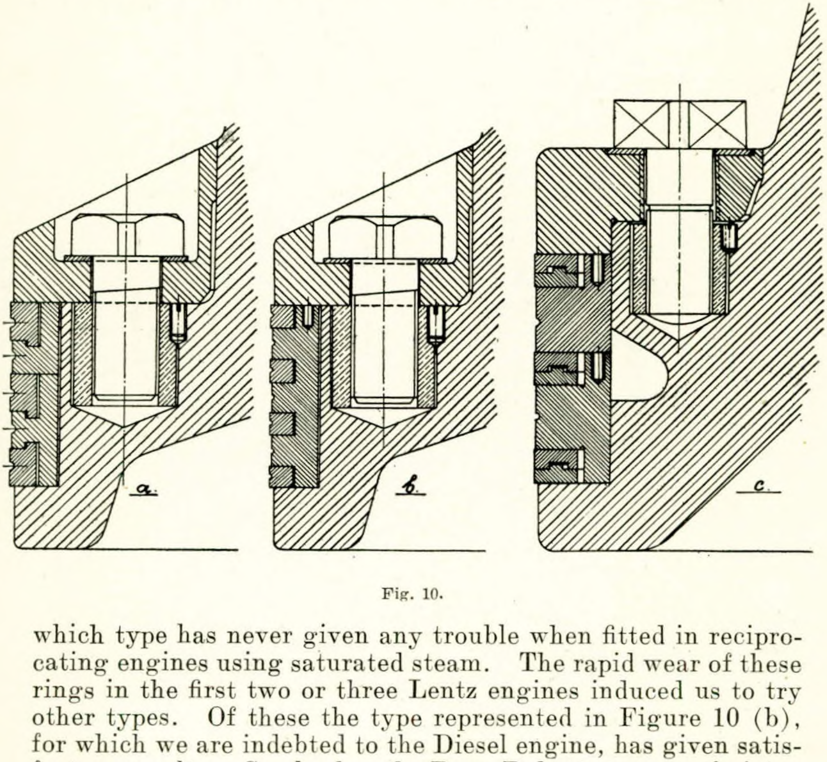


Fig. 10.

which type has never given any trouble when fitted in reciprocating engines using saturated steam. The rapid wear of these rings in the first two or three Lentz engines induced us to try other types. Of these the type represented in Figure 10 (b), for which we are indebted to the Diesel engine, has given satisfactory results. So also has the Davy Robertson type of piston rings shown in Figure 10 (c), especially in one case where the H.P. cylinders had been made of Perlit cast-iron. In the L.P. cylinders, Ramsbottom and Lockwood & Carlisle piston rings have been tried, both with satisfactory results.

The stuffing boxes shown in Figure 3 are of the multiple ring type, each ring being divided into four parts. In the first engines, rings made of nickel-bronze have been employed, but these have been replaced in the later engines by close-grained cast-iron rings of the Kreisinger type (Figure 11) with tangential cuts, allowing all the four parts to remain tightly fitted to the piston-rod, even when wear has occurred.

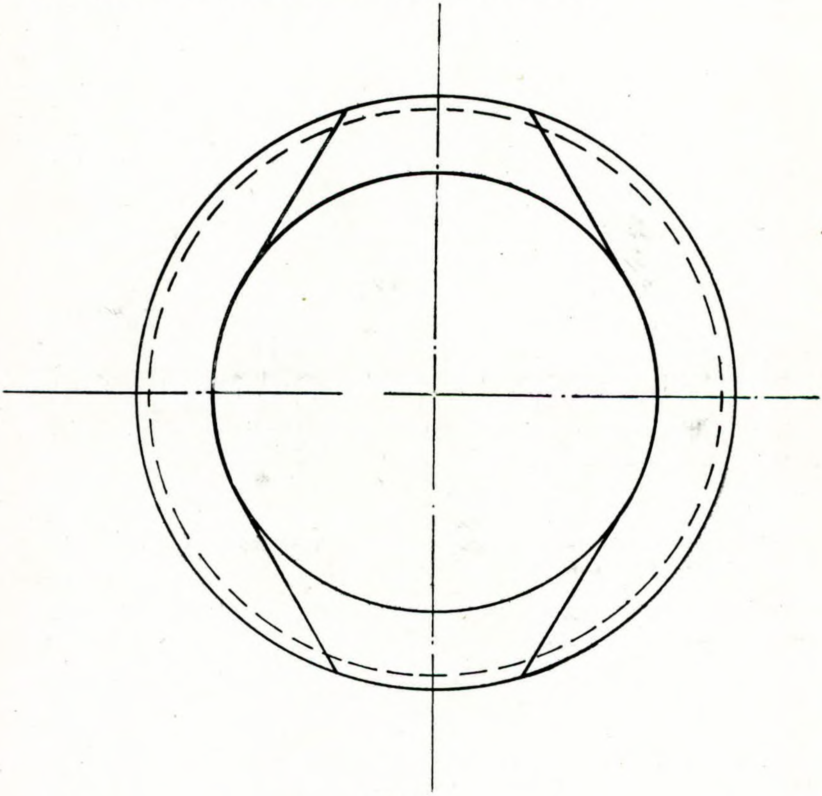


Fig. 11

As regards the lubrication of the cylinders, I have tried two systems and at this moment it cannot be said which of the two is superior. The first one tried is the ordinary system with an atomiser in the live steam line to the cylinders, which system is perhaps the better, so far as lubrication is concerned, but a drawback is that the greater part of the oil used remains in the vapour and does not even touch the cylinder walls, but is simply blown into the condenser. Also it would seem more sensible to lubricate a surface rather than a volume!

For that reason I have tried the other system of lubrication, by means of small holes in the cylinder wall through which the oil is brought into the cylinder, which has also been borrowed from the Diesel engine, and a number of Lentz engines of the K.P.M. have been fitted with this system of lubrication, the h.p. cylinders being lubricated at three points at half-stroke, and, in a similar way, the L.P. cylinders at four points. We have reasons to believe that with the latter system less oil is required for proper lubrication than with the atomiser system, and we have found that from 0·5—0·75 kg. (1·1—1·7 lb.) per 1,000 I.H.P. is sufficient when using the last mentioned system, whereas with atomisers $\frac{3}{4}$—1 kg. (1·7—2·2 lb.) are wanted for 1,000 I.H.P.

In connection with the question of lubrication I wish to mention that a recent trial with Lockwood & Carlisle piston rings fitted in the H.P. cylinders has not proved to be a success, so that we have been obliged to remove these rings and once more fit the Diesel engine type with four small rings; this experience, however, may have been influenced by the system of lubrication through holes in the cylinder wall, which perhaps may not be suitable when using Lockwood & Carlisle's piston rings, which, we have heard, have been tried successfully on other superheated steam engines. The lubricators used for the cylinders and H.P. piston rods are of the "Delvac" type, supplied by the Vacuum Oil Company, which have been shown in Figure 8.

As far as the general design of the Lentz standard marine engine for the K.P.M. vessels is concerned, I have only to add that this design differs from the original design of Messrs. W. Salge & Co., in that the engines made according to the latter design are not forced lubricated and therefore are not enclosed. Furthermore, Messrs. Salge do not use valve cages and have a slightly different design of valve spindles and valve chests. Generally speaking the K.P.M. engines are also of a more sturdy and heavier design, but as far as the valve gear and valve motion are concerned, we have followed the lines of Messrs. Salge's design with the exception of the cams, which we have altered slightly, according to our own practice.

Now I would like to say something about the action of the steam in the cylinders. As is known, in the Lentz standard engine the original principle of Woolfe's compound steam engine has been adopted, i.e., the steam from the H.P. cylinder flows to the L.P. cylinder, passing only one (overflow) valve, the difference with the Lentz engine being that the pistons in the H.P. and L.P. cylinders work oppositely, so that the steam at the top-side of the H.P. cylinder is also used for the top-side of the L.P. cylinder, and similarly for the bottom sides.

As mentioned before, the rate of expansion of the steam varies from 15·3 to 11, according to the cut-off of the steam in the cylinders.

In connection with this I should like to quote here a few lines from a book which has been written more than 100 years ago by Robert Stuart, entitled "A descriptive history of the steam engine," in which may be read on page 169:

"In practice (however) it has been found that the best proportion between the cylinders is to allow of an expansion of from six to nine times, being the rate of expansion as stated by Mr. Woolfe; above nine times being considered (at present) somewhat problematical!"

From this we may conclude that there have been made improvements in engineering since 1825, but also that "Mr. Woolfe" in his time must have had rather advanced ideas as regards the possibilities of the steam engine!

As regards the steam pressure which is generally used for Lentz standard marine engines it is about 14 kg./cm.^{2} = about 200 lb./sq. in. at the engine stop valve.

In Figure 12 a few diagrams, taken recently from a No. 8 engine during the measured mile trials of the ship, are shown. The first four are diagrams at full speed, the engine running at 105 r.p.m. and developing 1,050 I.H.P. with an average cut-off in the H.P. cylinders of 40%, the valve gear being linked up at $+16^\circ$. The second four are diagrams at a lower speed, the engine developing 820 I.H.P. at 97 r.p.m., with an average cut-off of 30%, the valve gear being linked up at $+12^\circ$. From these diagrams it will be seen that there is a remarkable difference in the horse-power developed by the H.P. and L.P. cylinders, a property common to all Lentz standard marine engines, which is due to the ratio of the cylinders originally chosen.

The difference in the form of the diagrams for top and bottom may also be seen, this being caused by the Klug link motion. In this respect the H.P. diagrams for full speed show the most remarkable differences, also as regards the pressure of the exhaust steam at top and bottom sides, which is slightly higher on the bottom-side than on the top. In Figure 13 one set of the above-mentioned diagrams is shown for the same pressure scale, and from these diagrams may be seen the effect of the resistance in the overflow valve between the H.P. and L.P. cylinders on the pressure of the steam, indicated by the

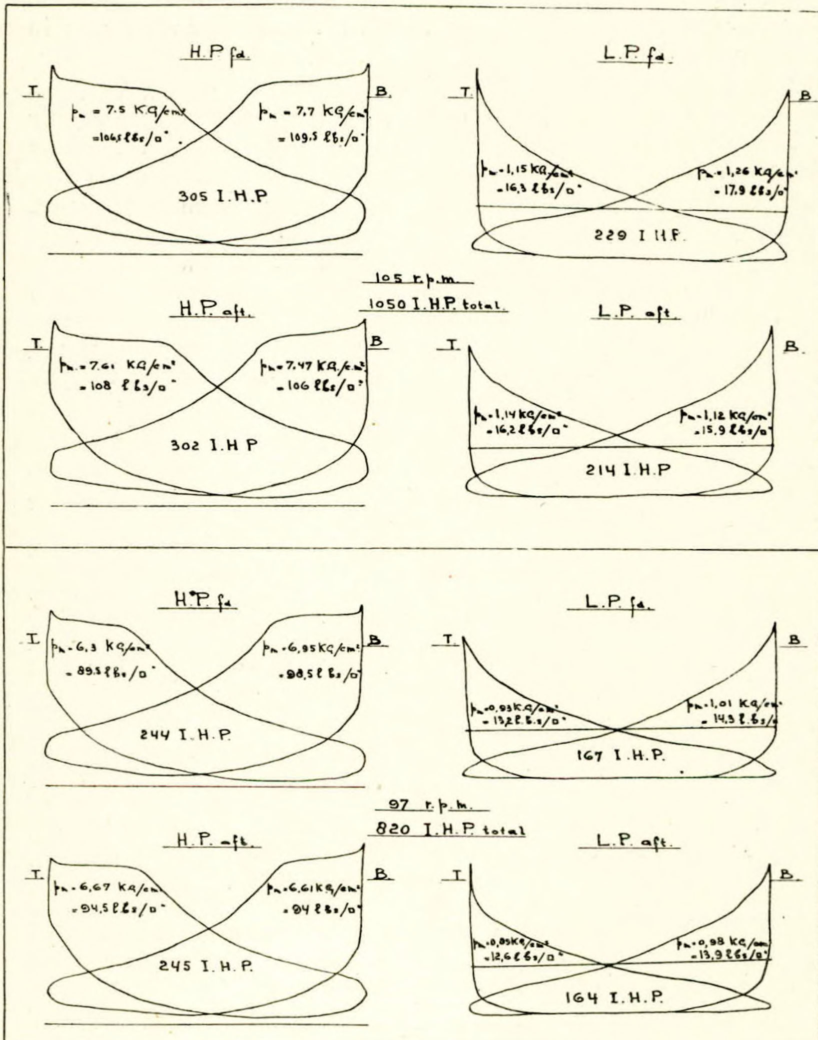


Fig. 12

hatched parts between H.P. and L.P. top diagrams and between H.P. and L.P. bottom diagrams. As the drop of pressure is about 0·5 kg./cm.^{2} (7·11 lb./sq. in.) we may conclude that the dimensions of the overflow valve are not sufficiently large to allow for a small drop of pressure, and therefore should have been made larger. As regards the temperature at which the steam is admitted to the H.P. cylinders, it has been our practice not to go higher than 300° C. (572° F.), which means 103° C. (185° F.) superheat. At this temperature the engines have been found still to work satisfactorily.

We now come to the results of steam consumption, which has been measured on several occasions in engines of different sizes. This consumption we have found never to be under 5 kg. or 11 lb. per I.H.P. per hour for the main engine only, without any auxiliaries, which is certainly not a striking result, but which must be regarded in the light of the circumstances. In this connection, I want to give a few particulars concerning the engine installations and the conditions under which the engines have to work.

The boilers on board all the Lentz engined K.P.M. ships are of the Babcock & Wilcox water-tube type which, in combination with the Underfeed mechanical stoker, has never given any serious trouble. In fact, they have proved to be very satisfactory on board the K.P.M.'s ships. The only important drawback of this type of boiler is its sensitiveness to lubricating oil from the cylinders, which it is practically impossible (without very special apparatus) to wholly extract from the feed water before this is pumped to the boilers. For this reason it is of great importance to lubricate as little as possible, but a certain quantity of oil is always necessary with superheated steam, and therefore it is a necessity to extract the oil contained by the steam or the feed water as far as possible. The first engines have been fitted for this purpose with oil separators placed in the exhaust steam pipes between the L.P. cylinders and the condensers. With these separators, which work on the centrifugal principle, it has been possible to get the greater part of the oil separated from the steam, before entering the condenser, the only drawback being the increase of the resistance in the exhaust steam line, as this, of course, affects the steam consumption.

For the latest engines I have, therefore, abandoned this system and have now applied an improved oil separator in the feed line, which has also given satisfactory results. As regards the amount of oil contained in the feed water, we have found it possible to reduce the quantity of oil carried over with the feed from 20 milligrams per kg. of feed water to 5 milligrams per kg. Although it has been found possible to extract all the free oil contained in the feed water, this is not so easy with the oil suspended in the liquid as an

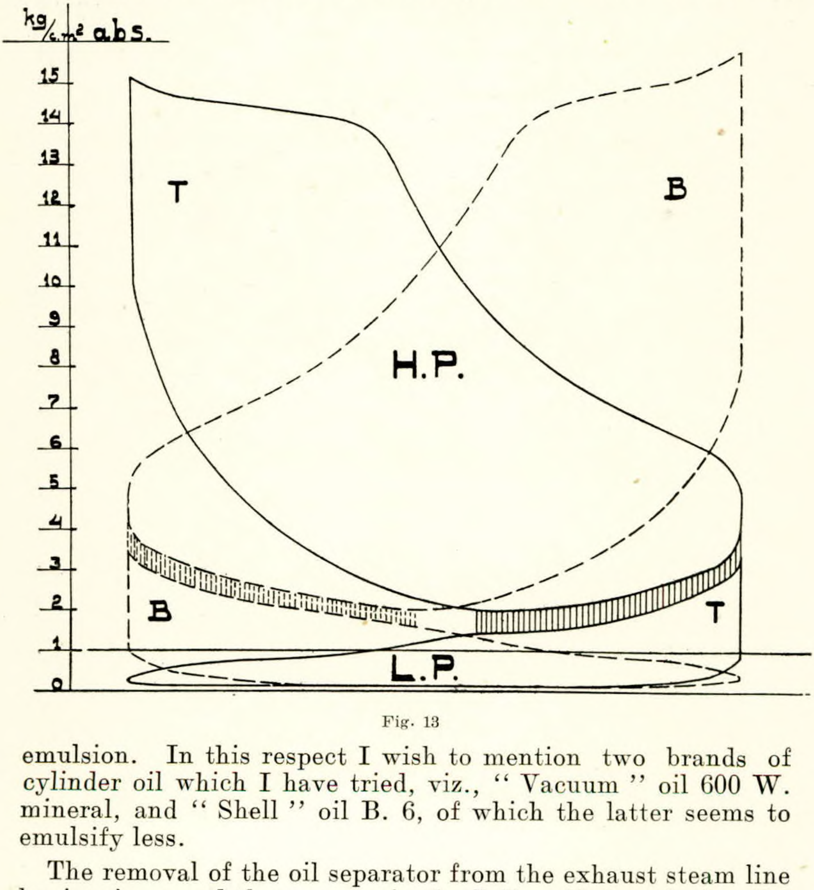


Fig. 13

emulsion. In this respect I wish to mention two brands of cylinder oil which I have tried, viz., " Vacuum " oil 600 W. mineral, and " Shell " oil B. 6, of which the latter seems to emulsify less.

The removal of the oil separator from the exhaust steam line having improved the vacuum in the L.P. cylinders during the exhaust period, it must also have improved the steam consumption, but as we have not yet records available, no reliable data can be given in this paper.

Further, it has to be remembered, in comparing the figure of 11 lb. of steam consumption per I.H.P. with figures obtained with other engines, that the K.P.M.'s ships trade in tropical waters at a temperature of 30° C. or 86° F., and for this reason the steam consumption must be higher than it would be with a higher vacuum in the condenser.

In table II have been given a few results from records taken from ships in the East Indies.

TABLE II.

Size No.	7	9	10	12
I.H.P. (designed)	750	1,200	1,800	2 × 3,000
Date	8/7/26	22/7/27	22/7/28	12/10/28
Hours measured	·16	6½	5	8
I.H.P. (developed)	580	1,060	1,450	4,300
Revs. per minute	120·0	100·0	109·1	93·6
Steam pressure	14·2 kg/cm.² (202 lb./sq.")	12·75 kg/cm,² (181·4lb./sq.")	12·5 kg/cm.² (177·8lb./sq.")	14·1 kg/cm.² (200·5lb./sq.")
Temperature of steam	295°C. (563°F.)	313°C. (595°F.)	290°C. (554°F.)	265°C. (509°F.)
Vacuum	69·3 cm. (27·3")	67·1 cm. (26·4")	69·0 cm. (27·1")	69·2 cm. (27·2")
Exhaust pressure in L.P. cylinders.	0·22 kg/cm.² (3·13 lb./sq.")	0·2 kg/cm.² (2·84 lb./sq.")	0·27 kg/cm.² (3·85 lb./sq.")	0·22 kg/cm.² (3·13 lb./sq.")
Steam cut-off in H.P. cylinders	30%	36%	36·5%	34·5%
Steam consumption per I.H.P., all told.	—	F 6·65 kg. (14·67 lb.)	F 6·4 kg. (14·11 lb.)	F 6·21 kg. (13·69 lb.)
Steam consumption per I.H.P. per hour, main engine only.	F 5 kg. (11·03 lb.)	F 5 kg. (11·03 lb.)	* 5 kg. (11·03 lb.)	* 5 kg. (11·03 lb.)

F—Measured. *—Calculated.

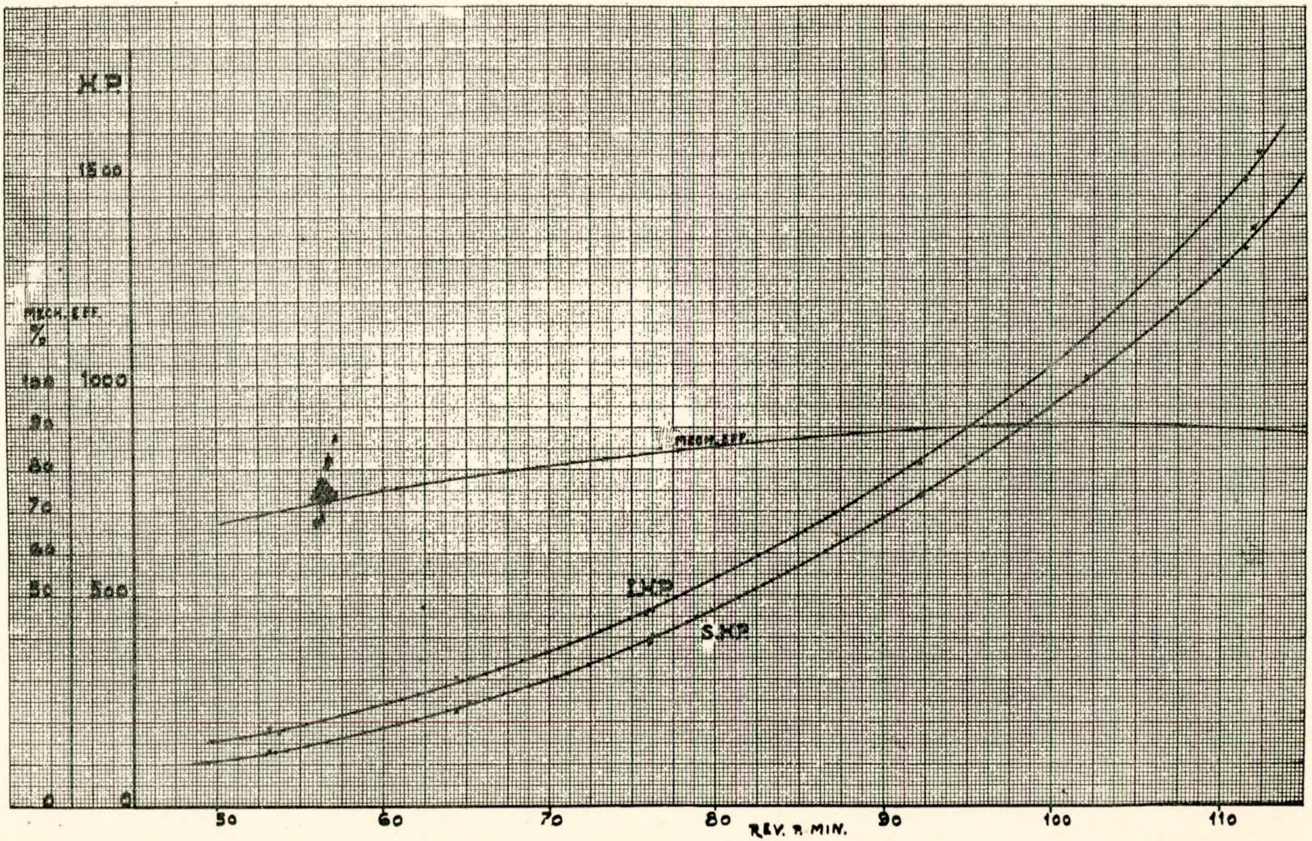
We have also had the opportunity to measure the shaft horse-power for various speeds on a number of ships by means of a torsionmeter, and as a result have found that the maximum mechanical efficiency of the force-lubricated Lentz standard marine engine is about 90-91%. It must be added, however, that the engines which we have measured do not drive any air, sanitary or feed pumps, only a bilge pump and a small lubricating oil pump, while in all cases a Michell thrust-block had been installed.

Figure 14 gives the I.H.P., S.H.P. and efficiency curves for a No. 10 size engine, designed to develop 1800 I.H.P.

As regards the working of the Lentz engine, we are able to say that all the 24 engines which we have put in service since 1926, when the first K.P.M. ships fitted with Lentz standard marine engines went to the East Indies, have not given any particular trouble up to the present time. On the contrary, we feel obliged to say that the valves and valve gear have always worked very satisfactorily; in fact we know of only two cases in which the poppet valves have been involved. Only once a break-down of an L.P. exhaust valve has been reported, but this was not a serious case, and after a spare valve had been fitted the ship continued its voyage. The second time, during an overhaul of the engine, a crack was found in one of the valves. In our opinion, both failures must have been due to faults of material. Generally speaking, I may say that the Lentz standard marine engine has proved to be perfectly reliable, also in heavy weather conditions with racing engines, which we have experienced more than once. Furthermore, the costs for upkeep and ordinary repairs have always been very low. Of the twenty-four Lentz engines installed on board K.P.M. ships, five are of the No. 7 size, five of No. 8 size, six of No. 9 size, six of No. 10 size, and two of No. 12 size, with a total developed horse-power of 33,000 I.H.P., while two No. 8 size engines and one No. 10 size engine are now in course of construction.

Figures 15 and 16 show the standard engine room arrangement of a number of K.P.M. ships equipped with a No. 10 Lentz standard marine engine and two Babcock & Wilcox boilers fitted with "Underfeed" stokers, while plate I is a photograph of a No. 7, plate II of a No. 10, and plate III of a No. 12 totally enclosed engine.

Concerning steam consumption, it will be seen from the figures mentioned that the actual steam consumption, as we



H.P.
1500
MECH. EFF.
%
100
1000
90
80
70
60
50
500
0
0
MECH. EFF.
I.H.P.
S.H.P.
50
60
70
80
90
100
110
REV. P. MIN.

Fig. 14

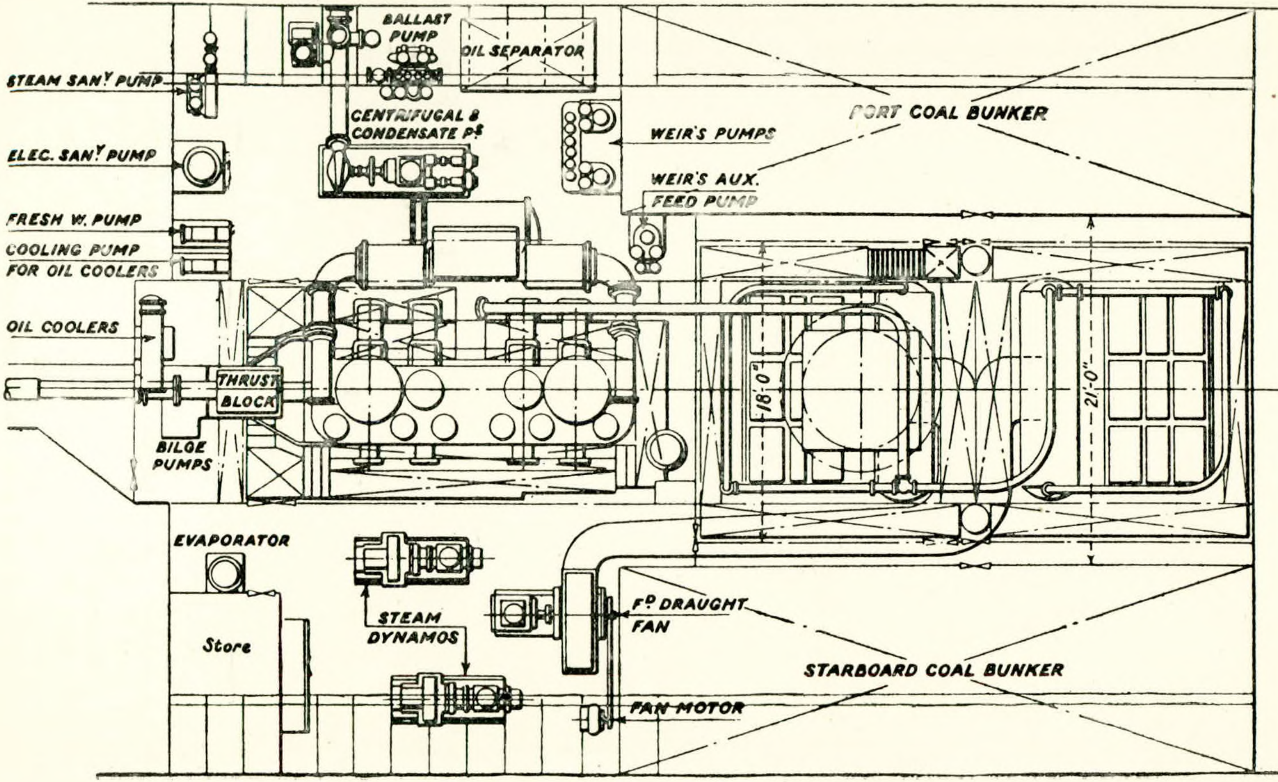

BALLAST PUMP
OIL SEPARATOR
STEAM SAN.Y PUMP
PORT COAL BUNKER
CENTRIFUGAL & CONDENSATE P.S
WEIR'S PUMPS
ELEC. SAN.Y PUMP
WEIR'S AUX. FEED PUMP
FRESH W. PUMP
COOLING PUMP FOR OIL COOLERS
OIL COOLERS
THRUST BLOCK
18'0"
21'0"
BILGE PUMPS
EVAPORATOR
STEAM DYNAMOS
Store
F.D DRAUGHT FAN
STARBOARD COAL BUNKER
FAN MOTOR

Fig. 15.

have found it, is higher than the consumption expected by the designers, Messrs. Salge & Co. Even when the resistance in the L.P. exhaust has been improved, we do not expect to find a better steam consumption than 4·9 kg. or 10·8 lb. per I.H.P. for engines of the original design. We believe that this result can be improved by enlarging the size of the overflow valve

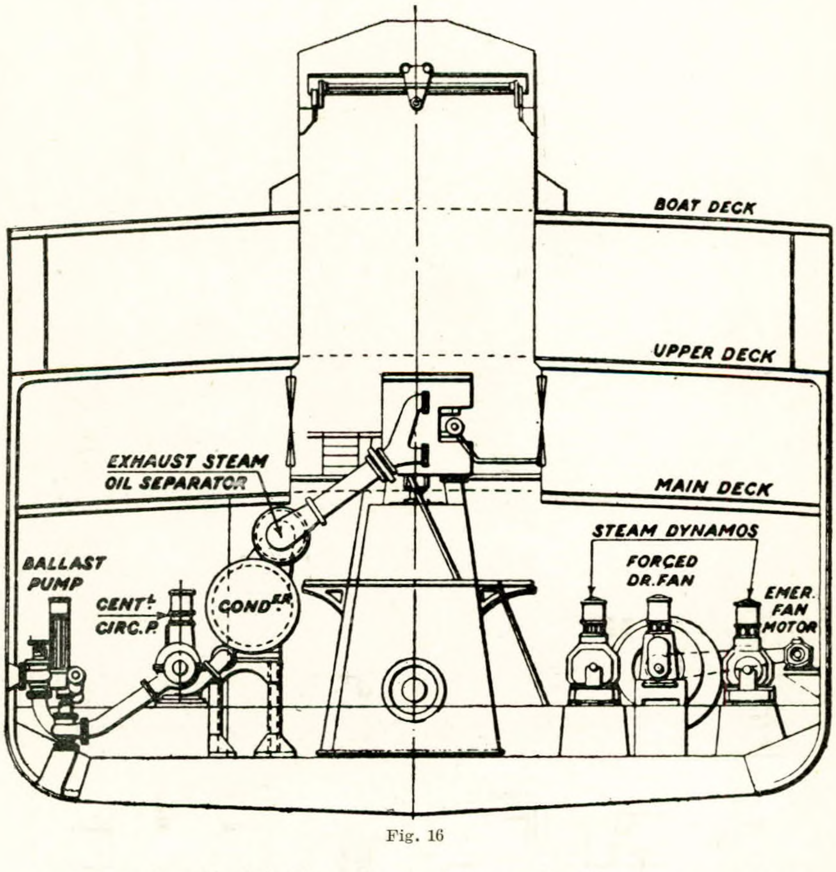


Fig. 16

and thereby diminishing the resistance in the steam passage between H.P. and L.P. cylinders, the drawback being however, if doing so, that the clearance volume of the L.P. cylinder which is already on the high side, might be increased. Also the resistance in the L.P. exhaust valve might perhaps be decreased, as the velocity of the steam appears to be rather high, as in the H.P. exhaust valve. As regards the temperature of the steam it must be stated that the maximum temperature of the steam on board K.P.M. vessels, 300° C. (572° F.) is lower than the temperature of 325° C. (617° F.) prescribed by

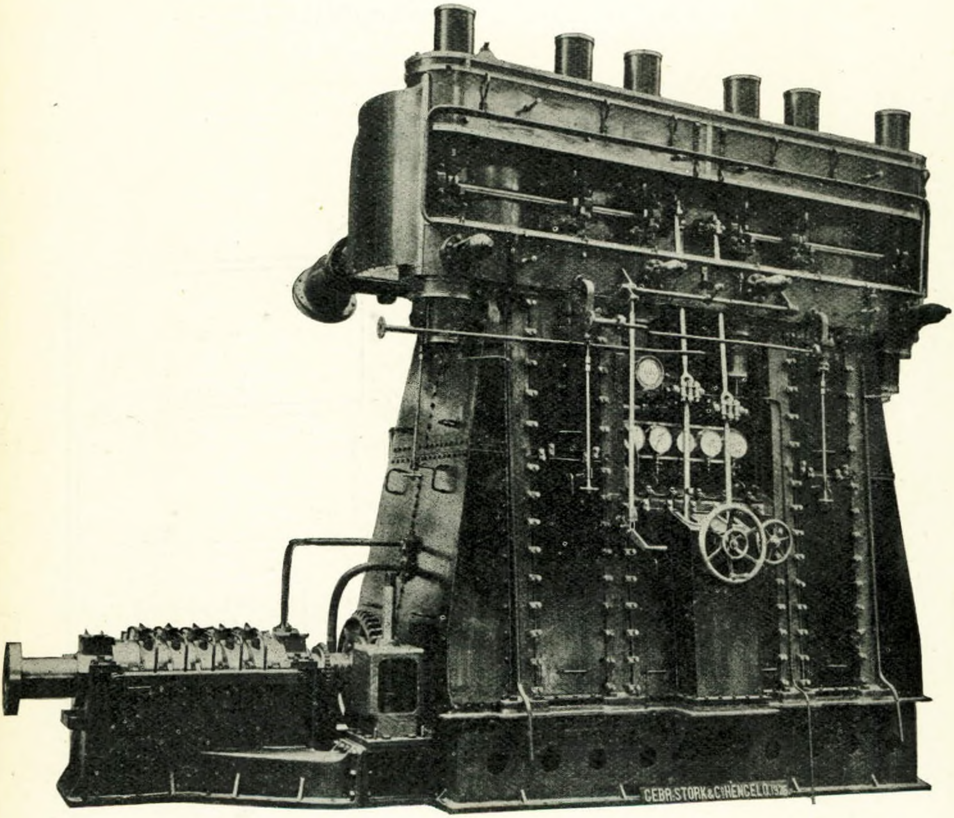


Plate I.

Messrs. Salge & Co. for the best attainable steam consumption, which of course should be taken into consideration when making a comparison. When comparing these figures with records taken from other superheated steam engines, the mechanical efficiency should also be considered, and although we have not yet been able to investigate the ordinary slide valve engine, we do not expect it to have a higher mechanical efficiency than 87 or 88% under similar circumstances to those obtaining with the Lentz engine. In this respect the Lentz engine has a positive advantage over the slide valve engine, and after all, it is the consumption per shaft horse-power which should be considered.

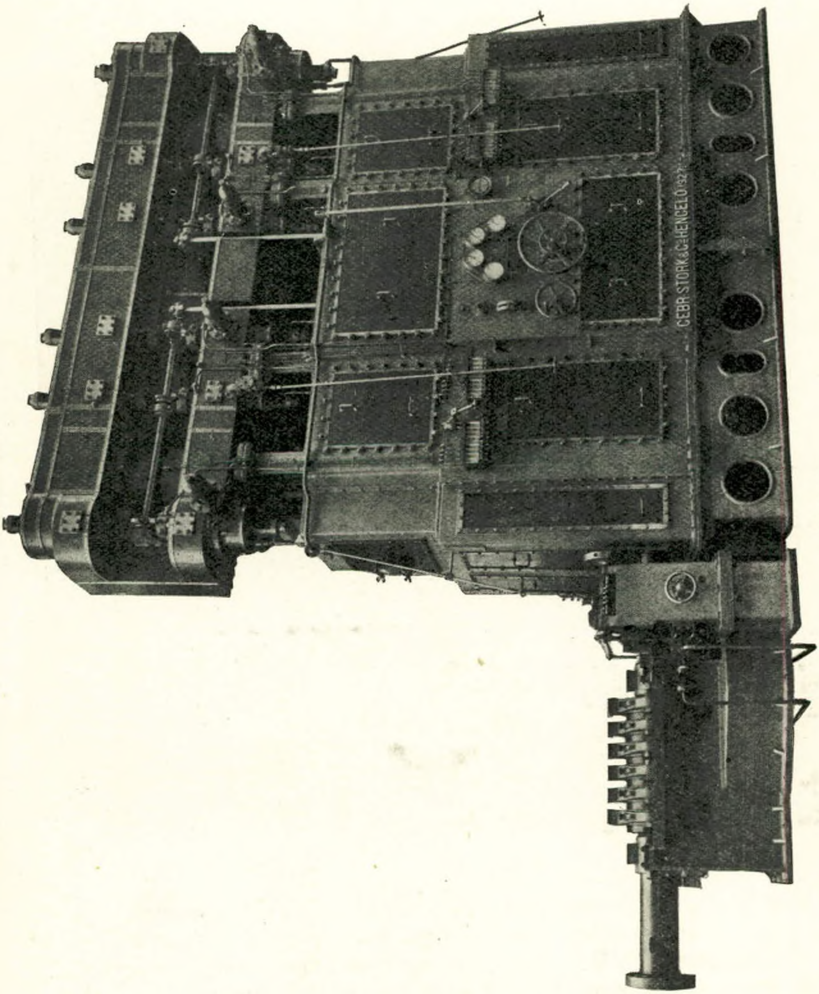


Plate II.

If I may now summarise my remarks on the results and properties of the Lentz standard marine engine, I might mention once more the following advantages:—

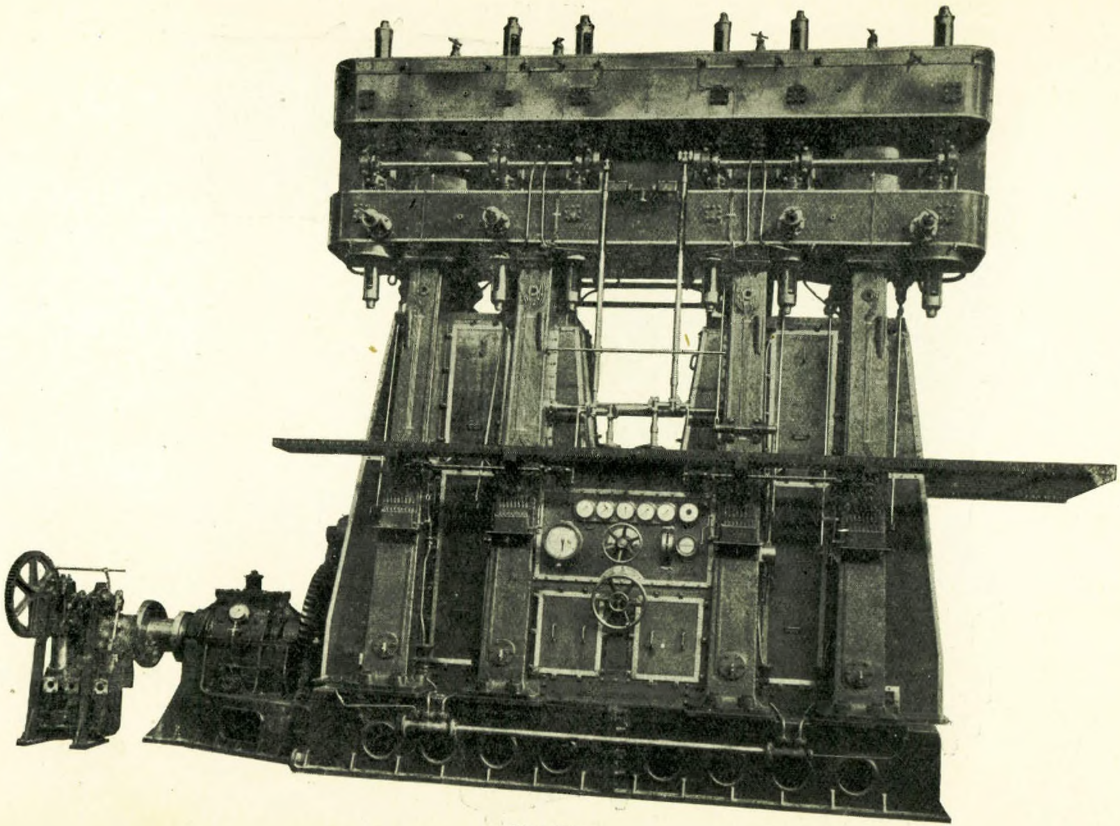


Plate III.

(*a*) The large ratio of expansion, which allows the use of superheat in the steam to a large extent.

(*b*) One-way flow of the steam through the passages between the cylinders, which means less condensation.

(*c*) Very effective insulation of the cylinders and steam passages and therefore little loss of heat.

(*d*) Simple design of valves and valve gears.

(*e*) Remarkably good and simple manœuvring, which certainly is one of the features of the Lentz engine.

(*f*) Possibility of overloading the engine and developing more horse-power, if necessary, without experiencing trouble with the engine.

(*g*) High mechanical efficiency.

(*h*) Suitability for totally-enclosing the engine to apply forced-lubrication.

(*i*) Suitability to use higher steam pressure and higher steam temperature, than will be advisable for ordinary slide valve engines, owing to absence of slide valves and because less lubricating-oil is required.

The drawbacks are :—

(*a*) There are four cylinders and driving mechanisms instead of three with the triple-expansion engine, which makes the Lentz engine heavier and more expensive to make.

(*b*) Relatively large clearance volumes.

(*c*) High velocity of the steam in the H.P. and L.P. exhaust valves, due to the resistance in the valves.

(*d*) Large difference in horse-power between H.P. and L.P. cylinders.

(*e*) No possibility of bleeding the steam for heating purposes, through absence of a receiver.

Before concluding I might add to what I have said about the Lentz standard marine engine that it has certainly proved to be a very good marine engine from a practical point of view, but that it will be questionable whether the steam consumption can be considerably improved, without increasing the steam temperature as well. Also I do not think that many *large* Lentz engines will be made, as it certainly cannot compete with a modern geared turbine installation of 3,000 S.H.P. or more as regards the steam consumption. Anyhow it will be interesting to watch the efforts of the designers of the Lentz marine engine and of those of the ordinary slide valve engine and of the uniflow marine engine, which type has also been tried now on board ships, to see which of the three will win in the long run.

DISCUSSION.

The CHAIRMAN: I am quite sure that you have all listened with great enjoyment and appreciation to Mr. Muller's paper, and his description of the Lentz marine engine, illustrated by the very complete and excellent series of lantern slides. I have no doubt that, notwithstanding his exhaustive treatment of the subject, there are points on which some of you would like to comment or to ask for further information, and I will now invite questions, to which Mr. Muller will be pleased to reply as far as time permits.

Mr. J. KUPKA (Visitor): As a representative of Mr. Willy Salge, the owner of the patent rights for the Lentz Standard Marine Engine, I most heartily congratulate Mr. Muller on the excellent way in which he has presented his most interesting paper to the Institution. Mr. Salge unfortunately is unable to attend the meeting, and I am desired by him to reply to Mr. Muller on his behalf.

I think you will agree with me that it was a very bold step indeed that the K.P.M. should have introduced a new type of marine engine on such a large scale, especially if it is borne in mind that at the time the decision was made there was very little known in the way of practical experience beyond the data obtained from S.S. *Bilbao*. Judging from Mr. Muller's paper it would appear that the actual working results are fairly satisfactory. I propose dealing with the various points of my reply in the sequence of Mr. Muller's paper.

1. There are seven sizes of the Lentz Standard Marine Engine, so that the power output thus varies from 400 cylinder horse-power to 5,000. However, up to the present time only six sizes have been actually built.

2. The cylinders ratio of high pressure and low pressure cylinder volumes is 1:4·75 and I do not quite know what Mr. Muller means by the ratio 1:4·6, as indicated in his paper.

3. The most important point, however, concerns the discrepancies between the steam consumption figures as anticipated by the designers and those obtained in actual service by Mr. Muller. In the first instance, Mr. Muller says himself that the K.P.M. have deviated in various ways from the designs pro-

posed by Messrs. Willy Salge. The K.P.M. engines had to be designed specially to suit tropical conditions which resulted in their being heavier and bigger than the original Lentz Standard Marine Engine as designed by Messrs. Willy Salge. There have also been modifications made in the steam and exhaust ports against the original designs inasmuch as valve cages have been employed.

I am not overstating the case in the least when I say that this modification is largely responsible for the higher steam consumption figures. The original designs as you will see from the lantern slide have unobstructed passages for the steam. There are no valve cages. Of course, it is perfectly understandable that at first sight one would be tempted to have cages fitted. In this country double beat valves are more commonly known as drop valves and quite naturally one associates this kind of valve with a hammering action. Obviously if this is the case, wear on the seats must take place. The cam action on the Lentz engines, however, is different. The valves do not drop on their seats. They do not hammer. The cam takes care that the valve comes down on its seat with the least possible amount of shock. Therefore the life of the valve seats and valves is very long indeed.

Some two or three years ago I was called upon to reset the poppet valve gear on an old triple expansion engine built in 1912. This engine was installed on a boat, owned by Messrs. Hogarth, of Glasgow, the S.S. *Baron Forbes.* I was told by the engineer that most of the original valves were still in place, and that the valve seats on the cylinder casting were in excellent condition. The engineer told me that in two instances during his time the valves had broken. He attributed this failure to the cam setting being wrong, which meant that the valves hammered on their seats. Nevertheless, the seat and the cylinder casting did not show any sign of damage. It was the valves which were damaged.

If it is desired to have renewable seats, which is rather of importance from the point of view of machining operations in manufacture, this object can be achieved by using cast iron rings which are fastened to the cylinder castings by means of set screws. These rings fulfil their purpose just as well as the valve cages, and, in addition, they do not impair the co-efficient of orifice.

One of the most important conditions for the efficiency of a compound engine or multiple expansion engine is the avoidance of wire drawing losses. As you well know it is quite an easy job to get the steam to enter into a cylinder, but it takes some gentle persuasion to induce it to get out, as one cannot make the exits wide enough. What, then, is the use of providing a poppet valve gear which gives favourable sectional areas for steam admission and exhaust if you put a very serious obstruction in the flow of the steam by providing these valve cages. They are a nuisance; and although I cannot give any definite figures to show what their harmful effect on the co-efficient of orifice amounts to, I should like to cite the following case.

Some little while ago my firm had to get out designs for a high speed compound poppet valve reciprocating engine. The cylinder castings were very intricate, and quite naturally it was desired that the valve seats should be renewable. One engine was fitted with valve cages, another with renewable rings. The valve working in the cage had a diameter of 220 mm., the valve working on a plain ring had a diameter of 200 mm. From subsequent indicator diagrams it was evident that the drop in pressure on the admission line was equal in both cases, in fact, especially at high speeds the engine working without cages behaved better. It was possible to obtain the same output of power with an earlier rate of cut off.

I should like, however, to emphasise the fact that on all the K.P.M. boats the valve dimensions have not been increased to suit the restricted co-efficient of orifice, and I submit that we must not be surprised at having these discrepancies in the steam consumption figures.

The estimated steam consumption figures per indicated horsepower hour as contained in Table 1 of Mr. Muller's paper are based upon certain assumptions regarding rates of cut-off, etc. They have been partly obtained by calculation and are partly based on results obtained on S.S. *Bilbao*, as well as experiments carried out by Messrs. Lanz, Mannheim. Thus the reason why these figures have not been obtained on theK.P.M. boats is due to the fact that the rates of cut-off required to obtain the necessary horse-power had to be increased because of the losses caused by the valve cages.

4. Mr. Muller suggests that it was a mistake that the high pressure inlet and high pressure exhaust valves were made the same diameter and provided with the same valve lift. I submit that this is not a mistake, and these dimensions have been chosen after careful consideration of the circumstances. In Germany as well as in Scandinavia it was not considered likely

that the higher engine speeds contained in the tables should be employed, because it was thought that the propeller efficiency at these higher speeds might be impaired. Therefore the steam velocities in the high pressure exhaust valves at the smaller engine speeds are quite normal under the assumption that the superheat on which the steam consumption figures were based was really obtained.

Later on, however, the K.P.M. decided with a view to obtaining the best possible utilisation of the engine to increase the speed, and obviously the steam velocities will increase accordingly, and in some cases the critical limits may have been reached so that the pressure drops as indicated by Mr. Muller are explained. Whereas in the case of motor ships the propeller speed corresponds in some instances to piston speeds as high as 6·2 m. per sec. or 19 ft. per sec. the valve dimensions of the original Lentz Standard Marine Engine are based on a piston speed of 4·5 m. per sec. or 13·7 ft. per sec.

Therefore, I would like to emphasise that it was not the valve dimensions of the Lentz Standard Marine Engines which were wrong to start with, but that the demands made on the engine speed have exceeded the original average estimate. Thus in all these cases where the engine speed is on the high side the high pressure exhaust valves which are at the same time low pressure inlet valves have been increased, with the result that the drop in pressure has been reduced considerably.

It may perhaps be of interest at this point to consider what can be obtained in the way of steam consumption figures on a 6-valve Woolf compound engine having poppet valves.

I have in my possession data referring to trial tests carried out with a locomobile built by Messrs. Lanz working on the Woolf compound principle and fitted with Lentz poppet valves. Full advantage of poppet valves was taken in this case by increasing the superheat to 413° C. in one case and 338° C. in another case. The absolute working pressures were 15·24 kg. per sq. cm. in the first instance and 12 kg. per sq. cm. in the second case, which brings the increase in temperature due to the superheat to 212·2° and 147° C. respectively.

The steam consumption figures per indicated cylinder horsepower hour were 3·502 kg. with a higher superheat, which corresponds to 7·8 lbs. and 4·15 kg. in the second case which corresponds to 9·4 lbs. The engine speed was in both cases 150 r.p.m. The cylinder dimensions were 210 mm. on the high pressure cylinders and 430 mm. on the low pressure cylinders.

The piston stroke was 480 mm. The condenser vacuum was approximately 91%. The results of these tests were checked by the V.D.I (Institution of German Engineers) and the International Association of Boiler Inspection Companies, according to the standards laid down in Germany for tests on steam boilers and steam engines.

I think you will agree with me, that if these results are possible with reciprocating steam engines working under conditions very similar to those on board ship there is every justification to call for still higher superheats for marine engines having poppet valves, in fact, the higher the superheat the more advantages are obtained by using poppet valves.

I may say that in locomotive practice the organisation that I am associated with has occasionally to reckon with total steam temperatures up to 400° C. at 16 kgs. boiler pressure. From a mechanical point of view the poppet valve gear works perfectly satisfactorily and it is needless to say that in locomotive service the demands made on the poppet valves are very much more severe than on marine engines. The speeds go as high as 375/400 r.p.m. and yet no trouble is experienced.

Mr. Muller refers to the uneven steam distribution as obtained with the Klug Gear, which of course must affect the area of the indicator diagrams.

Whilst the Hackworth Gear is generally capable of giving a better equalisation of the steam diagram cards, quite a simple device results in a substantial improvement with the Klug Gear. All that is necessary is a slight displacement of the angle of the keyway for the eccentric.

Whereas theoretically the eccentric should have the same angle as the crank it is found now that by moving the eccentric keyway by roughly 5° against the direction of rotation a main crank compensation of the diagram cards can be obtained. This improvement has been carried out by the Danzig Werft on a No. 9 type of Lentz engine on two boats, and as you can see from the lantern slides, the results are very good indeed.

7. On the question of lubrication it is very difficult to say definitely at the present stage which is the most efficient system. At the present moment a very exhaustive enquiry is being made on the subject, and it is hoped that in a few months time definite results will be available.

The K.P.M. have altered the cam design slightly in accordance with their own practice. It would be interesting to know if Mr. Muller would indicate the nature of the alterations. Perhaps he may have tried to compensate the unequal steam distribution for one rate of cut-off only, by making different angles of lap and lead for the top and bottom cams. With a valve motion of the Hackworth/Klug type this could be only done at the expense of other gear positions.

9. Another reason why the engine powers on the K.P.M. engines have been obtained at different rates of cut-off as against those which were investigated by the designers, may be that the boiler pressure was in most cases below the 14·5 atm. or 215 lbs. on which the designs were based. Since the mean effective pressure is largely dependent upon the pressure during the admission, the only way to increase the same is to lengthen the rate of cut-off. This means an increase in pressure drop between the low and high pressure cylinders due to the valve cages which in turn decrease the mean effective pressure in the low pressure cylinders. Thus, the discrepancies between the powers as developed in high pressure and low pressure cylinders can be explained.

10. Mr. Muller does not expect to obtain smaller steam consumption figures than 4·9 kgs. or 10·8 lbs. per indicated h.p./hour for engines of the original design. He believes that this result might perhaps be capable of some slight improvement by enlarging the diameter of the intermediate valve between the high pressure and low pressure cylinders, which in his opinion means that the clearance volume of the low pressure cylinder, which he thinks is already on the high side, might still be increased.

Firstly, it may be of interest to know that the No. 10 Standard Marine Engines as originally designed and working on the steamers *Ernest Hugo Stinnes* and *Elsie Hugo Stinnes* have shown the following results:—

I may say, and I think you will agree with me that it is of great importance that these results are based on correct measurements of steam and not based on coal consumption figures. The working pressure was 13·5 kgs. per square centimetre, or 198 lbs. per sq. in. The steam temperature at the stop valve was 282° C. and the vacuum was 88%.

The owners, Messrs. The Stinnes Steam Shipping Co., have stated that the steam consumption per indicated h.p./hour as measured by them, was 4·67 kgs. or 10·5 lbs. If the total steam temperature had been 313° C. the steam consumption would have dropped to 4·4 kgs. or 9·9 lbs., and with a steam temperature of 325° C. the steam consumption would have been 4·32 kg. or 9·7 lbs. per indicated h.p./hour.

To be perfectly fair, I feel obliged to repeat that if Mr. Muller is disappointed with the steam consumption figures, it is not the fault of the Lentz Engine at all, but rather due to the fact that certain primary conditions have not quite been fulfilled.

For the sake of economy it is essential that a compound engine should work with as high a superheat as possible. The maximum temperature so far obtained in actual working conditions has been found on the S.S. *Casablanca* owned by Messrs. Oldenburg Portuguese Steamship Co. where an average temperature at the stop valve of 340° C. has been measured, without unduly high temperature of the flue gases.

As the diameters of the intermediate valves have already been increased in view of the unexpected higher engine speeds, it is interesting to note that the increase in clearance volume, which Mr. Muller anticipates, is not the case in spite of the larger valve diameters. This was possible by improving the shape of the steam passage.

As regards the mechanical efficiency of piston and slide valve engines, Mr. Muller thinks that 87 or 88% should be a substantially correct estimate. From information received from shipbuilding firms in Hamburg and Stettin, it would appear that 84 to 86% would be nearer the mark.

I do not think it is an exaggerated statement to say that the difference in mechanical efficiency between the Lentz Standard Marine Engine and the ordinary types is approximately 5%, especially if it is borne in mind that in the case of the triple expansion engine there are six eccentric sheaves grinding round all the time and dragging along the heavy slide valves with their frictional resistances.

With a view to improving the engine efficiency the pumps have been separated purposely from the main engine, which in addition offers the advantage that the additional exhaust steam of the auxiliary engine is available for feed water heater purposes.

When Mr. Muller summarises the advantages of the Lentz Standard Marine Engine he omits to mention a very important feature, which is of great importance in view of the figures obtained by the Lanz Locomobile, which I have indicated previously.

It is desirable to use a higher steam temperature and to support higher steam pressures owing to the absence of slide valves. There is still to-day a considerable amount of prejudice on that account. It is frequently said that the poppet valve warps at high temperatures, and that it is impossible to keep it steam-tight. In locomotive practice, however, there is a growing tendency, especially in France, where the locomotive designers have always been masters in designing efficient compound engines, to work with total steam temperatures of about 400° C. at a working pressure of 17 atm.

A certain amount of trouble on account of valve lubrication is experienced and chiefly concerns the low-pressure cylinders, where with a view to obtaining a good co-efficient of orifice, the piston valves are substituted by slide valves. A slide valve, however, has a very serious disadvantage on account of inertia effects, when it is considered that the maximum engine speed is about 375 r.p.m. Very good results have been obtained by the substitution of slide valves by poppet valves.

When discussing the drawbacks of the Lentz Standard Marine Engine, Mr. Muller states that the Lentz engine on account of having four cylinders and driving mechanism is heavier. With the greatest respect I have for Mr. Muller, I beg to contradict that statement. Based on equal engine speeds the Lentz Standard Marine Engine as built to the original design is not only not heavier than a triple-expansion engine, but lighter. There is a difference of approximately 8% in favour of the Lentz Engine. Mr. Muller, of course, bases his statement on the K.P.M. variety, which has been reinforced on account of special conditions.

11B. On the question of clearance volume it should be borne in mind that the high pressure cylinder clearance volume has very little effect on the steam consumption.

On the original Lentz Standard Marine Engine the rates of compression are fixed in such a way that the admission pressure equals the terminal pressure at the end of compression which means that there is very little drop in temperature. The diagrams shown by Mr. Muller, which are taken on a K.P.M. engine, do not, however, fulfil this condition.

I would suggest that the selection of the valve events should be made to suit the above mentioned condition. If you compare the Lentz Standard Marine Engine with a triple expansion engine or a quadruple engine, you will find that the possible sources of losses must be smaller on a Lentz Engine than on ordinary engines. There are only two volumes in the case of the Lentz Engine where losses could occur, against five volumes with a triple expansion engine, and seven volumes with a quadruple engine.

11c. If the shape of the orifice round the valve seats is designed properly without undue restrictions the velocity of steam through the valves is not greater than the admissible values. There is also to be considered that a change of direction of the steam through the ports has a certain influence on the relative values so far as resistance of 1 sq. cm. of piston valve and poppet valve area is concerned. It is not quite correct to compare sectional areas only, regardless of the flow of steam.

11d. The great difference in pressure between the high-pressure and low-pressure cylinders is largely attributed to the intermediate valve between the high-pressure and low-pressure cylinder. So far, the Lentz Standard Marine Engine has been designed, as the very name says, as a standardised engine, which should be applicable throughout a certain range of speeds. In view of the experience gained in the meantime, however, the diameters of the intermediate valves have been increased and the results obtained are so satisfactory that all the new engines will have larger intermediate valves.

If it is desired to bleed steam for heating purposes special arrangements have now been made to fulfil this purpose. It can be done either by bleeding the high-pressure cylinder during the expansion period or, as another alternative, by bleeding steam overflowing from the high-pressure cylinder to the low-pressure cylinder through a special valve, which is actuated by the intermediate valve. Thus it was possible on a Swedish boat to increase the feed water temperature to 160° C. at the entrances to the boiler through this bleeding.

In conclusion, I may also mention that Messrs. Willy Salge and Co. are at present investigating the possibilities of high-pressure steam in conjunction with a reciprocating engine and it is anticipated that the upper limit of horse-power in order to compete with geared turbine will then be raised to approximately 4,500 H.P. as a steam pressure of 30 kg. per cm. sq. is considered. With still higher pressures the limit will be reached probably with 8,000 H.P. In conclusion, Mr. Salge wishes to express his greatest appreciation and thanks for the most helpful way in which Mr. Muller has always co-operated towards the perfection of the Lentz Standard Marine Engine.

Mr. Salge gladly acknowledges that he does not know of any other Marine Superintendent who showed such a great interest and who contributed so many valuable suggestions to make a success of the job. It was mostly due to his advice gained on the experience with the various sizes of the Lentz Standard Marine Engine service on the K.P.M. that we were able to make such great improvements on our original designs that to-day the Lentz Standard Marine Engine ranks foremost in Germany and Scandinavian countries.

I think we all ought to be very thankful indeed to Mr. Muller for having again proved himself a pioneer in the development of marine prime movers.

Mr. A. F. Evans: I am very glad to have the opportunity to congratulate, not only the designers, but also the users of the Lentz engine, which I think all internal combustion engineers look upon as one of the shining lights of the steam engine world.

It must have required a considerable amount of pluck and enterprise to follow the path prepared by the internal combustion engine when we consider that this departure was made just at the time when the Diesel engine, in its marine application, was certainly not looked upon in a very favourable light.

In departing from the orthodox they would appear to have adopted just those things that the steam engine lacked, and as regards standardisation, while this is somewhat of a novelty in steam engine practice, the more that can be done in this direction the better for all concerned.

With regard to the question of valves, it will be remembered that the internal combustion engine started with the sliding valve, but very soon changed over to the poppet type as being more suitable for dealing with hot gases.

In adopting the poppet valve for high temperature steam the designers of the Lentz engine are probably correct, notwithstanding that some types of the smaller high speed internal combustion engines have reverted to the sliding valve. In this connection I should like to ask Mr. Muller whether he has tried the use of high chromium steels for his valve heads.

With regard to lubrication, one can readily visualise that there must have been many difficulties to overcome, but the results appear to indicate that there must be at least a five per cent. gain in mechanical efficiency that can be credited to this departure in lubrication, and they have certainly reached the highest recorded mechanical efficiency of the internal combustion engine, 91%, a figure that leaves a very small field for further improvement.

The use of cams for operating the valves must have had a most beneficial result, both from the point of view of the mechanical efficiency as well as the indicator, and I have great pleasure in being allowed to congratulate both designers and users on this extremely interesting exhibition of definite progress.

Mr. B. L. Silley: I endorse the opinion of previous speakers, that Mr. Muller has given us a very interesting paper. It is a great surprise to me to know that there are so many ships fitted with this type of engine. I would like Mr. Muller to give us a few points of comparison between the Lentz engine and an engine of a similar type, the Caprotti engine. I agree with most of the advantages claimed, most of which are covered by the fact that there is no idle steam in the engine. With regard to the disadvantages, and in particular that of being unable to bleed steam for feed heating purposes, recent developments have shown that it is possible to get very high steam temperatures by making use of the funnel gases, and I do not think, therefore, that this can be considered as a disadvantage.

Mr. W. Hamilton Martin: It is indeed a pleasure to me to add a few words on Mr. Muller's most interesting and instructive report. The author has been known to me for many years, although we have not met for a considerable time. The progressive mind of the composer is admirably reflected by his paper.

Seldom, if ever, has such an extensive comparative trial been staged in marine work or have so many service results been so clearly rendered in a report on a new engine type. The author has been fortunate in having the co-operation of directors known for their foresight. The K.P.M. was one of the earliest companies to equip their entire fleet with oil-burners. I can recollect trials being carried out about thirty years ago by Mr. Muller's predecessor, Mr. Metselaar, in burning astatki and residue fuels under boilers before adopting it in the vessels.

Mr. Muller very soon equipped his fleet with watertube boilers and changed over from oil to mechanical stoking when economical reasons indicated the advisability of doing so, which has proved a correct step.

Probably no marine engineer has assisted more towards making mechanical stoking a success on board ship. Apart from mechanical difficulties encountered in its design for sea work and adapting it to the coals obtainable in the Dutch Indies, he has successfully overcome the strong prejudice existing amongst firemen against mechanical stoking—facts well worth mentioning. We have now heard of his next step forward, the adoption of the Lentz engine. As to this Lentz engine performance of 11 lbs. steam consumption per I.H.P./hr., it is certainly nothing exceptional taking into account that superheating was made use of, even allowing for the fact that the circulating water was hot.

In the discussion on Mr. Hutchinson's paper on reciprocating engines before this Institute, we were told that a small 40 I.H.P. vertical double acting Uniflow auxiliary engine on test gave 10·6 kg. (23 lbs.) of steam consumption per I.H.P./hr. when using saturated steam. This consumption is at least 40 per cent. better than that of the ordinary slide-valve type auxiliary of similar duty. If, then, a larger Uniflow engine of the latter type were built with piston valves, or some other more effective admission means, good results might be expected in steam consumption, and probably the engine would also show good mechanical efficiency.

The largest Lentz engine has balance weights fitted. I would like to ask whether vibration in vessels fitted with Lentz engines has been found to be more marked than in vessels fitted with the ordinary triple compound type.

The sensitiveness of water-tube boilers to cylinder lubricating oil carried over with the feed, as mentioned, is certainly a drawback, especially where the engines require somewhat more oil than usual, due to the use of superheated steam. The prevention of excessive entry of oil in emulsion with the feedwater must always demand the most careful attention of the staff. If the author could give us some more information on the improved oil separator, as now used, this would be appreciated.

To have reduced the amount of oil present to five milligrams per litre is very good, but to keep it down to this amount must require close watching and frequent cleaning of the oil separator parts. How is the actual oil content present in the feed checked, and is it done at regular intervals so that irregular or sudden increases may be duly noticed?

It is interesting to hear that the poppet valves and their gear have stood up so well, yet one feels more can be done with the piston or balanced slide valve. The large difference of horsepower between H.P. and L.P. cylinders would seem to be a decided disadvantage, also the high steam velocities through the exhaust valves, both of which, however, cannot well be avoided with such engines.

For the particular service of the K.P.M., who, I take it, employ native staffs, these installations have obviously proved an excellent solution, and the author and his Company deserve great credit for their pioneer work in adopting this type of engine so extensively in conjunction with water-tube boilers and mechanical stoking. The paper will prove to be a valuable addition to our Transactions.

Mr. G. R. Hutchinson : I feel that I am in the happy position of having practically nothing to say, because I think the first speaker stole all our thunder! There is quite a lot in what he said with regard to the somewhat disappointing performance figures of Mr. Muller's Lentz engines. I agree that the elimination of the valve cages would measurably improve the consumption figures, but what Mr. Muller said is perhaps also correct—practical considerations are of more importance than maximum economy. A definite saving would result if a slightly larger intermediate or " overflow " valve were fitted, as it would reduce the wiredrawing losses: this is clear from the indicator cards. Another feature which would improve the performance would be the introduction of a uniflow L.P. cylinder. I cannot see how eliminating valve cages only would make a substantial difference to steam consumption.

Mr. Martin mentioned lubrication. Has Mr. Muller tried the device adopted by Mr. Visker, namely, a water spray for cylinder lubrication? There is something to be said for this arrangement as I know that Mr. Visker has obtained quite good results with it. Although the steam temperature was 700° F. in the *Borneo's* engine, I believe Mr. Visker found that very little cylinder lubrication was required when the water jet system was used. When one recalls that this was on a vessel using water-tube boilers it is a step in the right direction.

If one increases the size of the valves in a Lentz or a similar engine, as is necessary in the larger sizes of engine, and at the same time increases the steam temperature to 600/750° F., how is one likely to fare with regard to valve distortion? I think it will be a problem which must be tackled, for we must bear in mind the competition of the balanced slide valve in the field of the high temperature marine steam engine of large size. Mr. Woolnough has developed an arrangement of using separate balanced slide valves of the Andrews and Martin type. These valves are quadruple-ported and the valve travel is extremely small. This seems to be an excellent line of development, and I think the advocates of the poppet valve will be on their mettle if that system becomes established.

I have had the privilege of being at sea in some of the K.P.M. ships, and I would like to say how well the Lentz engine runs and manœuvres. I did not notice any vibration, such as Mr. Martin mentioned; the engines are very smooth-running. The use of mechanical stokers, water-tube boilers, and Lentz engines gives a combination which is perhaps revolutionary to British cargo shipowners, and I think we should congratulate Mr. Muller on his courage in this pioneer work. His paper shows once more that "The proof of the pudding is in the eating."

Mr. J. Ward, B.Sc. (Eng.): The author states on page 342 that the grooved valve spindles are of stainless steel ground into cast iron liners and fitted in the usual way without any packing or stuffing box. In the first place I should be very pleased if he would give some particulars of the following:

(a) The working clearance for the valve spindles;

(b) the number of grooves; and

(c) the width and depth of the grooves.

What is the exact purpose of the cone-shaped plate placed around the spindle as shown in fig. 4? Are the grooves turned in the spindle to assist lubrication or for the purpose of preventing the leakage of steam? If for the latter, I am inclined to doubt their effectiveness since they do not act as a labyrinth packing, particularly when there is a reciprocating motion of the spindle. The valve spindle of the high pressure (1422 lb. per sq. in. abs.) stop valve on the Benson turbine is grooved, but the final sealing is by metallic packing and there is a leak-off arranged from a pocket between the grooving and the metallic packing. This tends to show that the designers had their doubts about the grooving acting as a labyrinth. I am inclined to think that a plain spindle, with the smallest possible working clearance, fitted in a long bush is more effective in preventing leakage than a grooved spindle with the same clearance. I base this opinion on the results of some recent experiments of mine on the leakage of oil through very small clearances between plain bushes fitted with either plain or grooved spindles. These results have yet to be confirmed for the leakage of compressible fluids. To the old marine engineers the idea of dispensing with stuffing boxes must seem revolutionary. In these days, however, we have superheated steam to contend with, but with higher class machining, high grade materials capable of resisting wear such as Perlit and stainless steel, and with lubrication on scientific principles, there is no reason why one should adhere to the old design of gland.

The statement of the author that owing to the arrangement of cranks the system is not balanced either statically or dynamically somewhat surprises me, especially after reading Prof. Dalby's recent paper on the balancing of marine engines.*

Engr.-Lieut. Comdr. A. J. ELDERTON, S.R., R.N. (by correspondence): It is interesting to note that the double compound steam engine, one of the latest methods of using steam in a prime mover, was also one of the earliest types of steam engine.

Hornblower invented the compound engine in 1781, and Woolfe, a Londoner, invented the double compound engine in 1804, which functioned much in the same way as the engine which is the subject of the author's paper. Woolfe might be justly credited with having invented the Uniflow engine, although he did not make use of central exhaust.

The author mentioned the drawback to the water-tube boiler due to the entrance of oil with the feed water. My experience seems to show that trouble with a water-tube boiler is more likely to occur through scale formation than through oil deposit. In 1916 I was serving in a battleship which had 18 water-tube boilers and three Scotch boilers. On one occasion it was necessary to do a number of days forced steaming; at the conclusion, when it was possible to examine the boilers, it was found that all the furnace crowns of the Scotch boilers had come down, whereas the water-tube boilers showed no signs of damage. The engines were reciprocating, partially enclosed and forced-lubricated. The only conclusion that could be come to was that the damage had been caused by oil deposit on the furnace crowns; oil was found in the water-tube boilers, but no damage had resulted.

The loss mentioned by the author, due to the resistance of the valves is interesting. Two years ago Professor Stumpf of Berlin was working on a Woolfe double compound engine in which one double piston valve was used to control the steam

* "The Possible Vibration of a Ship's Hull under the Action of an Unbalanced Engine." Proceedings of the Institution of Mechanical Engineers, Volume 4, 1928.

between the H.P. and L.P. cylinders, and the L.P. cylinder was made Uniflow with central exhaust; no doubt the author is aware of these experiments.

I am a little surprised that the steam consumption of 11 lbs. per I.H.P./hour for the main engines only on service is so high as compared with the theoretical consumption which is often nearly approached in land practice. Recent figures given for the machinery of the S.S. *Boniface* using a Bauer-Wach exhaust steam turbine working under more or less similar steam pressures and temperature are—

Steam consumption, main engines ...	9·89 I.H.P./hour.
Steam consumption, main engines and propelling auxiliaries	10·9 ,, ,,
Steam consumption, all purposes ...	11·44 ,, ,,

In fairness to the Lentz engine it should be mentioned that a vacuum augmenter was used, and a vacuum of $28\frac{1}{2}$ ins. $28\frac{7}{8}$ ins. carried, which I think would be difficult to maintain in constant service. No doubt some of the loss is attributable to high cooling water temperature, but I think the greater loss is caused by the use of poppet valves. These valves, in order to lessen their inertia effect, must be made light, and consequently are susceptible to distortion when used with superheated steam, leaky valves being one of the most usual causes of high steam consumption. In shore practice, piston valves have been found to be less subject to this defect than poppet valves. It would be useful to know if the author has experienced any trouble with the valve springs through high temperature; one sometimes hears that superheated steam had a bad effect on the springs of indicators.

I should like to thank the author for the pleasure his paper has given me, and I think it a nice compliment he has paid our Institute in preparing it and coming to London to read the paper.

The Author's Reply: Mr. Kupka has overwhelmed me with such an amount of matter that I do not think I should be able to answer all his questions before midnight! I hope he will be satisfied when I give only a few remarks on his notes on behalf of Messrs. Salge, and more especially the principal ones. First, I know very well that not six, but seven sizes of Lentz engine have been designed, but I have only said that until now only six sizes have been *made*. As regards the valve cages, Mr. Kupka thinks that the resistance of these is the principal reason why the steam consumption is higher than that expected by Messrs. Salge. I do not think so, and the indicator diagrams I have shown (Fig. 12) will support my contention. As regards the resistance of the valves, I do not think the resistance of the original valves is much less, as our valves have the same dimensions. Also if our diagrams do not show much difference from diagrams taken by Messrs. Salge there cannot be much difference in friction with or without valve cages. As far as renewable seats are concerned Messrs. Salge's design with cast iron rings fastened with set screws does not appeal very much to me. The only reason why I have put valve cages in the engine is not that I am afraid of damage, but *if* any damage is caused to the seats it is very difficult to get them tight again and it should not be forgotten that we have to be very careful in the Far East. In fact we have had one case, where by taking out the valve cage with valve and putting in a complete new set, we managed to get over the difficulty and run the engine again in a very short time. If the design had been made as recommended by Messrs. Salge, without valve cages, it would have been impossible to make a tight seat again. That is the principal reason why I have inserted the valve cages.

As regards my remarks on the dimensions of the valves, I was very interested to hear from Mr. Kupka that Messrs. Salge have found it advisable to *increase* the diameters in certain cases. Personally I do not object to increasing the valves; on the contrary, I think some of them have to be increased, and Mr. Kupka's words prove what I have said about the intermediate valve: that it is too small. As regards the figures given by Mr. Kupka for a Lentz locomobile, I can only answer that these figures are wonderful; I have always heard that a locomobile can be a very efficient engine, but it is not to be compared with a marine engine. The only point on which I may agree is that it will be possible to increase the steam temperature in marine engines in general, and at present there is a certain tendency to do that, but it must be done gradually. I know that Mr. Visker and a few German engineers have increased the steam temperature considerably and have obtained better results and I do not think anyone will deny the advantage of a high steam temperature, but in our engines we have only been comparing our figures with those which have been expected by the designers. As I have already said I consider it to be one of the advantages of the Lentz engine that it will be possible to use higher temperatures with this engine than with the ordinary slide valve engine.

As regards the steam velocities in the valves, Mr. Kupka says these are quite normal; I do not agree with him on this point, because the average steam velocities are normal, but the real maximum velocities are not. Mr. Kupka states that the increase of the speed of our engines is due to the higher steam consumption. In this respect I need only refer to the diagram shown in Fig. 12, which is taken from an engine running at 100 r.p.m., which is the average speed of several Lentz standard engines, and I do not think there is anything to be said against the form of this diagram.

As regards the improvement in the Klug gear by displacement of the angle of the keyway of the eccentric, I consider this solution to be very simple and I think it will give also a slight improvement as regards the form of the diagrams. Mr. Kupka asks whether we have altered the cams; we have done so, but not with the idea of equalising the horse-power between top and bottom; we have only altered the slope of the cams, making it a little greater, so that the valve is lifted more quickly. This has nothing to do with the equalising of the horse-power, but it has improved the diagrams. As regards the steam consumption I want to point out that the figures I have given have all been measured very carefully by a specially trained staff of engineers who have been dealing with this kind of work for years, whereas many figures given by Messrs. Salge have been based on coal consumption, but to my opinion it is a rather dangerous procedure to calculate steam consumption from a coal consumption trial. I have taken perhaps 20 to 30 records with our Lentz engines and what I have given is to be regarded as being the average. Mr. Kupka infers that I am disappointed as regards the steam consumption, but this is not right, I am not at all disappointed; as a matter of fact I have never wholly relied on the figures given by the designers and if I had, our boilers would have been too small!

As regards the possibility of increasing the valve diameters without increasing the clearance volumes, I can only congratulate Messrs. Salge on this step, and I shall not hesitate to adopt this improvement. With regard to the mechanical efficiency of slide valve engines, I cannot give any positive figures as I have no data so far. The only figure mentioned by me, namely, 84-86% efficiency for an ordinary slide valve engine, is perhaps on the low side. As far as the weight of the Lentz standard engine is concerned, I am sorry to say that, in fact, there has been no firm in Holland, making the engines, which has not been disappointed because the weight and therefore also the cost of the engines have been more than was expected according to the figures given by Messrs. Salge.

I now want to thank Mr. Kupka for his closing remarks, and I hope that Messrs. Salge will be able to improve their engine still more and to enjoy the satisfaction of their fruitful work, as they deserve to do.

Mr. Evans referred to the Diesel engine and he may have seen from my paper that I have adopted many features from the Diesel engine, such as the forced lubrication and the piston rings. I am somewhat a Diesel engineer myself, and I have copied the Diesel engine as much as possible. I certainly believe that the advantageous features of the Diesel engine will help in improving the Lentz engine. In reply to Mr. Evans' question whether we have used high chromium steels for the valve heads instead of cast iron, I may reply that we have not, because the valves for Lentz engines are of the double beat type, different from Diesel engine valves. As far as I know Messrs. Salge have tried mild steel in one or two cases, but we have only used cast iron and Perlit, and we have never found any difficulty with our valves; however, I do prefer Perlit. As I have said I cannot yet give figures on the mechanical efficiency of the ordinary reciprocating engine, but I hope to be able to do so later on.

Mr. Silley has asked for a comparison of the Lentz engine with other types of engines. I have indeed investigated the ordinary type of slide valve engine some time ago, but not the Caprotti engine, hence I cannot give comparative figures. As regards the bleeding system not being very well possible, I know that Messrs. Salge are carrying out trials to bleed steam from the H.P. cylinder by means of a special apparatus. I have tried to bleed steam for the heater from the indicator pipe; it resulted in an increase of temperature, but not much. As regards the heating of feed water by funnel gases, this is a problem by itself on board ships, and one which I consider to be very difficult to tackle, if we only think of the difficulties encountered in land practice with economisers.

I would like to thank Mr. Hamilton Martin for his kind remarks. His figure of 10·6 kg. steam consumption for a small Uniflow engine is certainly very good; I have found slightly higher figures for our small single cylinder high-speed Uniflow engines driving generators on board our ships. As regards the vibrations from a Lentz engine we have not found these to be more serious than the vibration caused by ordinary steam reciprocating engines, and I am glad that Mr. Hutchinson has confirmed this statement. The feed water oil separator which we now use in connection with our water-tube boilers is a separator of very simple construction, designed by Professor Dyxhoorn of Delft, and consisting of a number of oil-traps as may be seen from the drawing (Fig. A.) appended to this discussion, its principal feature being that it does not work on the cascade principle, but that it works with a low velocity of the passing feed water, keeping back the free oil in the traps.

In reply to Mr. Hutchinson, it may be possible that the higher steam consumption is due to a certain extent to the valve cages, but not much; more to the small dimensions of the intermediate valves. I must admit that the Uniflow engine, theoretically, is better than any other type, because the L.P. cylinder of the Uniflow engine works under the best possible conditions. Whether the Uniflow principle can be used with the Lentz engine is a question which I should not like to answer yet, because there are several points to be considered when the "Woolfe" principle is to be used in combination with the "Uniflow" principle, but if we could arrange to alter the dimensions of the cylinders, it might be possible to use the Uniflow principle as well. As regards the suggestion of the water jet for lubrication purposes, I may say that I know of Mr. Visker's system and I can readily answer Mr. Hutchinson by saying that this system cannot be adopted for our engines as it requires a turbine feed pump, in order to obtain a constant water jet in the steam flow, whereas we have reciprocating feed pumps.

As regards valve distortion, I have no experience of this, but I know of cases where other Perlit castings have distorted rather considerably. When increasing the steam pressure and temperature and making the engines larger we shall however have to change over from ordinary cast iron to another material, such as Perlit; but perhaps we have not found the right material yet.

Mr. Hutchinson makes a comparison between the manœuvring capabilities of the Lentz engine and the ordinary Diesel engine. I think the Lentz engine is far superior in this respect. I have never seen a medium-sized Diesel engine which could be reversed within six seconds, with the exception of the smaller type of solid injection Diesel engines.

Mr. Ward has asked for particulars as regards the breadth and depth of the grooves in the valve spindles. To answer this question I may here refer to Fig. B appended to this discussion.

Feedwater Oil-Separator.

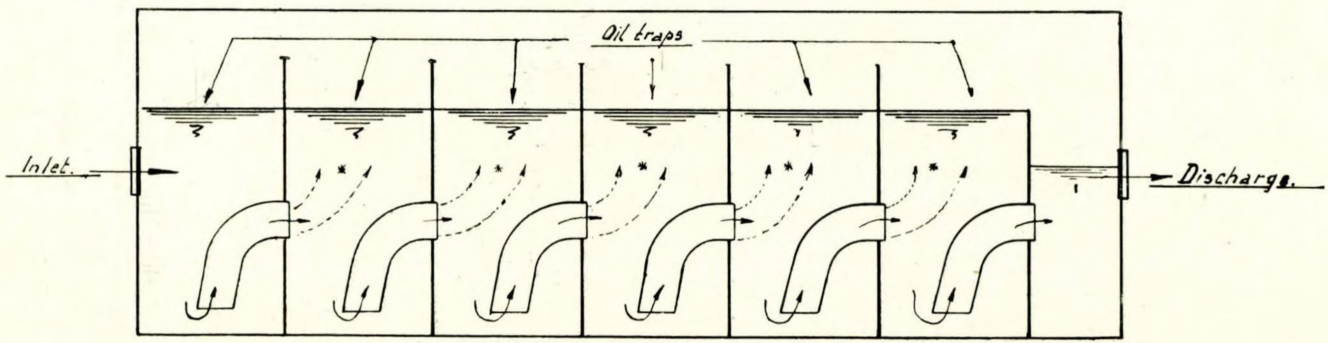


Fig. A.

Lubrication is provided for the h.p. valve spindles only. If we refer to Fig. 4, which shows the compensator and the lower part of the valve spindle, it may be seen that there is no packing at all. We have used packing in the first Lentz engines, but

Valve Spindle

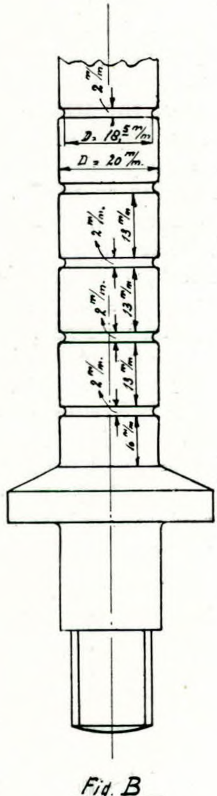


Fig. B

we have found that the valve spindles were apt to seize up in the packing so that the valves did not move at all. After doing away with the packing we have experienced no more difficulties in this respect. Also the steam pressure is not so high as to necessitate the use of packing.

Mr. Ward has also asked details about the balancing of the engines, and as I have already stated, we have had no difficulties due to vibrations of the engines. On the contrary we have always found them to vibrate less than the ordinary slide valve engines.

Eng.-Lieut. Comdr. A. J. Elderton refers to Woolfe's invention of this type of compound engine as I have also remarked in my paper. I was interested to learn from his remarks that trouble with feed water, in connection with water-tube boilers, has occurred through scale formation and not through oil deposit, whereas our experience shows the contrary, but in Mr. Elderton's case the Scotch boilers showed the damage caused by scale formation and not the water-tube boilers. I am also inclined to believe that perhaps the higher rate of evaporation used in boilers for naval purposes as compared with boilers for the mercantile marine is due to the fact that no oil deposit is experienced with the former kind of boilers. Also the water circulation in a Scotch boiler is quite different from the circulation in water-tube boilers, and for this reason there must also be a difference in performance between the two systems. As regards the engine designed by Prof. Strumpf, which is known to me, I can only say that in my opinion piston valves have been adopted for this special type of engine only for the purpose of simplification, Prof. Strumpf using one valve gear for the steam distribution of two cylinders (one H.P. and one L.P.). But it must be remembered that this simple solution has also drawbacks, as regards leakage of steam and also the slow movement of the piston valves moved by eccentrics, as compared with poppet valves moved by cams.

In conclusion, I may answer Mr. Elderton's remarks on the steam consumption figures by saying that I cannot accept his views on valve distortion being the cause of steam losses with poppet valves, as with land engines the poppet valves have proved to be far superior to slide valves for some time past. As regards the effect of the temperature of the steam on the valve springs I can readily say that I have never experienced any trouble, the valve springs being placed outside the valve chests in open cages, which are kept relatively cool.

The Chairman: You will no doubt share my opinion that this paper will be an outstanding acquisition to our Transactions, and Mr. Muller may be assured that it will be gratefully appreciated by our widely scattered members when it is subsequently issued in the Journal. In concluding this meeting I have much pleasure in proposing that we accord to Mr. Muller a very hearty vote of thanks for his interesting and valuable paper, and the most enjoyable evening he has afforded us; I am sure that your reception of my proposal is a foregone conclusion.

The vote of thanks was carried with applause, and a vote of thanks to the Chairman was also carried unanimously on the proposal of Mr. A. Cross.

Notes.

*From the "Mechanical World and Engineering Record" of January 18th, abridged:—

Electric Brakes for Industrial Service described.

For direct-current service, brakes are built from 1 to 300 h.p., and are magnet-operated. They are of simple design and rugged cast-steel construction. Fig. 1 is a sectional diagram of a d.c. brake of the M type by the Igranic Electrical Company Limited. This brake is applied with a quick steady

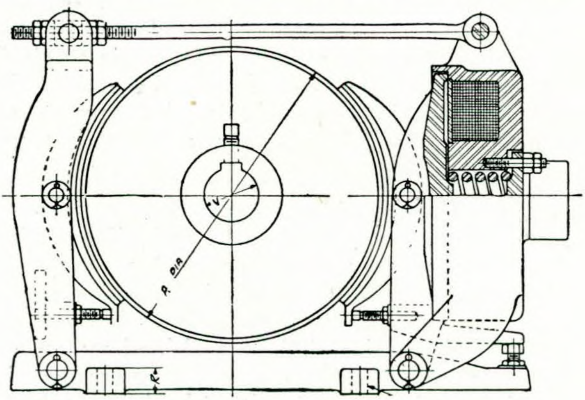


Fig. 1.—Type M Brake for D.C. Service.

pressure which brings the motor to rest in the shortest possible time consistent with safety by means of a spring, which, situated in the centre of the coil, and eliminating all toggles, bell-cranks, and levers, tends to force the magnet and armature apart. The force exerted acts directly in line with the centre of the brake-shoes, so that when the brake operates, the wear

* The Editor is a Member of the Institute.

on the linkwork is reduced to a minimum, and the retarding torque on the brake-wheel is the same in both directions of rotation.

Another feature which tends to minimise wear is that the armature and magnet are both movable, and rotate on the same centres. This construction, together with the short magnet stroke, reduces the angular movement on all bearings to less than 1°, and eliminates side friction. The very small air-gap on which the magnet works increases the efficiency, and the projection on the outer pole shoe tends to produce silent operation.

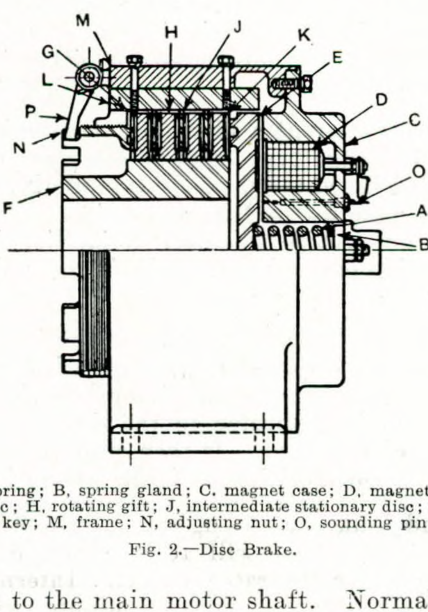
Adjustment for the braking intensity is obtained by varying the compression on the spring in the centre of the field. Special wrenches are unnecessary for either this or the brake-lining adjustment. There is no necessity to disturb the alignment between motor and brake for inspection, as almost the only point needing observation is the wear on the brake linings, which can be compensated for by means of nuts on the tension rod above the brake-wheel. Moreover, if it becomes necessary to take out and replace the brake-shoes the removal of one pin for each shoe is sufficient, and the dismantling needed to permit the removal of the motor armature is of similar simplicity. The withdrawal of one pin at the end of the rod to be turned back, and the hinged brake shoe-arm swung out of the way, permit the motor armature to be easily removed.

Series-wound brakes are constructed for either half-hour or one-hour duty. They will release with 40% of full-load motor current when set for the rated torque, and will remain released with 10% of full-load motor current. When operated at rated duty the temperature rise of their winding does not exceed a safe value. Continuous duty series-wound brakes can also be constructed. They require 80% of full-load motor current to release, and have the same torque and temperature rise of the winding as the continuous-duty shunt-brakes.

Shunt-wound brakes are designed for either intermittent or continuous duty. They will release with 80% of normal voltage when set for the rated torque. Intermittent duty is defined here as current on for one minute, and off for one minute, or its equivalent. However, the longest application of voltage should not exceed half an hour. When operated under these conditions the temperature rise of the intermittent-duty windings does not exceed a safe value. To reduce the inductance and make the action " snappy " shunt windings are wound for about half-line voltage, and are fitted with a reducing resistance.

The use of disc-brakes for direct-current service is confined primarily to those installations where the conditions demand a fully enclosed structure. Occasionally disc-brakes are specified for other reasons, special mounting arrangements, very limited space available, and others; but for the majority of installations, brakes of the shoe type will show greater capacity and handle more work at a lower maintenance cost than will disc-brakes.

The working parts of the disc-brakes (see Fig. 2), weatherproof operating magnet, heavy steel compression spring, and stationary and rotating brakes, are all assembled compactly in an enclosed case. The stationary discs are faced with a metallic asbestos brake lining, and are keyed to the hub, which



A, compression spring; B, spring gland; C. magnet case; D, magnet coil; F, hub; G, end stationary disc; H, rotating gift; J, intermediate stationary disc; K, friction lining; L, frame key; M, frame; N, adjusting nut; O, sounding pin; P, lock.

Fig. 2.—Disc Brake.

is itself keyed to the main motor shaft. Normally the spring pushes the magnet armature away from the field, and forces the two sets of discs into frictional engagement. The pressure exerted by this spring can be varied to suit the load conditions. The brake is released by energising the magnet, the spring being compressed, and the pressure between the discs relieved. The rotating discs are then free to turn with the motor armature.

The intensity of the braking force is regulated by varying the compression on the heavy spring placed in the centre of the field. For this purpose suitable adjusting nuts are provided at the back of the magnet case. Lock-nuts prevent any change in this adjustment. A large nut on the motor end of the brake is provided to adjust for wear on the brake linings. The amount of wear on the linings can be checked at any time by means of a sounding pin which projects through the magnet case. A lock prevents the nut from turning after the adjustment has been made.

Disc-brakes are series-wound for either half-hour or one-hour duty. They will release at 40% of full-load motor current when set for the rated torque, and will remain released at 10% of the full-load motor current. When operated at rated duty the temperature rise of the windings does not exceed 75° C. These brakes are also shunt-wound for either intermittent or continuous duty.

For alternating-current a reversible shoe-brake, operated by a special squirrel-cage type polyphase torque motor, is used. This type was designed to act smoothly, quietly, and positively, and has found wide use on lifts and hoists. They are usually recommended for service wherever reliability is essential, or where a solenoid-operated a.c. brake is too noisy or unsatisfactory.

The construction of the a.c. or RS brake is very simple. A small pinion on the torque motor engages with a toothed sector, which is linked to the arms carrying the brake-shoes. When the torque motor is connected to the line the motor revolves until the brake is released. It then stalls and maintains the brake in the released position until the power is disconnected. For each cycle of operation the motor turns approximately two revolutions. The brake is applied by means of a heavy spring, the tension of which can be varied to suit load conditions. Fig. 3 shows a section of the RS brake.

These brakes will release when set for full-rated torque, with 80% of normal voltage impressed at the terminals of the torque motor. The torque motors used on intermittent-duty brakes are designed for one-half time duty, whereas those used on continuous-duty brakes will remain across the line continuously without overheating at the rated voltage.

When these brakes are used on reversing service it must be remembered that the torque motor should be connected to the line between the main switch and the reverse switch on the

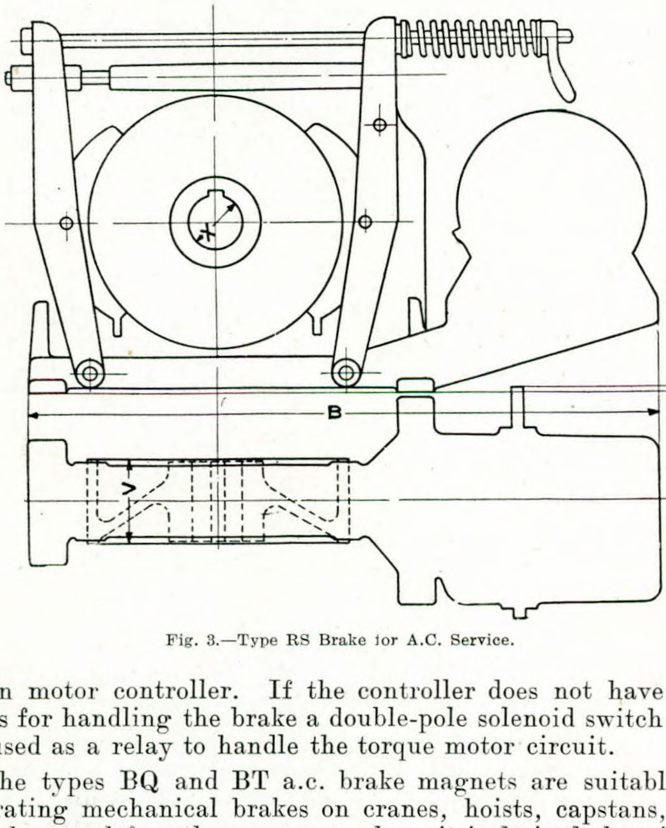


Fig. 3.—Type RS Brake for A.C. Service.

main motor controller. If the controller does not have contacts for handling the brake a double-pole solenoid switch may be used as a relay to handle the torque motor circuit.

The types BQ and BT a.c. brake magnets are suitable for operating mechanical brakes on cranes, hoists, capstans, and winches, and for other purposes where it is desired electrically to exert a definite pull through a limited resistance. The magnets are arranged so that when the current is switched on, the solenoid action causes the plunger to lift a weighted lever, which relieves the brake-wheel of pressure. As soon as the current is switched off the plunger drops and allows the weight on the lever immediately to tighten up the brake. An air dashpot is provided to minimise the shock and ensure a steady action of the brake. The magnets are arranged for pulling action only. They have protected frames which are rainproof, and are suitable for working in the open, but are not water-tight, and must not be installed in positions liable to submersion.

Ironclad solenoids are designed for use wherever straight-line motion must be produced electrically, and are used for operating brakes, clutches, and similar devices. The solenoid consists of a bobbin-wound coil enclosed in a cylindrical cast-iron pot with a tight-fitting cover over its open end. A heavy brass tube, which serves as a guide for the plunger, passes through the coil bobbin, with a tight fit in both cover and case. Inserted in one end of this tube is a loosely fitting plug, which is faced with a 1/16th inch brass washer, and is provided with

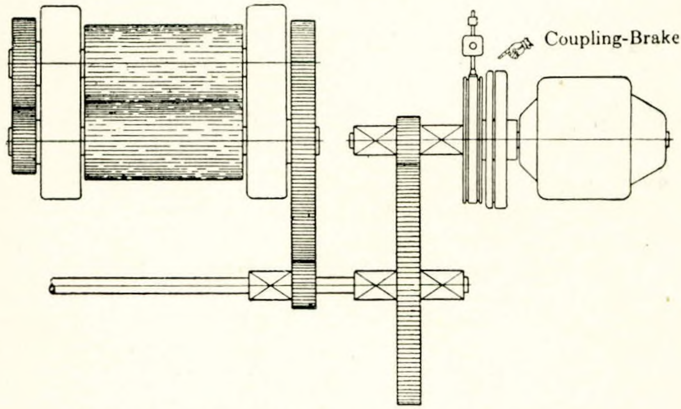


Fig. 4.—Typical Rubber Mill Drive with Magnetic Clutch Brake.

a shoulder to limit its entrance. A cast-iron cap is fitted over the plug in such a way that it prevents it from leaving the tube, but allows it considerable end motion. The steel plunger has a loose sliding fit in the tube, and engages the plug at the end of its working stroke.

The use of a floating plug eliminates the hammer blow and the accompanying shock and noise which are characteristic of solenoids having rigid stops.

Magnetic clutches are often used in conjunction with magnetically released band-brakes. In this construction the hub carrying the armature member of the clutch also carries the brake-wheel, which is encircled by a band lined with a friction material consisting of woven asbestos and brass wire. The friction band is designed to be released by means of a solenoid connected in parallel with the winding of the clutch, and to be applied by means of a weight on the end of the brake lever. When the magnetising winding of the clutch is de-energised by the tripping of one of the safety switches, that of the brake solenoid is also de-energised and the brake thus applied. The driving power is thus cut off, and the brake applied instantaneously, so that the equipment is brought to rest in a period of time which will prevent injury to workmen.

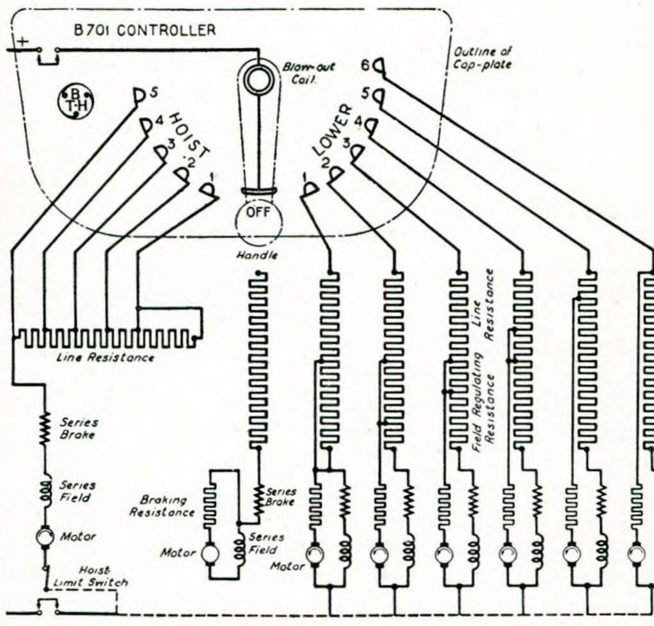
This type of brake has found special application in the rubber industry, where the magnetic clutch is very popular, and in this connection the figures of the following tests carried out in a well-known rubber mill in this country may be of interest. Three rubber mills (20in. × 22in. × 60in.) were driven from a lineshaft by a 200 h.p. 590 r.p.m. motor geared to it. The speed of the lineshaft was 100 r.p.m., that of the drive rolls 21 r.p.m., and that of the front rolls 13·23 r.p.m., giving a friction ratio of 1·45 : 1. With the motor running at full speed and all the mills without load, the equipment was shut down by disengaging the magnetic clutch between the driving motor and its pinion, and simultaneously applying the brake on to the driven side of the clutch. The chronograph used indicated that the movement of the drive-roll periphery, subsequent to the operation of the cut-off device, could be made as small as 4 in. This is a sufficiently quick stop for safety, as it does not cause shock to the machine.

On cranes an efficient method of controlling the lowering speed is by dynamic or electric braking. This can be done when the mechanism permits the load to drive the motor when lowering, thus causing the motor to generate and serve as a variable braking device.

It will be seen from the simplified diagram of connections Fig. 5 that the resistance, series-brake solenoid, and series field are connected in series across the line whilst lowering, and that the armature, with a breaking resistance in series with it, is connected in parallel with a portion of this circuit. A movement of the controller cylinder from the off position increases both the voltage across the armature and the speed of the motor.

Under ordinary working conditions when lowering, the load on the hook will determine whether power is to be applied to drive a light hook downwards or dynamic braking is to be applied to check the speed of a heavy load. In the latter case the motor would generate and send current round a closed circuit, as shown in the diagram, thereby unloading the motor and producing a braking effect.

The heavier the load the greater the e.m.f. and field strength will be. This produces a braking action which rapidly increases with the speed, until the torque exerted by the load and the braking effect of the motor are counterbalanced.



Electric Brakes.—Fig. 5.—Connections for Dynamic Braking Controller (B.T.H. Company).

The dynamic braking type of controller gives complete control of the load when lowering, as well as when hoisting. If the supply current should fail when lowering a load heavy enough to overcome the crane mechanism, the load can still be lowered under perfect control, as the motor acts as a self-excited series generator. This is, of course, a valuable feature of electric braking control.

Further, a Weston type of brake is not required with these controllers. If a mechanical brake exists it should be put out of action, as this type of brake cannot be used with this control. A reference to the connections at the off-position will show that in moving from the first point lowering to the off-position, a closed circuit is still retained for the armature and field, external to the series solenoid brake, so that the motor is still acting as a brake for retarding the load. This saves wear on the solenoid brake, which is used only for finally bringing the load to rest.

Controllers of this type are suitable for use with series-wound brake solenoids, the latter being designed to lift at 40% of full-load current. All cases in which it is desired to use shunt solenoids with dynamic braking controllers should be studied very carefully in collaboration with the controller manufacturers.

If the horse-power transmitted exceeds the horse-power rating of the brake chosen by the above method, the brake must be selected on a horse-power basis instead of on torque. Brakes selected in accordance with the above procedure will be found satisfactory for all normal conditions, though severe service will sometimes demand a larger brake. In all cases it is as well to place complete particulars of the contemplated installation before the brake manufacturers, and leave the matter to them as far as the submission of proposals is concerned.

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*Coal-Dust Firing.—At a meeting of the Institute of Fuel, held in London on January 16th, Dr. R. Lessing in the chair, Messrs. Berg and Erich Vogt, of Cologne, read a paper entitled "Coal-Dust Firing for Boilers and Industrial Furnaces." which was illustrated by numerous lantern slides. The authors, in the course of their remarks, pointed out that coal-dust firing had been introduced on the Continent during the past six years with such great success that its use in many cases could no longer be left out of consideration when installing new or modernising old plant. The saving in fuel which coal-dust firing brought with it was so great that motives of economy offered the strongest recommendation for it use. In various types of firing practised hitherto, such as, for instance, grate or semi-gas firing, or in the case of gas producers, it was still necessary to use expensive fuels such as nut or lump coal. As, however, in the case of coal-dust firing, the coal had to be

* Members who are interested in this subject can obtain a copy of the paper from the Institute of Fuel or a full report from the "Iron and Coal Trades Review."

pulverised before being used, it followed that coals which were cheaper to obtain, such as slack or pea coal, could be used with advantage. This slack or pea coal, which to-day did not find a sufficiently ready market, could, with the help of coal-dust firing, be used effectively for the home industries, leaving the valuable nut and lump coal free to be exported. Naturally it is necessary to ascertain carefully in each case whether coal-dust firing was the correct method for the purpose under consideration. Coal-dust firing, however, had been adopted with great success for re-heating furnaces, through furnaces, continuous furnaces, and for boilers of all types.

The authors then proceeded to throw on the screen illustrations of typical examples of coal-dust-firing equipment, including plant for drying and pulverising; they also showed several types for furnaces for use in boiler firing and in industrial works.

Discussion.—The Chairman said one point he would like to stress was that, in Germany particularly, as mentioned by the authors, a great deal of coal dust, mainly in the brown-coal districts, was carried to the works in a condition ready for the burner, having already been prepared at the colliery. A beginning had been made in this country in collecting dust from coal-cleaning plants, and transporting it in dust wagons. He pointed out again, as he had already done in a paper read before the Institute, that there was available in this country a quantity of from 20 to 25 million tons per annum of natural coal dust, which did not require to be ground any further, and would be ready, if conveyances could be found for it, for the burner direct. That was a point of very great importance, when it was considered that to-day, in the whole question of coal-dust firing, the milling of the coal, the grinding of it, the maintenance and replacement of mills, represented the most serious part of the problem. If that problem could be solved, the burning of the coal dust was a comparatively simple matter, and the advantages to be derived from it could readily be realised.

Properties of Engineering Materials.—An interesting paper on "The Relations between the Properties of Engineering Materials and their Ultimate Structures" was read by Mr. G. W. Todd before the North-East Coast Institution of Engineers and Shipbuilders at Newcastle last week. In the first part he reviewed the atomistic doctrine of matter, with reference to the kinetic theory of gases and equations of state. He pointed out that mutual interactions of the Van der Waal type between the ultimate particles of a gas were totally inadequate to explain the fields of force in the neighbourhood of the constituent particles of a solid. By considering the atoms to be arranged on a space lattice it was possible to produce an equation of state for a solid. The introduction of the quantum theory, he went on, led to expressions from which the specific heat of a solid could be obtained in terms of its absolute temperature and the characteristic frequencies of vibration of its atoms. Metals, which were the most important structural material of the engineer, were too often regarded as isotropic. The fact that they consisted of minute crystals with random orientations was all-important in connection with their elastic properties. Mr. Todd then considered the evidence of X-ray analysis, and gave some account of the electrical theory of a crystal lattice. He described experiments in which elastic and plastic deformations of a single crystal were "watched" by X-rays, and concluded his paper with some observations on alloys.

The Representative Committee interested in the Shipping, Engineering and Machinery Exhibition to be held at Olympia, September 12th to 28th, met on June 18th, when Mr. Bridges, the organiser, reported that the number and quality of the exhibits booked for places were such that the success of the Exhibition was assured. Notices and invitations had been forwarded to the oversea Dominions and Colonies of the British Empire so that the interest might be wide spread and bring forth a fruitful issue.

The opening Ceremony, it was hoped, would be performed by His Grace the Duke of Northumberland, who had accepted the office of President.

Several suggestions were made by members of the Committee and considered. It was deemed desirable to encourage exhibits from the Fishing Industry, Coasting Vessels, River Steamers, Light Ships, Tugs and Dredgers, in order to embrace as wide an area of the shipping community as possible. It was hoped that the shipping companies would be invited to show models and illustrations of their various types of vessels. It would be a good asset from an historical point of view to obtain a loan collection of drawings, pictures and models of vessels and engines dating back to the *Comet* or the earlier days. This would be a desirable addition for many visitors, interested specially in artistic and inventive genius; it would also be of special interest to juniors. The educational aspect of these exhibitions has always been kept in the foreground, and the rising generation of shipwrights and engineers have always been encouraged to visit the exhibition to gain the advantages of examining details and taking notes with a view to writing essays, or committing their thoughts to paper for further development with later experience. The Sir Arch. Denny Award was founded on these lines of thought.

Members who are specially interested in the mechanical and transmission losses in marine engines, shafting and propellers are referred to the "Journal of Commerce and Shipping Telegraph" Supplements of June 5th and 13th, which contain Parts 1 and 2 of a paper by J. Hamilton Gibson, read at the North East Coast Institution of Engineers and Shipbuilders. The subject is not only of interest to all concerned in the efficient and best output of power from start to finish, but is laden with controversial elements which ought to be fully thrashed out to a standard. There are many debatable points such as the composition of cylinder liners, pistons, shafting, bearings, propellers, rudders, also lubrication.

In the same Journal there is a series of articles by A. C. Hardy on "The Motor Ship Week by Week," and the movements in different parts of the world of the vessels with internal combustion engines; in June 6th the Coast Line of South America and Brazil are dealt with, and in June 13th the comparison is made between the turbo-electric liner and the motor ship.

The following descriptive notes referring to the reconstruction of the Blue Star Liner and to building of the Whaling Factory Ship are of interest, and the latter may be of value for further information by members who made enquires on the subject of Whaling Factories, and where situated, some time ago:—

"A remarkable vessel, the first of her kind ever built, and which is expected to revolutionise the whaling industry, was launched last week by Messrs. Workman, Clark (1928) Ltd., Belfast. She is the *Kosmos*, built for the Kosmos Whaling Company, and will be used as a whale oil factory and oil tanker.

"The naming ceremony was performed by Mrs. Christensen, the wife of Mr. C. F. Christensen, the designer and naval architect for the vessel in conjunction with the firm of Messrs. Arnesen, Christensen and Smith, of Newcastle-on-Tyne. The launching party consisted of Mrs. Christensen, Miss Boe, Mr. Anders Jahre (managing director of the Company), Mr. Harlofsen der Lippe, together with officials of the Whaling Company, and a number of the builders' officials and guests.

"The *Kosmos* is a vessel of about 32,000 tons displacement and 550ft. in length, and is constructed on the longitudinal system to the highest requirements of Lloyds Register and the Norwegian sea control regulations. The whaling factory itself is situated in the upper 'tween decks which are over 15 feet deep, and is equipped with the latest plant for dealing economically with the maximum catch of whales. The weather deck above the factory has been arranged clear of obstructions to facilitate the handling of the whales and the cutting up. The vessel is fitted with numerous powerful winches capable of handling loads up to 40 tons, in conjunction with special derricks.

"The propelling machinery has been built by Workman, Clark (1928) Ltd., and consists of quadruple expansion engines taking steam from five cylindrical oil-fired multitubular boilers working at 250 lbs. pressure under forced draught, and with superheated steam. In the engine-room there are a number of new features designed to cope with the special trade on which the vessel will be employed in the Antarctic seas.

"Accommodation is provided for over 300 with special facilities for storage and cooking provisions necessary for the long voyage and service, and in this connection reference might be made to the enormous fresh water distilling plant.

"The vessel is the first of her kind specially built as a whaling factory."

The reconstruction of the *Arandora Star* from a meat carrier to a luxurious passenger steamer was carried out by the Fairfield Shipbuilding and Engineering Co. at a cost of £200,000, and according to the description the passenger cruiser is a creditable vessel.

The address by Lord Kylsant at the Annual Meeting of the Royal Mail S.P. Co., is worthy of study—see also in June 13th.

In "The Electrical Review" of May 3rd, the electric auxiliaries of the *Rangitiki* are described and illustrated; these were referred to in our June issue. The illustrated article on Electric Brakes in "The Mechanical World" is available for consideration as an appliance in connection with the electric driven machinery and what dependence can be placed upon brakes.

There is also an article on the Hydro-Electric Works in course of construction on the River Jordan in Palestine, with very good illustrations of the water flow at different parts of the land.

The extensions that have been made in the Lots Road Power House since we paid a visit to it some years ago are outlined in a short article in the April 5th, "Electrical Review," with references to the further extensions under way. It is stated that 925 tons of coal per day is used by 32 boilers delivering 10,000,000 lbs. of steam per hour to nine turbo alternators, which carry 100,000 k.w. of load with an output of 1,300,100 k.w. hours daily at a pressure of 11,000 volts. Some 431 miles of h.p. cable deliver the energy generated to 43 sub-stations ranging from 1,800 to 10,000 k.w. capacity and supply 91 miles of railway and 49 miles of tramway, which carry 2,000,000 passengers daily.

The electrical salinometer fitted in the R.M.S. *Statendam* is also described and illustrated in the April 5th "Electrical Review." There is only one indicating instrument on the control board which is calibrated to read from 0 to 70 milli-grammes of salt per litre. The temperature compensation is for from 80° to 130° F. In the event of excessive salt being present a warning lamp commences to glow and should the excess increase the relay operates and rings a warning bell. The amount of salt in the water in any of the circuits can be indicated.

In "The Electrical Review" of May 10th, there is an article of value on "The Training of Apprentices," with reference to the Pamphlets issued by the City and Guilds of London Institute outlining its courses for electrical installation work revised to date. The article aimed specially to advocate the best and most efficient training for electrical work, but many of the paragraphs can apply with advantage to all classes of industrial work and it is recommended for the consideration of parents and guardians of the young as well as to the apprentices and students.

In April 19th issue there is an illustrated detailed description of the Stretford N.D.C. electricity generating station fitted with water-tube boiler using powdered coal. The steam pressure is 175 lbs. per sq. inch and rated at an evaporation of 25,000 lbs. of water per hour with chain grate stokers. The two burners are of the Buell type. From the overhead bunker the coal-dry slack is fed through a magnetic separator to an automatic feeder, whence it passes into the mill. The powdered fuel is then drawn by an exhauster fan through the classifier into a pipe leading to the burner. It is worthy of note that the mill is so constructed that coal which has not been reduced to a sufficiently small size automatically passes to the inlet and again goes through the mill.

There is a description in the April 26th issue of the experimental work at the Birmingham Corporation's Electricity Station, which has demonstrated amongst other things, that the use of powdered coal results in a higher combustion heat efficiency in the boiler than is obtained with mechanical stokers.

In the Liverpool " Journal of Commerce and Shipping Telegraph " Supplement of June 20th, there is a full descriptive article on the *Statendam*, giving details of the hull, accommodation for passengers, main and auxiliary machinery.

A new simple balanced rudder is also described. It has been produced by the Deutsche Werft of Hamburg, and is said to be both reliable and cheap, having been in use for nearly two years on various types of vessels with good results. The method of constructing the stern post for the Simplex Rudder does not differ to any extent from that of the ordinary single screw vessel. The ordinary type of rudder post is rectangular, that of the Simplex type is cylindrical, connected to the ordinary rudder post by strong flanged couplings at the upper and lower ends, thus forming a rigid stern frame. This cylindrical stern post is incorporated in the stream lined body of the balanced rudder and serves as its rotary axis, pivoted by two strong neck bearings. The cross sectional shape of the rudder area fore and aft of the rotary axis is so calculated that the system of water pressing against the hull must pass through the rotary axis at all rudder angles, the result being that for moving the rudder, only the frictional resistance has to be overcome. This is illustrated in M.S. *Kulmerland*, Hamburg-America Line, of 10,000 tons, 14 knots speed, a 4 h.p. steering engine being ample for working the rudder, whilst an ordinary blade rudder requires 35 h.p. The lack of steering efficiency when running astern by other semi and fully balanced rudders is entirely eliminated, due to the whole of the rudder area lying in the direction of the effective stream, whether running ahead or astern, even at the smallest rudder angles. The method of fitting admits of easy access to the propeller, and of the drawing of the shaft. A great saving in weight and cost is claimed by the adoption of this rudder and more than 20 vessels have been equipped with it, including two conversions from an earlier well known type of balanced rudder.

SHIPBUILDING FOR THE SHIPOWNER. FRAME SPACING AND DOUBLE-BOTTOM FRAMING.—This is a subject which has been dealt with very fully in a set of interesting articles which have appeared in successive weeks in the Shipbuilding and Engineering edition of the "Journal of Commerce."

EXPORTS OF SCRAP IRON.—Attention is called to the large export of scrap iron from Britain in spite of the fact that the requirements of our foundries are greater than can be met. It is therefore well to call attention to the exportation of an asset which is of value to the home market.

In "The Shipping World" of April 24th, there is an account of an interesting repair to the reduction gear shaft of the *Matakana*, which worked loose from the wheel on the outward voyage. A temporary repair was made by drilling and tapping holes, then inserting screwed plugs at the junction between the shaft and the boss. This carried the vessel home, when the shaft and wheel were disconnected and the wheel was bored out true; the spare shaft was built up by the Fescol process to allow for the bore and machined to a good fit. The loose shaft was also built up by the process, turned and kept for spare.

In the same Journal there is a photograph and appreciative notes of the late Joseph Havelock Wilson.

From the "Engineer," of June 28th, 1929:—

GERMAN LINER *Bremen* AT SOUTHAMPTON.—As the large dock at Hamburg—the only one in Germany capable of taking very heavy ships—is occupied at present by the *Europa*, the 46,000 ton North German Lloyd liner, which was seriously damaged by fire last March, her sister ship, *Bremen*, is to be docked at Southampton for the final survey of her hull before being delivered to the owners. According to present arrangements, the *Bremen* will arrive on Monday next, July 1st, at a very early hour, and will be placed as soon as possible in the great floating dock belonging to the Southern Railway Company, which has a lifting capacity of 60,000 tons. It is anticipated that the survey will be completed in two days, after which the ship will return to Bremen to be made ready for her maiden voyage across the Atlantic, beginning on July 16th. It is no secret that her owners expect this vessel to establish a new speed record on the Southampton-New York route.* She was laid down in the Weser Shipyard on June 18th, 1927, and was launched on August 16th of the following year, but her completion was delayed by the prolonged shipyard strike in Germany which began last autumn. She has a length of 933ft. overall, a beam of 100ft., and is propelled by quadruple-screw, single-reduction, geared turbine machinery of 96,000 S.H.P., taking steam from oil-fired boilers. The contract speed is $26\frac{1}{2}$ knots, which will probably be improved upon when the engines have been " run in." The design of this ship and her consort has been enveloped in a certain amount of mystery up to now, but the North German Lloyd announces that complete details will be released as soon as the *Bremen* has begun her maiden voyage. Her cost is officially stated to be £2,600,000.

The new tug for Durban Harbour, which was built by Sir W. G. Armstrong, Whitworth and Co., has arrived safely at her destination after a voyage of thirty-three days. She is 170ft. long by 34ft. 6in. beam and has engines of 3,500 horsepower. Her speed is 13 knots. The boilers are of the Babcock and Wilcox type.

From the " Engineer," June 21st, 1929:—

THE FORMATION OF SCALE IN BOILERS.—The most troublesome of all the scale-forming constituents of feed-water is undoubtedly calcium sulphate. Sulphate scale is a hard, dense deposit almost like porcelain; it is particularly difficult to remove from the metal surfaces, and is probably responsible for more bent, blistered or burst tubes than all other causes put together. The presence of calcium sulphate also renders other deposits more dangerous, for those that would be porous or friable by themselves are entangled by its needle-like cry-

* This has now come to pass, and the news is being circled round.—J.A.

stals and consolidated into a hard layer capable of giving more trouble than either deposit singly. The importance of calcium sulphate as an impurity of feed-water has led to numerous studies of its nature and effects. Three forms of it are found in boiler-scale, ranging from gypsum with two molecules of water of crystallisation to the anhydrous salt with none. All three forms produce deposits which are essentially similar. The first two, however, are associated with temperatures lower than those met with in modern steam practice, and as they both tend with time to pass automatically into the anhydrite, the latter alone is of practical importance to boiler users. All forms of calcium sulphate are thrown rapidly out of solution as the temperature rises, water which can hold about 650 parts of the anhydrite per million at atmospheric boiling temperature depositing as much as 91·5% of the salt by the time a temperature of 220° C., or a boiler pressure of about 320 lb. per square inch is reached.

Two theories have been advanced as to the way in which the sulphate is deposited. According to one belief, as soon as the water reaches its limit of saturation, the salt comes out of solution in the form of minute particles distributed through the mass of the water, which eventually attach themselves to the heating surfaces and build up a thickness of scale. This, which may be called the colloid theory, has given rise to various attempts to prevent scale either by maintaining an electric potential tending to oppose the contact of the charged particles with the metal, or by adding other colloidal solutions with the idea of preventing the sulphate particles sticking together or to the metal surfaces. The alternative theory, which is that the scale is formed in position, appears to have been definitely established by Dr. E. P. Partridge and Professor A. H. White, who have embodied the results of some very interesting experiments in a paper contributed to the monthly journal of the A.S.M.E. By examining microscopically the highly polished surface of a metal plate through which heat was being transmitted to water containing calcium sulphate in solution, it became evident that scale always started as a fine ring of minute crystals, marking the place where a bubble had been detached. From these rings needle-crystals grew outwards into the solution, became interlaced with similar crystals from adjacent rings, and so on until the whole surface was covered with a crystalline deposit. Experiments with air and other gases in solution, which were liberated as bubbles before the boiling point was reached, confirmed the view that a bubble of any kind was sufficient to start deposition, though in boiler practice steam bubbles alone need be taken into account. According to the views of the authors the mechanism of scale formation in steam boilers is somewhat as follows:—When boiling temperature is reached the film of water next to the heated metal begins to vaporise at some point. The surface under the vapour then becomes hotter still, owing to the insulating effect of the vapour. This local overheating causes the film of solution surrounding the dry spot to be evaporated, the bubble therefore growing until it becomes detached from the metal by its own buoyancy. When such a process takes place in a saturated solution of calcium sulphate, the fluid film at the edge of the dry spot becomes supersaturated by the increase of temperature, and is forced to deposit minute crystals in the ring where metal, vapour and water meet. These crystals are always in contact with a supersaturated solution, first on account of the evaporation of pure water into the bubble; and secondly, by the return of liquid now supersaturated, after the departure of the bubble. They thus tend to grow continuously as long as heat enters the solution through the metal.

If this view is correct—and the experiments of Messrs. Partridge and White seem to leave little room for doubt about it—the collodial theory is untenable, and electrical methods of preventing scale are founded on false premises. Many processes work, however, in spite of their theory being wrong, and investigations into electrical methods are being proceeded with.

On Friday, June 14th, 1929, at the June meeting of the Diesel Engine Users' Association, Mr. C. H. Faris read a paper on "Repairs to Diesel Engine Parts by Electro-deposition."

The author described a method of electro-chemical deposition which has been evolved and has been successfully used for building up worn or corroded hydraulic rams, compressor plungers, steam engine piston-rods, pump impeller shafts, and numerous automobile parts. While the cost of the deposition operation was less than that of replacement, additional satisfaction had been derived from the longer subsequent service obtained. It was pointed out, however that the process under discussion was not to be confused with that of ordinary plating, in which no real adhesion of the thin deposited layer occurred. In the deposition process referred to, very heavy deposits of nickel, and in certain cases of copper, chromium, cobalt, cadmium, and lead, could be obtained with perfect adhesion.

With regard to the question of wear, it was stated by Mr. Faris that the general idea that nickel is a soft metal was not borne out by the data obtained in actual service conditions. The melting point of nickel was given as 1452° C., and an average hardness figure would be 320 Brinell, though in special circumstances as high a figure as 370 Brinell can be obtained. The metal responded very satisfactorily to the Herbert pendulum hardness tester. Examples were given showing reduced wear and increased resistance to corrosion after the process had been applied to worn parts.

Dealing with matters of more direct interest to the Diesel engine user, the author said that it was worthy of note that in four new motor ships now under construction, all the inlet and exhaust valves were being reduced 0·020in. below the standard diameter on the spindle portion, in order to allow for a nickel deposit of 0·010in. Such treatment of the parts as a part of the manufacturing process probably ensured that the fullest possible advantages were derived from the process of deposition.

Other parts on which electro-deposition can be successfully carried out included fuel oil needle valves, plungers for fuel valves, starting and air inlet valves, air compressor parts, pistons, gudgeons, crank shafts, pumps, cam shaft journals and cams and other details, and it mattered not if the surface was iron, steel, or bronze. Further, localised treatment could be applied if required. The author stated that it was not advisable to fit a piston with a nickel surface into a liner, the bore of which has been surfaced with the same metal. Recent extensions to the plant with which he was concerned had made it possible to handle individual jobs up to six tons and up to 17ft. by 6ft. diameter, and to grind or turn parts 22in. in diameter, with a length up to 26ft.

From the "Engineer," of June 14th, 1929:—

Powdered Fuel Steamships. — On Friday, June 7th, there was launched from the yard of William Gray and Company, Ltd., West Hartlepool, the steamer *Swiftpool*, which is being constructed for Sir R. Ropner and

Co., Ltd., and is the first steamer to be equipped with boilers fired on the "Brand" powdered fuel system. The new ship is a modern cargo steamer, built to Lloyd's highest class survey, with a length of 434ft. 4in. and a beam of 54ft. 3in., and a deadweight carrying capacity of 9,000 tons. She will be propelled by triple-expansion steam engines, having cylinders $26\frac{1}{2}$in., 44in., and 73in. diameter, with a stroke of 48in. designed to work at a steam pressure of 180 lb. per square inch. The three single-ended boilers will be equipped with the latest type of Brand burners, pulverisers and distributors, and the ship will have a designed speed of about 11 knots.

THE PROPULSION OF SHIPS.—Nowhere, we venture to say, is the march of progress more rapid than in the domain of marine propulsion. Hardly a month passes without bringing some interesting item of news bearing on this subject. The contest between the steam engine in its manifold forms and the internal combustion motor is raging with unabated energy, yet the issue is still in doubt. Ships of unprecedented tonnage, to be equipped with one or other of the rival systems, have already been or are about to be ordered. It is an understood thing that the new White Star liner *Oceanic* of 60,000 tons, now on the stocks at Belfast, is to have Diesel-electric drive, a decision involving unheard-of developments in this method of propulsion, hitherto tried afloat on a very modest scale.

Further, there are definite forecasts of the building of one or more great Cunard liners, even larger than the *Oceanic*, which rumour credits with high-pressure steam turbines up to 160,000 S.H.P. Turning from plans to actualities, we find a German liner, the *Bremen*, on the eve of making a bid for the "blue riband" of the Atlantic; the twenty-two year old *Mauretania*, and the younger but by no means juvenile *Berengaria*, blithely breaking their own speed records, and the French Navy claiming speed supremacy by virtue of the 39·93-knot trial run of its new destroyer *Valmy*. Nor must mention be omitted of the P. and O. turbo-electric liner *Viceroy of India*, which lately completed a most successful maiden voyage from Tilbury to Bombay and back. Besides these outstanding events, there are others which, if less sensational, are of equal significance from the engineering point of view, such as the launch on the Clyde last month of the *Berwindlea*, the first vessel to be specially designed for burning pulverised coal, and the building of a large German warship to be fitted with internal combustion engines, in which the normal weight per unit of power has been reduced to an almost unbelievably low figure. Sluggish indeed must be the imagination which is not stirred by these happenings.

From the "Shipbuilder" of June:—

By desire of the Council on recommendation of a committee, the following is quoted by permission of the "Shipbuilder":—

BIOGRAPHICAL SKETCHES. MR. JAMES ADAMSON.—Few personalities in shipbuilding and marine engineering circles are better known, and none is more beloved, than Mr. James Adamson, the veteran honorary secretary of the Institute of Marine Engineers, who, in his 80th year, is to be found each day at the office of the Institute, for which he has done so much, from 10 to 5 and on meeting nights till about 9 o'clock. Marine engineers the world over, we venture to think, will rejoice to see the portrait which adorns the frontispiece of our present issue, and will read with interest this all-too-brief record of a busy life, so largely lived for others.

James Adamson was born in Stirlingshire on the 8th January, 1850. His grandfather was a shipbuilder at Aberdeen over a century ago; but the site of his yard being required for harbour use, he removed to Grangemouth. After his death, about 1860, his youngest son and a nephew carried on the shipyard and dry dock there, the ships built by them being launched on the River Carron. A grand-uncle of our subject—Thomas Adamson—was a shipbuilder at Dundee, vessels built by him including the *Seahorse* in 1834 and the *Forfarshire*, the crew of which were saved by Grace Darling and her father, a lighthouse-keeper on the Farne Island when that ship was wrecked off the Northumberland Coast in 1838. Later, Thomas Adamson removed to Alloa, and carried on shipbuilding there until his death.

The subject of this sketch was educated at schools in Falkirk and Alloa and at the Dollar Academy. The first year of his apprenticeship was served with a Mr. Taylor, blacksmith and millwright, of Falkirk, during which young Adamson had his first experience in the construction of marine engines. He then proceeded to Glasgow, and while working there he had a fall of about 30ft. into a ship's hold. On recovery from this mishap, and while still suffering from a damaged arm, he began drawing-office work, and afterwards served with Messrs. Alexander Stephen and Sons, Messrs. Rait and Lindsay, and Messrs. James Howden and Co. He also attended the Glasgow University for three sessions.

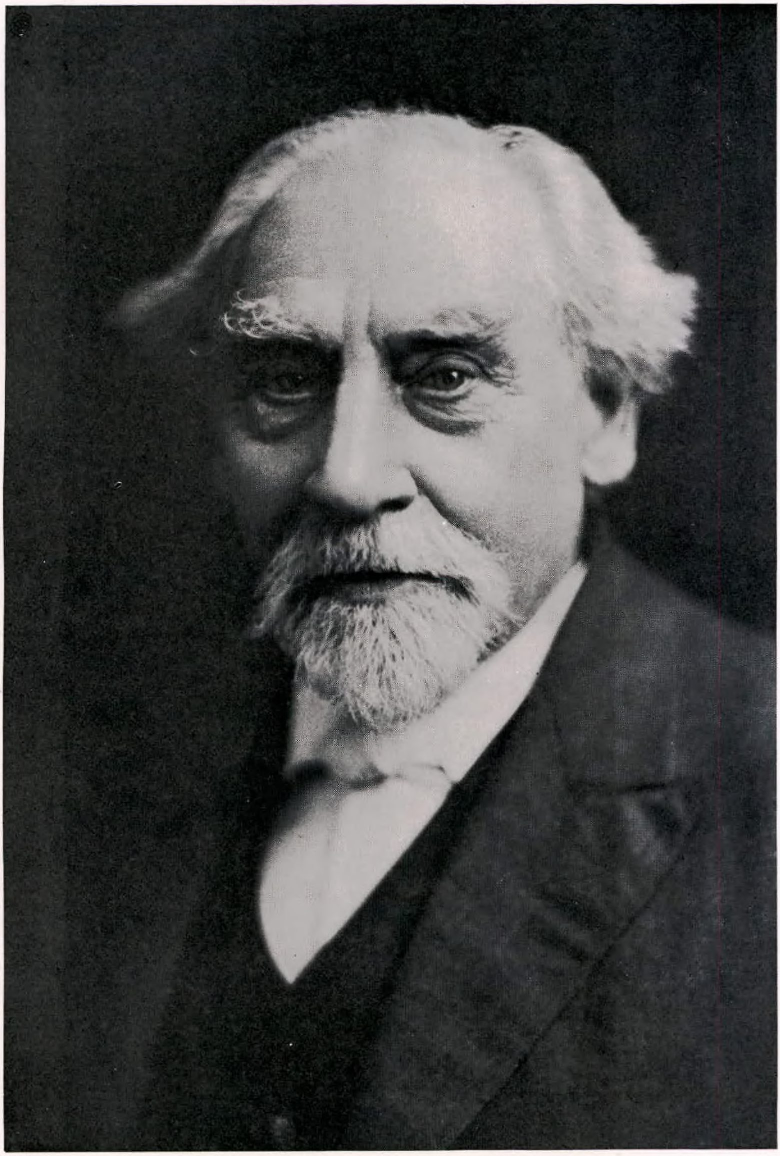
Removing to London, Mr. Adamson served as draughtsman with Messrs. J. and W. Dudgeon; and after the death of the head of that firm, he gained experience at sea as an engineer. During the period spent as a seagoing engineer, he visited the Principal of the Imperial College of Engineering at Tokyo.

About 1878 our subject obtained an appointment as draughtsman and assistant to Mr. Malcolm Campbell, superintendent engineer to the British India Steam Navigation Company and the Ducal Line; and on Mr. Campbell's death in 1889 he became superintendent engineer to the company at the Royal Albert Dock, London. As superintendent engineer he took a special interest in the boilers of the steamships under his charge, examining the interiors every voyage in order that he might see for himself the condition of the plating and stays. His opinion on marine boilers was highly valued, and when cases of doubt or difficulty arose outside his own special sphere his advice was often sought and willingly given.

In the autumn of 1888, several superintendent engineers and others associated with marine engineering in the neighbourhood of the Royal Albert Dock considered the question of founding a society for the benefit of marine engineers, and to afford them opportunities to meet and discuss experiences and their bearing on the work and maintenance of steamships. A meeting was held at Stratford, London, to examine the proposal, and a committee was formed (including Mr. Adamson) to give effect to the scheme. A reading room was rented on the 1st February, 1889, and members of the committee furnished it with papers and books. About two months later—on the 5th April—the first paper was read, the author being Mr. Arthur J. Maginnis, whose death took place at Liverpool in January of this year, as recorded in the February number of the "Shipbuilder." The subject of this paper was "Steering Gears"—a very appropriate one for the occasion, and in some respects the paper proved prophetic. The expenses involved in the foundation work were borne in the hope and expectation of progress, and were met by those who joined, each paying his subscription in advance in order to meet the outlay. The Institute of Marine Engineers, to give it its full title, was incorporated in July, 1889. The meetings, held fortnightly, were well attended; papers were read and discussed; and coal-testing was carried on weekly, samples being provided by chief engineers, who attended the meetings in order to discuss the characteristics of the coal tested with a view to arriving at the best methods of burning it. Undoubtedly important benefits accrued from these early meetings as they led to economical results in using many types of coal bunkered at ports all over the world. For the benefit of juniors and apprentices, certain evenings were also devoted to special lectures on various subjects with a view to widening their mentality, and classes were held to encourage study; while social gatherings, visits to works, and exhibitions of engineering appliances were among the other activities of the Institute.

In 1893 new premises were purchased at 58, Romford Road, Stratford, and several alterations were carried out so that the building might be suitable for the purpose in view, a lecture hall being provided together with a billiard room above. Prior to this step, and in order to meet the increasing membership, meetings took place in the city, generally at Gresham Hall or at the hall of the Royal Society of Arts.

Later, it became necessary to consider the advisability of obtaining a site for the erection of premises in the city, and meetings were held to consider ways and means. Subsequently a fund was opened, and donations were soon forthcoming; one of the founders of the firm of G. and J. Weir, Ltd.—Mr. James Weir—generously giving £1,000 towards the fund. At length a sufficient amount was in hand, and a site was purchased near the Mint, overlooking the Tower of London. In 1913 the foundation stone was laid by the then Lord Mayor of London (Sir David Burnett), Sir Thomas L. Devitt being at that time the President of the Institute. The following year the Institute removed into the new premises, the opening ceremony being performed by Sir Archibald Denny. In 1919 His Majesty the King was graciously pleased to accept the office of Patron. The list of the Presidents of the Institute include such honoured names as Lord Kelvin, Dr. Peter Denny, Sir William H. White, Sir Thomas Sutherland, Sir A. J. Durston, Sir J. Fortescue Flannery, Dr. John Inglis, Colonel J. M. Denny, Sir Charles A. Parsons, Viscount Pirrie, Sir David Gill (at one time Astronomer Royal at the Cape), the Duke of Montrose, Sir Archibald Denny, Lord Weir, Sir George G. Goodwin, Lord Kylsant and Sir Alan G. Anderson (the present President), to mention only a few at random.



Mr. JAMES ADAMSON.
One of the Founders and first Hon. Secretary of the Institute.
(Reprinted by permission of *The Shipbuilder*.)

ing to one who has been able to make a survey of this nature than the divergence of type of engineers who are in control of the machinery. It would appear to us that some shipowners, and especially those who are taking delivery of motor vessels for the first time, have not paid sufficient attention to the question of the choice of men with the right mentality for successfully operating Diesel machinery. In some instances we have found the control vested in engineers who frankly dislike this type of motor. However wrong we may feel their attitude to be, few will quarrel with them if they honestly hold this view; but the owners cannot be too strongly criticised for permitting such engineers to have the responsibility of controlling plant costing scores of thousands of pounds. We have always found the operating results to be less favourable than those in corresponding vessels in which the engineering staff is enthusiastic, and vitally interested in Diesel machinery.

The difference between the Diesel and the steam engineer is largely one of mentality, for the former has to work on the principle of anticipating and diagnosing. In some ships it is only the chief engineer who is consciously, or subconsciously, antagonistic to Diesel machinery, and in those cases he relies on his subordinates—an anomalous situation that should not be permitted to exist.

We cannot urge too strongly on shipowners, through their superintendents, the necessity of paying very special attention to the choice of the engine-room staff for their new vessels and particularly passenger ships. Promotion by seniority should not be the order of the day, but men with capacity for handling Diesel engines should be moved up rapidly.

From the "Motor Ship," July, 1929:—

Pressure Charging with Diesel Engines.—At the time when publicity was first given in the columns of this journal to the system of increasing the output of four-cycle Diesel machinery by exhaust-gas charging, or pressure charging, considerable scepticism was shown in most quarters and the general belief was that small practical application of the method would result. It takes considerable time for ideas of this nature to be sifted out and a clear perspective to be gained of the possibilities that may be anticipated in service as distinct from what may theoretically be attained in the workshop.

But it may now fairly be stated that pressure charging has reached a stage where it must be considered very carefully by shipowners and shipbuilders.

It cannot, however, be stated that a defined system of pressure charging, limited in its details, may be considered as standard practice. Probably a long period must elapse before this situation will arise.

So far as can be now judged, the pressure induction system will find its widest application in four-stroke-engined fast cargo liners, for it affords a ready method of increasing the output of the engines to a substantial extent and, moreover, provides a means of flexibility whereby the normal speed may be exceeded by one-half or one knot.

Its utility viewed from this aspect is readily understood. The modern fast cargo liner, which must average, say, 13 or 13½ knots over a voyage of anything up to 20,000 sea miles or more, will almost necessarily encounter weather that for a shorter or longer time will set back the speed to a marked extent. If supercharging permits of this loss of time being made up without overloading the machinery the advantage to the shipowner needs no emphasis.

The question of pressure charging has come into prominence in this country during the past month on account of the orders placed for some remarkably interesting fast cargo liners, four for the Silver Line and three for the Blue Funnel Line, all of which, it is understood, will be provided with this system. The vessels in question will represent the highest-powered cargo ships that have yet been built and the employment of pressure charging on such ships indicates that the system must not be considered as in any degree experimental. The results achieved by it on the first tanker to which it has been applied are given on another page and, here again, unexpected advantages seem to have resulted. Whatever opinion may be held concerning pressure charging, therefore, it is quite certain that its further development must be watched with the closest attention.

From "Engineering," June 28th, 1929:—

TURBO-ELECTRIC PROPULSION IN THE *Viceroy of India*. — Though it is still too early to give final figures, it may be mentioned that, over the Skelmorlie measured mile, a speed of 17·1 knots was attained, with a displacement of 19,086 tons and a mean draught of 23ft. $8\frac{3}{4}$in., the guaranteed speed being 16·5 knots. Under these conditions, the fuel consumption worked out at 0·74 lb. per shaft horse-power hour, the propeller speed being 97 r.p.m., and the power developed 10,410 shaft horse-power, including a lighting, heating and cooking load of 700 kw. This figure agreed very closely with the estimate made. It is not without interest to learn that one of the R class P. and O. vessels, which are some 3,000 tons gross smaller than the *Viceroy of India*, recorded a speed of 17·1 knots, on 13,000 shaft horse-power. The superior performance of the turbo-electric ship is thus an excellent testimony to the value of the system, as well as to the advantages of high-pressure and high-temperature steam, while the optimum combination of hull and propeller, which was obtained by model tests in the Experimental Tank at the National Physical Laboratory, is another factor which must not be neglected in making this comparison.

It may be added that, on a six-hours' consumption trial with one turbo-alternator driving the propelling motors at half-load, the total power generated was 7,561 kw., corresponding to 9,810 shaft horse-power at 91·5 r.p.m., the fuel consumption, with a vacuum of 28·5 in., being the same as that given above. On the full power trials with both turbo-alternators in operation, a speed of 19·62 knots was obtained, the mean propeller speed being 113 r.p.m., while later a maximum speed of 19·8 knots was obtained. On the fuel consumption trials under full-load conditions at a scheduled speed of 18·25 knots, the power developed was 13,322 shaft horse-power at a mean propeller speed of 103·54 r.p.m. Under these conditions, with a vacuum of 28·93 in., the fuel consumption worked out at 0·581 lb. per shaft horse-power hour. During the whole of this time the boilers performed well, and pressures and temperatures in excess of those specified were maintained.

In addition, reversing, manœuvring and turning trials were carried out with success, during which the ship was pulled up in 2min. 10sec. when steaming at 19 knots. When the ship was turned sharply, the propelling motors did not pull out of synchronism, and there was complete steadiness and absence of vibration. It is admitted that, when running through two critical speeds, a slight tremor is experienced, but this can be overcome by raising or lowering the speed by one revolution. All the measurements we have given were made on sensitive kilowatt meters, fitted both on the main control board and on a special test board, which was rigged up in the children's playroom on the boat deck. On the latter board, in addition to the instruments, there was a clock and a large seconds chronometer, and during all the manœuvring trials, a continuous cinematograph film of the board was taken, so that any variations in the current and voltage could be analysed.

Finally, it may be said that, on her maiden voyage, it was found that, compared with similar recent vessels fitted with the latest type of quadruple-expansion engines, the *Viceroy of India* consumed less fuel by more than 30 tons per day and less lubricating oil by 25 gallons per day. The commander, and all the pilots who have handled the ship, report that she manœuvres with great ease, and speak highly of the advantages of having the full power available for going astern. The absence of vibration and propeller racing has been remarked upon by the passengers, and it is claimed that, barring accidents, the maintenance costs should be considerably less than with any other type of machinery.

From "Ice and Cold Storage," of July:—

THE LEAKAGE OF HEAT INTO SHIPS' INSULATED HOLDS.—Special Report No. 34, Food Investigation Board, London: H.M. Stationery Office, Adastral House, Kingsway, London, W.C. 2. 1929. $9\frac{1}{2} \times 6$. v + 34 pp. Price 1s.

The report under review has an unusual character in that the experiments it describes were initiated not by the Food Investigation Board, but by a private firm, namely, Messrs. J. and E. Hall, Ltd., of Dartford, the well-known makers of refrigerating machinery. They arose as an attempt to supply a very practical need, the need of the engineer and designer to know what is the amount of the leakage of heat that his plant will be called upon to deal with. There are accurate data available of the thermal conductivities of most common insulating materials, but these data are not in themselves sufficient to supply the information needed, because the structures involved in the leakage of heat, particularly in the case of ships' holds, are too complicated to lend themselves easily to calculations of the heat-flow. Hence arose the project of making direct measurements of the rate of leakage of heat into the insulated spaces of an actual ship.

Messrs. J. and E. Hall, Ltd., invited the assistance of the Department in making these experiments, and at the conclusion of them, they generously placed the results at the Department's disposal for publication. The owners of the ship, who had already done a great deal to make the experiments a success, by placing an eminently suitable vessel, with its plant, entirely at the disposal of the investigators, readily gave their consent to the publication of the data, and the present report is the result.

The results refer, strictly speaking, only to one particular ship, although a representative ship, and to one particular set of conditions. The results represent an initial effort in a difficult field of measurement, which will need to be more fully explored in future investigations.

From the "Shipbuilder" of July:

The Effect of Velocity in Avoiding Corrosion by Water.—An interesting experiment was conducted recently before the members of the Institution of Civil Engineers, to demonstrate the action on metal of water at high and low velocities respectively. In this particular case the metal was steel. A circular steel plate about 10in. in diameter, with a polished surface and cleaned to remove all traces of grease, was mounted horizontally, so that a jet of water impinged on its centre, the velocity of the flow being controlled by a suitable stop valve. The axis of this jet of water being perpendicular to the face of the plate, the water, on coming in contact with the plate, flowed completely over its surface. For a certain distance from the centre the water travelled radially, and then a small circular wave appeared, after which the velocity of the water was much slower. By altering the velocity of the jet, it was found that, as the velocity was increased, the diameter of the wave circle increased, and diminished as the jet velocity decreased.

The valve was then set to give a constant jet velocity, so that the wave circle was about 4in. in diameter. After a short lapse of time, it was noticed that small bubbles appeared on the surface of the plate outside the wave diameter, and these bubbles remained stationary on the plate surface, whereas on the area inside the wave diameter small bubbles were seen moving radially across the plate surface, but were never stationary. After a few hours, the surface of the plate outside the wave diameter started corroding and becoming covered with oxide, whereas the surface of the plate inside the wave diameter was perfectly bright. The plate was then removed and wiped clean, and it was seen that on its outer diameter corrosion had commenced, while its inner surface diameter was perfectly bright.

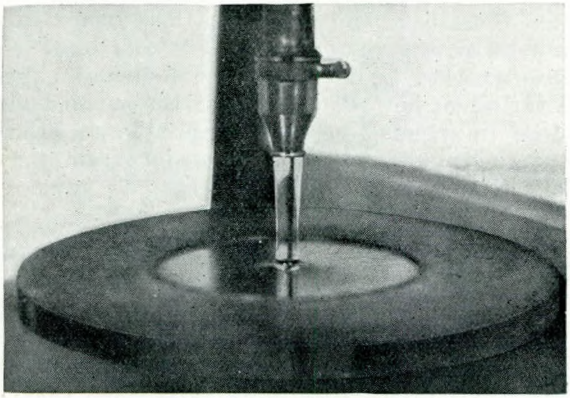


Fig. 1.

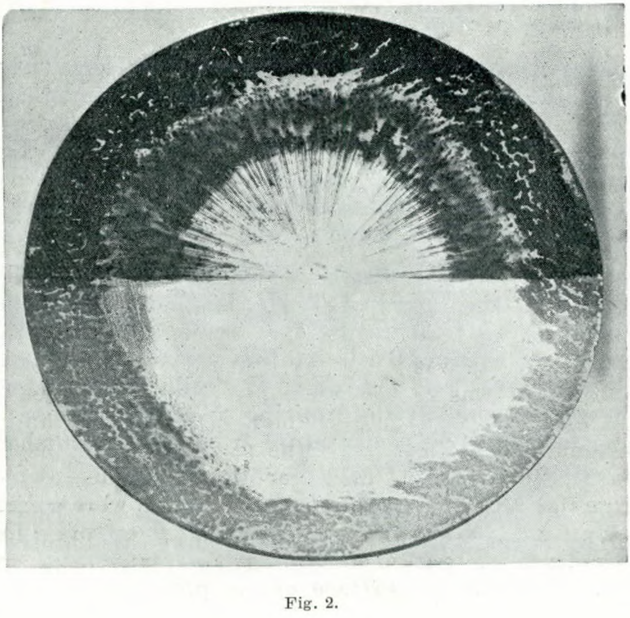


Fig. 2.

The explanation is that each particle of water as it leaves the jet loses velocity as it radiates from the centre, and when the velocity reaches a certain figure a wave is formed. This wave indicates the critical velocity of the water at which turbulent flow ceases and gives place to stream-line flow. In the experiment described, the water on the surface of the plate inside the wave was in turbulent flow and outside the wave in stream-line flow. All the small bubbles of oxygen in the water in turbulent flow were swept off the surface of the plate, while those in stream-line flow were able to adhere to the surface of the plate and allow corrosion from their oxygen to take effect.

The experiment was conducted originally in order to determine the effect of high and low velocities of water on the tubes of the Foster economiser, with a view to preventing internal corrosion. It clearly demonstrated that if the velocity of water is above its critical point, *i.e.*, in a state of turbulent flow, the small oxygen bubbles are swept away and not allowed to cling to the tubes and so damage them; while if the velocity is below the critical point, allowing stream-line flow, corrosion will take place.

PROPERTIES OF MATERIALS AT HIGH TEMPERATURES.—Research on the properties of materials at high temperatures has been carried out at the National Physical Laboratory, Teddington, under the direction of the Department of Scientific and Industrial Research, and the recently published fourth report deals with the strength at elevated temperatures of low-carbon steels for boiler construction.

The object of the research, which has been carried out at the request of the Board of Trade, has been to determine:—(1) The limiting temperature for "creep" corresponding to a range of stress from 0·5 to 4·0 tons per sq. in. on boiler and superheater tubes and on bar steel similar to the steels used for the tubes; and (2) the limiting "creep" stresses corresponding to a range of temperature from 400° C. to about 530° C. on superheater and steam drums.

Copies of the report, which is entitled "Engineering Research, Special Report No. 14," may be obtained from H.M. Stationery Office, Adastral House, Kingsway, London, W.C.2.

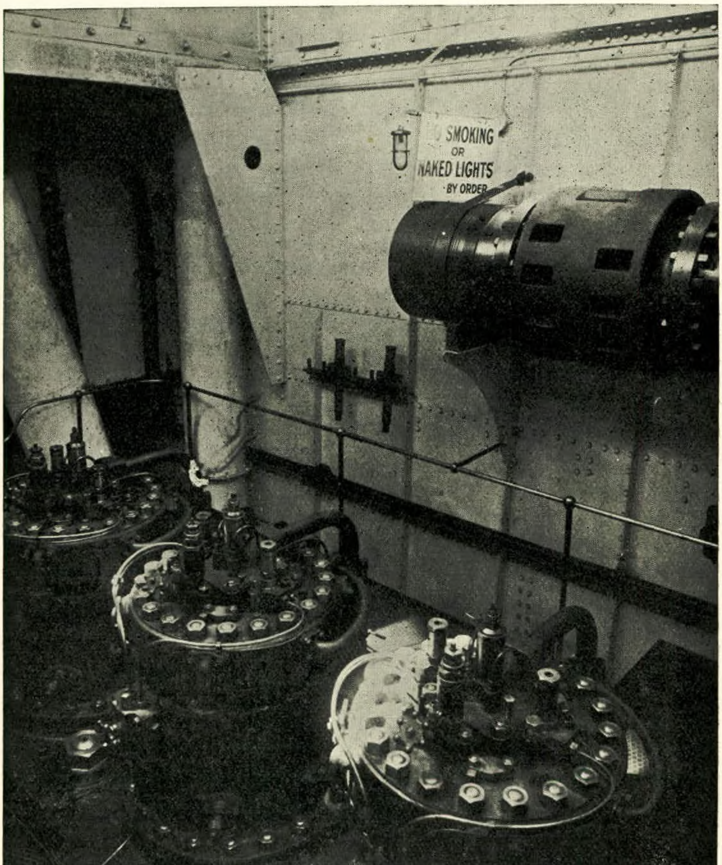
From the "Shipbuilder" of July:—

THE PERFORMANCE OF THE *Irania*.—The all-British double-acting, two-stroke cycle, marine heavy-oil engine which Messrs. Richardsons, Westgarth and Co., Ltd., of Hartlepool, have been developing for the past three or four years, has rightly created considerable interest in technical circles by reason of its novel design, inherent simplicity, and great promise of being cheap to manufacture. The first commercial engine of this type—a three-cylinder set capable of developing 1,250 B.H.P. at 90 r.p.m. was installed in the single-screw oil-tank ship *Irania*, built by the Blythswood Shipbuilding Co., Ltd., of Scotstoun, Glasgow, for the Iranian Tanker Co., Ltd., of London.

The *Irania* completed a successful series of trials in the Firth of Clyde some few weeks ago, and then sailed immediately following the trials for Gibraltar. Very bad weather was experienced from the outset, but the vessel and her new type of machinery behaved exemplarily, and a speed of 10½ knots was averaged as far as that port. Between Gibraltar and Stamboul the weather was also bad, but an average speed of 10½ knots was again maintained, the main engine running throughout without a hitch. The fuel consumption per day averaged 3·8 tons, which is very moderate for a vessel of about 3,000 tons deadweight capacity. Moreover, the consumption of lubricating oil for the main-engine cylinders and piston-rod glands was only three gallons per day. We are not aware of the average power under which the vessel made the passage to Stamboul; but if 75 per cent. of the maximum figure is assumed—bearing in mind the fact that the weather was bad throughout and the machinery new—the excellent specific consumption figure of under 0·38 lb. per B.H.P. per hour is arrived at, which is confirmatory of the test-bed performance of the engine.

A fully loaded trip was made to Constanza and Piræus, and thence back to Batum, where the ship was fully loaded (3,000 tons) for Rouen. This latter trip was non-stop from Constantinople, the vessel arriving at Rouen in excellent condition, with an average consumption of 4½ tons per day for all purposes and an average speed of 10¼ knots. Going up the Seine, the engine ran perfectly smoothly at 35 r.p.m. for a period of over one hour, which gives an indication of its flexibility at the lower speeds.

One of the cylinders was opened out for examination at Stamboul, and no measurable wear was apparent, while the condition of the various parts was excellent. The fuel-valve nozzles were quite clear, not a single hole being choked, and



Cylinder Tops of the "Irania's" Main Engine.

no carbonised oil was found in the region of the nozzle holes. This is of considerable interest, as the prevention of nozzle carbonisation is one of the problems of airless injection. It is too early, of course, to hail this new engine as a complete success, and to say that its system of airless injection is perfect, because the initial run of the *Irania* has been so satisfactory. The success achieved, however, augurs well for the future, and it is apparent that the design is sound in its broad principles.

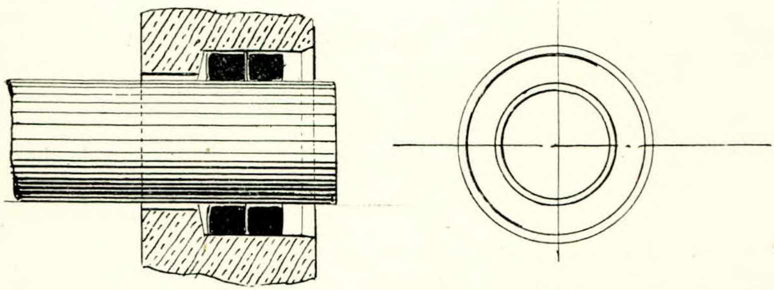
Hard service will show—and eradicate—those little ills to which all new engine designs are heir; but the excellent performance of the *Irania's* machinery on the vessel's first trip must give great satisfaction to Messrs. Richardsons, Westgarth and Co., Ltd., and to its designer, Mr. W. S. Burn, M.Sc. Further orders for Richardsons-Westgarth oil engines will be forthcoming in the near future, it may safely be prophesied.

An Early Type of Condenser Tube Packing. By H. Coke Powel (Member).—In the January, 1929, Transactions, page 982, a description of condenser tube packing as used on the Continent is given by Mr. J. B. Hastings. The following particulars of a condenser tube packing used in the 1850/60's may be of interest to our members. My recollection goes back to that time. The first tubular surface condenser was made by Mr. Hall, and failed, I believe, due to the rapid destruction of the tubes. Mr. J. Frederic Spencer, about that time, was granted two patents in connection with surface condensers and they turned out a decided success. The packing is that shown on the accompanying sketch, consisting simply of two rings of india-rubber, and during Mr. Spencer's management of his splendidly arranged works of the North Eastern Engine Works, Sunderland, that packing was exclusively used. I was their leading draughtsman and took the diagrams and notes of all their ship trials; and for the many years that I was there I never heard of a condenser failing in any way. This packing was followed by compressed wood plugs, patented by a marine superintendent. Subsequently the Admiralty produced the stuffing box with cotton packing, with a screwed follower. This was a complicated device, and like many Government inventions, was adopted regardless of cost.

Mr. Spencer's second patent provided for the admission by means of a small tube (about $\frac{3}{8}$in. from memory) with valve, of a small quantity of the condensing water to cover the tubes with a thin scale. I never heard of tube trouble then.

Mr. Hastings, evidently with astonishment, and justifiably so, quotes from the Liverpool Journal of Commerce, that an engineer had had no trouble with condenser tubes containing

30% zinc. It would be interesting to know what his tube packing was. In Antofagasta in 1889, when I managed the railway during the Chilian war, the only water obtainable for



Spencer's Condenser Tube Packing (1850-60).

all purposes was sea water evaporated and condensed. Even this water so destroyed our boiler fittings that we had to get them replaced by bronze fittings free from zinc. It is possible that the warmed condensing water in a surface condenser gives off a gas which conduces to the generation of an electric current, with its destructive properties? In Spencer's condenser the tubes did not touch the tube plate, and the scale protected the different metals of the tubes themselves.

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Books added to Library.

Purchased. "International Convention for the Safety of Life at Sea." 1929. Board of Trade Report. Published by H.M. Stationery Office. Price 4/- net.

Presented by the Publishers. "Engineering Economics," by T H. Burnham, B.Sc. Hons. (Lond.), B.Com. (Lond.), A.M.I.Mech.E. Pp. 332. 8½ in. x 6 in. Published by Sir Isaac Pitman & Sons, Limited, Parker Street, Kingsway. Price 10/6 net. 1929. — Our members, especially those who spend their lives at sea, have not had the opportunity of obtaining knowledge of Economics, or even a superficial knowledge of this very necessary subject. The author has supplied a long felt want. It should appeal not only to those who have already established themselves ashore, but to those aspiring young engineers who hope eventually to make their way in the commercial world. He unlocks the door to the mysteries of bimetalism, and places before us what is considered very dry matter, in a simple and interesting way. The author runs through various systems of Banking, Foreign Exchange, Trade and Credit, and shows the importance of Trade Unions and their management as well as their relation to the well-being of the country and trade in general. Industrial and Shop Management is dealt with most fully, and should appeal to all engineers. It is a book which can be highly recommended, especially to our members both ashore and afloat. —A.J.

Presented by the Author.—" Successful Stoking and Smoke Abatement," by Ernest Dickinson, M.I.Mar.E., A.Inst.P.I. Pp. 53. 18 illustrations. $8\frac{1}{2}$ in. x $5\frac{1}{2}$ in. Obtainable from the Author, " Clitheldor," Chevet Lane, Sandal, Wakefield. Price 2/-.—An interesting and useful little volume which can be read with advantage by those other than the boiler attendant for whom it has purposely been written. The author has in mind the enormous amount of loss and damage caused by smoke, due to conditions so ably set forth in his book, and he proceeds to show how they can be remedied. He could with advantage have added another chapter for the attention of employers, and those responsible for the plant. If the fireman has to fight for steam because of inferior coal and lack of adequate boiler power the inevitable result, notwithstanding his care, is smoke.

Presented by Mr. T. Scott Whyte (Member).—" The Failure of Metals under Internal and Prolonged Stress."—Report of a general discussion held jointly by the Faraday Society, the Institution of Mechanical Engineers, the Iron and Steel Institute, the Institute of Metals, North-East Coast Institution of Engineers and Shipbuilders, West of Scotland Iron and Steel Institute, and the Institution of Engineers and Shipbuilders in Scotland on Wednesday, April 6th, 1921, in the hall of the Institution of Mechanical Engineers.—Published by the Faraday Society, 10, Essex Street, London, W.C.2.

Boiler Explosion Acts.

Report No. 2,923.

Report No. 2,923 deals with the explosion from a water tube boiler at Newport Iron Works. The investigation was conducted by Mr. C. W. L. Wren, Board of Trade Surveyor, North Shields. The only one injured was a foreman electrician, but fortunately not seriously. The report is very full and contains many interesting points for consideration.

The boiler, known as No. 68, was of the Stirling type, of steel, consisting of two lower water drums, three steam and water drums, and one steam drum, connected together by batches of tubes; it was constructed for a working pressure of 160 lbs. per square inch and was fired by gas from the blast furnaces, its total heating surface being 3,230 square feet.

The lower water drums and the steam and water drums were three feet internal diameter; the shells of the former were 11 ft. 2 ins. long, and of the latter 11 ft. 6 ins. long, and were each formed of two plates, the tube plate being 9/16th inch thick, and the other 7/16th inch; the seams were lap jointed and double riveted, the pitch of the rivets being $2\frac{3}{4}$ inches, the rivet holes 13/16th inch in diameter and the two rows being spaced $1\frac{1}{2}$ inches apart. The ends of the drums were formed of dished plates flanged and single riveted to the shell, the pitch of the rivets being 2 inches and the rivet holes 13/16th inch diameter; the end pierced for the manhole was $\frac{3}{4}$ inch thick, the other being 9/16th inch in thickness. The solid drawn steel main tubes totalled 272, and were arranged in four banks of four rows each, with 17 tubes in each row. The tubes were $3\frac{1}{4}$ ins. in diameter outside and 10 S.W.G. thick, except the front rows which were 9 S.W.G. thick; cross tubes of the same size connected the lower water drums and the steam and water drums respectively, the total number of tubes being 350.

The shell of the steam drum was 3 feet diameter and 10 feet 6 inches long and was formed of two plates each $\frac{1}{2}$ inch thick. The longitudinal seams were lap jointed and double riveted, the riveting and thickness of the ends being similar to those of the other drums. The steam drum was connected to the centre steam and water drum by two steel stand pipes 5 inches bore and 6 feet apart.

The usual mountings were fitted including a $2\frac{1}{2}$ inches dead-weight safety valve and a high steam and low water safety valve, both on the rear steam and water drum.

Various tubes were renewed from time to time as required until January, 1924, when Preliminary Inquiry No. 2658 was held concerning the blowing out of a tube from one of the drums, which resulted in injury to an attendant; since then various other tubes have been renewed. On the 21st March, 1927, the following repairs were made:—Tubes renewed, 16th and 17th tubes in front row fourth bank, 2nd, 3rd, 4th, 5th, 6th bottom row steam tubes middle drum to back drum, and 4th tube top row, middle drum to back drum. At this time the rear lap joint of the back water drum was caulked. The boiler was tested by hydraulic pressure to 240 lbs. per square inch on the 1st November, 1918, and 5th May, 1921.

The boiler has been regularly inspected by Inspectors to the National Boiler and General Insurance Company, Limited, Manchester, the last internal and external examination having been made on the 16th December, 1926. It was further examined by the foreman boilersmith at Newport Iron Works on the 21st March, 1927, twelve days prior to the explosion, when it was laid off for cleaning and repairs.

The boiler was insured with the National Boiler and General Insurance Company, Ltd., Manchester, for a working pressure of 165 lbs. per square inch.

The shell of the rear bottom drum failed at the back longitudinal seam and opened out, releasing the left end entirely and the right end partially. The contents escaped with great violence, and the boiler was lifted from its seat, over a group of other boilers, and deposited on a vacant space 237ft. away, breaking the brick lined steel chimney into three parts, dislodging the adjacent Stirling boiler a distance of 2ft., and damaging the tubes.

A number of mountings were severed from a Woodeson boiler on the left, branch steam and other pipes and numerous fittings were torn away, the gas main was pierced, and other damage was done, necessitating the shutting down of eleven boilers and the temporary stoppage of the furnaces in blast.

referred to were renewed on account of reduction in thickness, and the back longitudinal seam of the bottom rear drum, which subsequently exploded, was caulked on the left side for about 2ft., owing to some dampness having been observed at that part.

The boiler worked without any hitch until the 31st March, when the attendant found, after blowing down the boiler, that he was unable to shut off the sludge valve on the front bottom drum, but was able to close the check cock which retained the water in the boiler: he then put the boiler out of service by shutting off the gas and the main steam valve, easing the safety valve, and blowing down the boiler from the rear bottom drum sludge valve, using the injector to cool the boiler, so that it would be cool enough for the mechanics to repair the valve. Even with the gas shut off, a large amount of heat is retained by the brickwork and it was about three hours before the boiler was sufficiently cool to allow of repairs being effected. It was then found that a $\frac{3}{8}$in. bolt had become lodged under the sludge valve; the latter was renewed and the boiler put into service again at about 4 p.m. the same day.

An arrangement was in force whereby, when the quantity of steam generated by the boiler plant was in excess of the requirements at Newport Works, any surplus could be passed over to the Cleveland and Durham Power Station, the supply being regulated by an automatic device, after the connecting stop valve had been opened by the boiler plant attendant. This arrangement was in operation on 2nd April until 12.10 p.m., when, the steam pressure having fallen somewhat, the Power Station shift engineer shut off the steam, but later, finding the steam pressure had risen to over 160 lbs. per square inch, resumed taking surplus.

The men were leaving the Works, when, at some 20 minutes past noon on the 2nd April, without any warning, No. 68 boiler exploded with exceptional violence, doing damage as previously stated. Johnson Richardson was leaving the Works by the usual route when portions of the wreckage struck him, injuring the upper part of his body; he was taken to the Works' ambulance station and, after treatment, removed to hospital.

The two boiler attendants were standing together at the side of a battery of other boilers, and were uninjured.

The explosion temporarily disorganised the works, as the high pressure steam main had been torn from its branch pipes to several other boilers; from the apertures thus formed, steam from the remaining boilers escaped to the atmosphere, no isolating valves being fitted. Steps were taken at once to shut off the gas, which was escaping into the air from the damaged gas main and was a source of danger to the man shutting down the plant owing to its poisonous nature; this necessitated opening the bells of the furnaces under blast, and subsequently shutting down the blowing engine.

The boilers at the other end of the blast furnace plant were got under steam as quickly as possible and two of the blast furnaces were by this means re-started at 5.35 p.m. the same day. As the furnaces were not prepared for standing, it was important to get them going again with as little delay as possible, because it becomes a matter of some difficulty to re-start a furnace after a stoppage of any length of time: the third furnace was re-started at 1 p.m. on the following day.

On Monday, 4th April, I visited the scene of the explosion and found the boiler lying on vacant ground with the shell of the rear water drum opened out, having torn apart at the inner row of rivets of the bottom plate of the back longitudinal seam. The left end had been projected some distance away; the drum end was intact and exhibited no sign of damage at the rivet holes. The shell had been unwrapped from it, showing that the releasing of this end was secondary; the rivet holes in the shell at this part were slightly cracked on the inner surface of the joint.

The other end was still attached to the tube plate, but the bottom shell plate had ruptured along the line of rivets of the circumferential seam, the outer part of the lap of the plate being still attached to the end. The shell plate disclosed numerous cracks extending from, and between, the rivet holes, the latter being elongated in the direction of the axis of the drum; the extent of the old flaws found in the circumferential seam, which all started from that surface of the plate which was within the lap joint, varied from being through the full thickness of the plate, except 1/16th of an inch, to being half through the plate. The tearing of this plate also appeared to be secondary to the failure of the longitudinal seam.

The tube plate was forced about one foot over the ends of some of the tubes, the latter being also displaced and projecting into the steam and water drum above. The steam and water drums were driven together and their connecting tubes distorted and pulled out of place; the dry steam drum was lying on the ground, having broken from its connections on the centre drum previous to my visit.

In addition to the steam ranges, the feed and blow down pipe lines were all fractured, and portions of these were carried considerable distances by the force of the explosion. The brickwork base of the chimney stack had been scattered, the site of the boiler and the public railway alongside the works being littered with brickwork; houses on the opposite side of the railway were also slightly damaged.

The fractured longitudinal seam was examined and the flaws from the rivet holes which had been in existence some considerable time were discovered. Of the part holes remaining in this seam, twenty disclosed cracks at the backs, away from the line of fracture. Recent caulking was observed at one part of the seam and a strip of the shell 2ft. 8ins. long was consequently cut off and compared with that part of the plate from which it had been torn; it was then seen that the flaws in way of the rivet holes had extended until they were through the plate where the seam had been recently caulked. The remainder of the seam disclosed cracks between the rivet holes, which clearly radiated from the holes and pierced the metal in the remainder of the seam, varying in depth from under to over half of the thickness of the plate.

The ruptured shell plate showed little sign of corrosion internally or externally, and allowing that most of the scale would have been dislodged by the force of the explosion, was comparatively free from signs of adherent deposit. The thickness of the bottom shell plate at the left end varied from 15/32nds to 7/16ths of an inch, along the fractured longitudinal seams, and at the right circumferential seams the thickness was 7/16ths of an inch.

The boiler was being worked in line with and at the same pressure as others in the battery, and the main stop valve was found full open after the explosion. Of the other boiler mountings, the high and low water alarm float and lever inside the drum were broken into a number of pieces, the outside lever being bent; the deadweight safety valve was some distance away broken off at the neck, but the valve and bridge piece were missing and have not been found. The feed regulating valve, which was open, was at the side of the works' railway line; the feed check valve was in place on the top of the back steam drum. The injector was at the side of one of the works' railway lines, the steam stop valve on the steam drum and the regulating valve being open and the water cock shut; the water gauge fittings were attached to the back drum on the left end, the handle of the top cock being in the upright position, and that of the bottom cock in the downward position and not fully open; the passages were found clear but considerably scaled up; the handles were easily movable and it is quite possible that they had moved when the boiler struck the ground. The pipes connecting the second water gauge to the centre drum were found among other debris, together with the water gauge fittings, and were tried with water and found clear; the top steam cock was broken off the boiler and was found open; there was no cock on the boiler for the pipe to the bottom of the water gauge; the gauge fittings were clear and the handles of the cocks were easily movable.

The weights and case of the deadweight safety valve were weighed together with a valve and bridge piece from another boiler, from which the valve was estimated to have been loaded to 179 lbs. per square inch; as the bridge piece was a casting only partly machined, it is possible that its weight differed from that of the actual valve. After the bent lever of the high steam and low water safety valve had been straightened, the weights and leverages were checked over; the pilot valve was found to be adjusted to lift at 160 lbs. per square inch, and the complete main valve to 175 lbs. per square inch; the distance between the fulcrum and the valve may have been slightly increased when the lever was straightened; there were also several small parts missing and weights were estimated for these.

The chart from the automatic recorder connected to the main steam pipe from these boilers registered the steam pressure at the time of the explosion as 173 lbs. per square inch; this recorder was checked *in situ* against a Board of Trade duplex standard gauge, and found to register 10 lbs. too high, that is to say that the pressure of 173 lbs. shown on the chart was equivalent to 163 lbs. registered by the Board of Trade gauge: the results are as follows:—

A new pressure gauge was compared with the Board of Trade gauge and found accurate.

	In Cleveland and Durham Power Station.	At Recorder—Recorder disconnected.
Readings of Gauges.	140 lbs. (New Gauge)	150 lbs. (B.T. Gauge) (showing that the pressure at the C. and D. power Station was 10lbs. below that at recorder due to length of piping, &c., between the two points).

Recording apparatus connected.

In Cleveland and Durham Power Station.		At Recorder.	Boiler Gauges.	
Readings of Gauges.	139 lbs.	150 lbs. (B.T. Gauge). 160 lbs. Recording apparatus.	No. 72.	150 lbs.
			No. 73.	150 lbs.
			No. 74.	143 lbs.

The foregoing showed that the recorder registered 11 pounds more than the pressure at the Cleveland and Durham Power Station and 10 pounds more than shown by boiler gauges Nos. 72 and 73; No. 72 gauge was checked and found to register one pound more than the standard gauge at 150 lbs. pressure.

To ascertain whether the surface of the shell plate at the riveted joint had become hard, Brinell tests were made as under; the results disclosed no hardening of the plate inside the joint:—

	Near fracture inside lap joint. Brinell hardness number.	On plate adjoining seam. Brinell hardness number.
A. Outside of shell	143	143
Inside of shell	143	143
B. Outside of shell	143	143
Inside of shell	137	137
C. Outside of shell	140	134
Inside of shell	143	137

Further tests were made on the inside surfaces of the seams with a Shaw Schlerescope, which, on being checked with the standard soft mild steel bar, gave a " hardness " number of 31; the lowest reading was 9, the highest 19, the average for all readings being 16; these tests supported those made with the Brinell instrument, showing no hardening of the surface of the plate within the joint.

The cause of the explosion having definitely been established as due to old flaws which were concealed within the lap of the riveted joints, the following observations may be made regarding their origin:—

Overheating due to scale or shortness of water.—The exploded drum and the boiler generally were examined for signs of overheating. None were, however, discernible, and there was no discolouration of the plates; the force of the explosion was such that a considerable body of water must have been in the boiler just prior to its failure; if the seam had been overheated at any previous time due to thick scale sufficient to have caused cracks in the material, such cracks would have appeared at the outside of the lap of the plate exposed to the hot gases; the cracks found were of a totally different nature from fire cracks.

Overpressure.—For the boiler to have exploded from this cause it would have been necessary for both safety valves to have been inoperative, and the main stop valve closed. The latter was found full open, and the highest calculated load on the safety valve was quite insufficient to have caused the explosion, and could not be considered a factor in the origin of the flaws in the material.

Defective material.—Various tests have been made regarding the strength, ductility, and structure of the material of the fractured shell plate, which, in addition to the usual tensile and bending tests, has been subjected to chemical and microscopical examination. The chemical analysis showed the phosphorous content both of the fractured shell plate and the tube plate, to be higher than usual, but insufficient to have caused failure, *vide* Appendix D. The mechanical tests, the results of which will be found in the Appendices, disclosed nothing abnormal. The microscopical examination showed the plate to be laminated, with numerous slag inclusions and a marked segregation of sulphur. It was also ascertained that the plate was rolled in the direction of the axis of the drum. Owing to the Motherwell Works having been closed since 1908, the boiler makers are unable to state where the plate was obtained.

Straining of the longitudinal joint.—Lap joints have been known to show signs of fatigue due to the tendency of the boiler, or drum, to assume a truly circular shape under internal pressure, the boiler not being truly circular by the thickness of the plate at the lap. The strains set up in such a case would be localised at the thiner plate forming the joint and would be most severe at the inner row of rivets in the thinner plate of a double-riveted seam. In the exploded drum the cracking at and between the rivet holes was found to be nearly as extensive in the right circumferential seam as in the longitudinal seam; consequently, fatigue due to the straining action at the lap joint could not have been the cause of the flaws found, although it would probably be a contributory cause in the case of the latter.

Regarding the circumstance that the right circumferential seam showed numerous cracks, whereas at the left seam only slight cracking was apparent, the right end was considerably thinner than the left, which was pierced for the manhole, and would necessarily deflect more under pressure. It is consequently possible that greater strains were set up at the rivet holes of the right circumferential seam than at those of the left.

Material strained during manufacture of the boiler.—A number of ring indentations were found on the inside of the drum at the longitudinal seam and also inside the flange of the left end, evidently caused by the snap head of the riveting machine. They were 2ins. in diameter externally, 5/16ths of an inch in width and varied in depth from 10 to 20 thousandths of an inch; on the drum end pierced for the manhole the depth was 1/16th of an inch.

The result of this treatment would probably be some surface hardening of the plate at those points. As, however, the indentations inside the drum were on the *outside* of the inner plates of the seams, and the cracks which caused failure started from the *inside* of the seams, no connection can be found between the latter and the indentations. Moreover, there were no similar marks on the shell plate at the circumferential seams.

Material worked at a blue heat during construction, or strained due to unskilful repairs.—It is known that material which is worked at a blue heat is apt to become brittle. In making a lap joint it is necessary to set in the plate to form the lap: the laps of the longitudinal seams of the drums are scarphed to take the ends and are frequently drawn down in the fire. Either of the foregoing processes, if performed at a blue heat, would stress the material and might cause cracking, and if done at a proper heat but not subsequently annealed, the plate would be left in a stressed condition.

The laps in this boiler were, however, bent to shape without heat and it was ascertained on examination that the scarphs had been machined.

There was no evidence at the fractured seams of unsatisfactory methods of repair.

Overpressure during riveting.—During hydraulic riveting operations it sometimes occurs that an excessive pressure is used. This may generally be detected by the bulges at the edge of the plate in way of the rivets, and is more liable to occur in the thinner plate when two plates of different thickness are riveted together, the riveting pressure being suitable for the thicker plate. The holes in the thinner plate are permanently enlarged and if the rivets are withdrawn they will be found to be " shouldered."

Along that row of rivets in the longitudinal seam adjacent to the fracture, two bulges at the edge of the bottom plate were observed; numerous rivets were withdrawn and some found "shouldered," the holes in the thinner plate being 1/32nd of an inch larger than in the other plate forming the lap. Both the holes and rivets were carefully examined in each case. One of the rivets was found to have a very fine circumferential crack under the head.

Of 12 rivets withdrawn from the longitudinal seam along the line of fracture, five were 1/32nd of an inch larger in the thinner plate, the others showed no appreciable enlargement. From the circumferential seams six rivets were removed at the right end, of which four were found staggered 1/32nd of an inch and two shouldered 1/32nd of an inch. Three of the foregoing were cracked circumferentially under the heads; of six rivets removed from the left end, five were embossed under the heads with semi-circular marks caused by indentation of the plate by the snap head of the riveting machine before the rivets were put in: otherwise the rivets were fair and none of the holes was distorted.

Generally, the rivets and holes examined in the various seams gave no indication of an unusually high riveting pressure having been used.

To ascertain whether riveting temperatures and pressures had any effect on this particular material, a piece of plate cut from the fractured shell was riveted to another 9/16ths of an inch thick, the size of the holes and pitch of rivets being similar to those in the lap joint of the burst drum, and the maximum riveting pressure available at the works being used; this, however, only gave a load of 31 tons on the rivet. After a week the rivets were cut out and the holes examined. In no case was there any enlargement of the holes nor sign of cracking.

Two pieces of plate were then cut from the fractured seam in way of the rivet holes, a few inches apart, and etched by the special method introduced for the detection of strain in mild steel, in which copper chloride is used: the process produces surface markings which are evidence of deformation of the material. One specimen showed evidence of overstrain: the other piece, the surface of which had been removed by machining, disclosed no sign of distortion in way of the hole. In neither case were the indications sufficient to support the theory of overpressure during riveting.

Subsequently, the makers were able to ascertain from their late works' manager and chief foreman at the Motherwell Works, details of the method employed in the construction of this boiler. The drum ends were pressed hot in one operation. One of the plates for drum barrels was marked from a standard template and the plates then drilled in batches, the part forming the outer half of the lap joint having all holes drilled, while that part which would form the inside lap was only drilled at intervals of 2ft. for bolting up purposes. The edges of the plates were then planned and bevelled for caulking and the inside laps at the ends of the barrels scarphed by machine and not heated to take the ends. Before being rolled the plate in way of the longitudinal seam was pressed to the required curvature in a special hydraulic press: the ends and barrels having been assembled and bolted together, the holes were drilled in place: the drums were then taken apart and all sharp edges removed from the holes and the frying surfaces cleaned with a wire brush.

The longitudinal joints were afterwards riveted hydraulically, the total riveting pressure on each rivet varying from 40 to 60 tons, according to thickness of plate and size of rivet. The blank ends were riveted by long stroke pneumatic hammer and the ends, which were pierced for the manholes, were riveted hydraulically, the seams of the drum being then fullered but not caulked, and tested to the required pressure.

Caustic embrittlement.—In the riveted seams of caustic evaporators subject to tension, the metal has been observed to develop brittleness, and fractures have been found variously described as "inter-crystalline" or "intergranular." indicating that failure has occurred principally around the crystals or grains instead of across them, due to alkaline corrosion.

Similar cracking has been discovered under the water line in the joints of steam boilers in which caustic soda has been used habitually in considerable quantities.

No surface hardness having been disclosed by the various tests, a portion of the shell plate at the circumferential joint which had been attached to the right drum end was carefully removed for further examination; when the surface of the joint was being cleansed, it was found that a pink "scale" on the inside of the seam rapidly dissolved in water, leaving the plate clean with patches revealing a very finely crystalline surface. In consequence other seams of the exploded drum were taken apart, and sufficient of the "scale" recovered in a powdered form for analysis. From the report given in Appendix B it will be observed that sodium carbonate ·068 grains and sodium sulphate ·074 grains were found in the first sample, and sodium carbonate 2·20 grains, common salt 7·33 grains and sodium sulphate 2·31 grains were found in the second sample. In the first sample the equivalent caustic soda was ·040 grains and in the second 1·27 grains; the opinion was expressed, however, by the chemist who made the analysis, that the quantity found was quite insufficient to have caused embrittlement.

Further investigations were made and it was ascertained that when the rivet holes of the *tube plate* of the exploded drum were polished, numerous fine cracks were found starting from the inside of the seam, both in the holes of the fractured longitudinal seam and in the intact longitudinal seam. Other fine cracks were also apparent in the rivet holes of the right *drum end*, also starting from the inner face of the joint.

In the case of the thinner shell plate, as the cracks were found to have started on the inside of the longitudinal seam and also on the inside of the circumferential seam, although those seams were *on opposite sides of the plate*, it appeared obvious that the cause of the fractures was to be sought within the joint.

The following are particulars of the results of inspection of seams in the various Stirling boiler in the battery:—

No. 68 *boiler.*—Back bottom drum. The other longitudinal seam to that which fractured; this joint was perfectly tight from appearance and no feeler could be inserted. Two holes were trepanned between rivets, the cores and holes being examined with a magnifying glass; no cracks were visible. Nine rivets were removed from the seam; seven holes showed cracks, two holes nothing. All cracks were in the thinner plate and on the inside of the joint between the plates. Three more rivets were removed from this seam; one hole showed three cracks, another one crack, all in the thinner plate; another, three cracks in *both plates;* all cracks were on the inside of the joint.

No. 68 *boiler.*—Back bottom drum. Fractured longitudinal seam. Ten rivets were removed from that row next to line of fracture. No. of rivet hole: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; No. of cracks: 0, 1, 2, 2, 0, 3, 3, 3, 5, 6 (all in thinner plate on inside of joint between plates).

Two slight bulges were observed in way of Nos. 2 and 3 rivets. Rivets were removed from 30 holes in this seam for removal of lap of plate in order to analyse the sediment between the plates at the joint.

Outer row of rivets.—No. of rivet hole: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15; No. of cracks: 2, 0, 1, 0, 1, 4, 3, 8, 3, 4, 4, 5, 3, 1, 1.

Inner row of rivets.—No. of rivet hole: 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30; No. of cracks: 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 2, 2, 1.

The foregoing were found in the *tube plate* or thicker plate forming the seam, and were shown up after polishing the holes. Some of these cracks may be seen in Fig 1, Appendix B. Cracks had previously been found in the thinner plate.

No. 68 *boiler.*—Back bottom drum. Six rivets were removed from the right circumferential seam. No. of rivet hole: 1, 2, 3, 4, 5, 6; No. of cracks: 1, 2, 2, 1, 2, 0. These cracks were in the *drum end* on the inside of the joint between the plates.

No. 68 *boiler.*—Back bottom drum. Six rivets were removed from the left circumferential seam; no cracks were visible in holes. In this end some rivet heads had been torn off in tension, others were sheared.

No. 68 *boiler.*—Back bottom drum. Circumferential seams; cracks in shell as follows:—Left end: Several cracks from rivet holes on the inside of the joint only. Right end: Thinner bottom plate extensively cracked from and between rivet holes from inside of joint.

No. 68 *boiler.*—Top back drum. Twelve rivets were removed from the outer row; no crack was discovered. Top middle drum. Three rivets were removed from the top row front seam; no cracks were found. Bottom front drum. Three rivets were removed from front seam bottom row; one slight crack, not definite, was found. The seams of the foregoing drums were examined internally; no feeler could be inserted.

No. 67 *boiler*, adjoining that which exploded.—Bottom back drum. Eight rivets were removed from the lower row, back seam, and three rivets from the circumferential seam, left end.

The seam was trepanned in four places between rivets, cores and holes being examined with a magnifying glass. Further rivets were removed in this seam making a total of 17; in no case were cracks found.

Top centre and two bottom drums. Three rivets were removed from each drum, no cracks being observed. The joints were close in all drums internally and no feeler could be inserted; the drums were practically free from scale.

No. 66 boiler.—Centre top and two bottom drums. Three rivets were removed from a longitudinal seam of each drum. No cracks were observed.

No. 65 boiler.—Centre top and two bottom drums. Three rivets were removed from a longitudinal seam of each drum. Front bottom drum and back bottom drum. One slight crack, not definite, was observed in one hole in each drum. All the drums from which rivets had been removed were examined internally and found practically free from scale at the seams and on the plates, and no feeler could be inserted in joints. Nos. 65, 66 and 67 boilers were all about two years older than No. 68.

To discover whether the plate within the seam had altered its nature compared with other parts of the shell, two pieces of plate were cut side by side, one just inside the longitudinal joint, the other just outside, and tested in an Izod machine, the results being as follows:—

Plate A1.	Position.	Foot pounds absorbed.	Appearance of Fracture.
	Inside joint	65	Silky.
	Outside joint	62	Silky.

Three further pieces were cut, two side by side, one just inside the circumferential joint, the other just outside, and the third piece in a corresponding position, but on the outer side of the rivet holes.

Position.	Foot pounds absorbed.	Appearance of Fracture.
Inside joint, on outer side of holes	20	Finely crystalline.
Inside joint, on inner side of holes	13	Finely crystalline.
Outside joint	53	Silky.

Plate A. Two pieces were cut side by side, one just inside the circumferential joint, the other just outside.

Position.	Foot pounds absorbed.	Appearance of Fracture.
Inside joint	$18\frac{1}{2}$	Finely crystaline.
Outside joint	$43\frac{1}{2}$	Silky.

Specimens cut from positions similar to the first five of the foregoing were bent and flattened upon themselves with only slight cracking on the outside of the bend. All the test pieces were from pre-existing cracks.

Conclusions.—To recapitulate the possible causes of failure of the boiler, overheating, overpressure of steam, overpressure during riveting, or working at a blue heat, may for the reasons given under those headings be definitely dismissed.

While the phosphorous content in the fractured plate was higher than usual and there was considerable lamination, the material passed the usual mechanical tests and the failure cannot be attributed directly to these factors.

Particular attention is directed to the position of the cracks in the riveted seams:—

(*a*) In the thinner shell plate they started from the *inside* of the longitudinal joint and also on the *inside* of the circumferential seam, although these seams were on opposite sides of the plate.

(*b*) Cracks were also found in the tube plate starting from the *inside* of the seam, *i.e.*, at the junction of this plate to the fractured shell plate. These are quite clearly shown in Fig. **1**, Appendix B.

(*c*) Cracks were also observed in the *drum end* on the right, which developed from the *inside* of the circumferential seam.

(*d*) Cracks were apparent in both plates at the *longitudinal seam which was not fractured*, in each case starting from the *inside* of the seam.

(*e*) Cracks were discovered under the heads of some rivets in the circumferential seam at the right end and in the longitudinal seam.

It will be apparent from the foregoing that fatigue due to straining at the longitudinal lap joint could not have been the direct cause of the failure. Frequent caulking throughout the life of the boiler would, however, tend to open up existing cracks at the rivet holes, or actually to cause them by forcing the plates apart, if the surface of the metal within the joints had become brittle. The last Izod tests referred to, which were taken from plates actually forming the lap joints, proved the steel to be notch-brittle in places and to differ from the tests taken from the plate outside the joint.

Regarding caustic embrittlement, the theory has been advanced that caustic alkalinity would require to be about twenty times the concentration present in a normal boiler to cause intercrystalline or intergranular fractures, and that, to reach such concentration, evaporation probably takes place locally in seams and around rivets, the water being blown out as steam through minute leaks.

The fact that the fractured shell plate was laminated and had numerous slag inclusions would possibly account for that plate being more subject to alkaline attack, but the tube plate and right drum end, of a different thickness to the fractured shell plate and probably rolled from a different ingot, were also affected although to a much less extent. A chemical analysis of both shell plates is given in Appendix D. The right circumferential seam was heavily caulked on the outside, leaving a considerable hollow between the plates, which was found filled with the pink deposit or scale. There is no doubt that soda, in its various forms, obtained access to the inside of the seam, as the analysis disclosed its presence both in this and in the longitudinal joint. On the other hand, the intact longitudinal seam of the back bottom drum was examined for soda with no tangible result, *vide* Appendix C, although cracks were apparent in a number of rivet holes.

The investigations recorded in Appendix D disclose that the fractures in parts of the seams were intercrystalline, and similar in character and occurrence to those found in steel which has been subjected to the combined action of concentrated caustic alkalis and comparatively high stresses. From the evidence, however, there is no proof of undue concentration of caustic alkalis either in the seams or in the treated feed water.

No. 68 boiler which exploded was the farthest away from the water softener and the feed pumps, and would consequently receive its feed last of the battery; the main feed pipe however did not end at No. 68 boiler but continued towards another group.

It appears, therefore, somewhat difficult to understand why No. 68 boiler, which was the youngest of the battery and had apparently been subjected to similar treatment to the other three, should be attacked by soda, always supposing that any soda introduced at the softening plant was sufficient to cause embrittlement and further, that the other *drums* of the exploded boiler, where rivets had been removed, disclosed no definite sign of cracking, although the same water would be circulating throughout the boiler.

While therefore the cracks found in the various plates forming the drum cannot be definitely attributed to any particular circumstance, it is probable that they originated from a combination of some of the causes investigated.

At the inspection of the boiler in December, 1926, it is quite possible that the flaws although nearly through the material in places, had not appeared through the water side of the plate, and that when dampness at the longitudinal seam was observed on 21st March, necessitating caulking, some penetration had occurred locally; further extension of the cracks would undoubtedly be caused when the boiler was cooled down a few days prior to the explosion and steam was raised again within a few hours. A suitable hydraulic test would have disclosed the weakness of the drum, but there appeared to be no reason to subject the boiler to such a test having regard to its age compared to others in the battery. It is satisfactory to note that the owners have decided to scrap the other three boilers in the battery.

The greatest assistance has been rendered by the staff of Messrs. Dorman Long and Co., during the inquiry.

Observations of Mr. A. E. Laslett, Engineer Surveyor-in-Chief.

The explosion of the water drum of a water tube boiler, dealt with in this report, must be regarded as a very serious and startling occurrence. The plant had been under the supervision of a well qualified staff and this boiler, as all the other units in the steam plant, had been regularly inspected by the experienced Surveyors of an Insurance Company. And yet the drum shell ruptured longitudinally from end to end and on examination was found to have been in a seriously weakened condition, probably for some time. The defects had been on inner surfaces of the lap joint and therefor invisible under ordinary inspection, and there had been but the slightest indication of any defect prior to the explosion.

The very thorough inquiry held has revealed no cause for the cracks in the plate and its consequent failure under ordinary working conditions which can be accepted as conclusive, though various theories have been advanced and discussed in the report. For each theory there are certain arguments which justify its existence and, since the holding of the preliminary inquiry, those requiring special scientific knowledge have been submitted to the investigation of some of the best known experts, chemists, metallurgists or engineers. Nothing definite has been arrived at from these investigations, and the cause of the explosion still remains a matter of doubt.

It was suggested that the material of the drum shell was itself defective in quality, but analysis and microscopic examination, though showing that the plate was not of the highest quality, did not justify the opinion that failure was due to any fault in the steel, nor did it suggest any reason why the cracks found to exist started in nearly all cases from the inside surfaces of the joint and did not often penetrate to the full thickness of the plate. The physical tests showed the plate to have the qualities suitable for boiler making purposes to a satisfactory degree.

The suggestion that the material had been damaged by over pressure on the rivets during construction was not supported by the evidence, and there was no sign of fatigue of the material or of grooving due to the drum not being of truly circular form in the vicinity of the lap joint.

Embrittlement of the steel, by the action of caustic soda on the material while under stress, was suggested as a possible cause of cracking by the discovery of a deposit which had been enclosed between the adjacent surfaces of the joint, the plates themselves not having been fitted very closely together in this joint. This cause of failure of steel plates has been investigated and accepted as probable in America, as accounting for the fracturing of many boiler plates. In this country it has been received with some reserve, as similar failures have occurred when the presence of caustic soda could not be proved and in some cases where it certainly was not present.

In the case now dealt with, analysis proved the presence of small quantities of caustic soda, or at least of its equivalent in other forms, but expert chemists and boiler experts, who have been investigating this theory in this country for some time and who have been consulted in this case, are strongly of opinion that the quantity of caustic soda found in the joint and the degree of concentration could not have affected the structure of the material, at any rate to the extent to which it had been affected, if at all.

The opinion of such authorities must carry great weight and if it does not absolutely rule out this theory of embrittlement, it certainly removes it into the region of mere conjecture. We are therefore left in a state of uncertainty as to the cause of this very serious explosion, which, had it happened during working hours, might have had most disastrous results as regards loss of life. And one is driven to wonder how many boiler drums or other vessels under steam pressure may be in a similar state, and yet not giving any direct indication of their condition. It would certainly be prudent on the part of those responsible for their supervision to watch for the slightest indication of anything abnormal and to investigate carefully the cause of such appearances when found.

Two incidents in the history of this boiler suggest some comment. In describing the method followed in cooling the boiler when laid off for repairs on 31st March, it is stated that the attendant used the injector, apparently forcing the cool feed water into the upper back steam and water drum from which it would pass down into the lower back drum (which afterwards exploded). Such drastic treatment of a boiler is, it is hoped, unusual; it is likely to cause trouble and may have accelerated the failure of the drum in this case as the lower and thinner shell plate would be cooled much quicker than the thicker tube plate and consequently be subjected to stress at the joint.

It is also stated in the report that, at the examination of this boiler on the 21st March, it was found necessary to caulk the rear lap joint of the back water drum as there were signs of leakage and it is later stated that, after the explosion, it was found that where this caulking had been done, the flaws in way of the rivet holes had extended through the plate, suggesting that the leakage seen at the inspection was due to the greater development of the cracks at that part. It is, of course, easy to be wise after the event, but these facts do certainly point to the need for vigilance on the part of boiler inspectors and others in charge of steam plants, who would, in view of this case and of others in which such indications have coincided with similar defects, be justified in calling special attention to the circumstances and in requiring the removal of rivets for examination of the holes. If, on inquiry, it is found that caustic soda is used in the boiler for any purpose, this should, I think, be taken as an additional reason for special caution.

An additional and inexpensive safeguard would, of course, be an hydraulic test to at least $1\frac{1}{2}$ times the working pressure.

3rd June, 1927.

Results of Chemical Analyses of two pieces of Steel Boiler Plate received from Messrs. Dorman Long and Co., Ltd., Middlesbrough:—

Test No.	*JJJ* 1750. Plate A. Per cent.	*JJJ* 1751. Plate A1. Per cent.
Carbon by combustion ...	0·113	0·125
Silicon	0·015	0·014
Sulphur	0·047	0·047
Phosphorus	0·064	0·063
Manganese	0·488	0·507
Copper	0·037	0·033
Nitrogen	0·0039	

28th February, 1928.

Report upon two pieces of Steel Plate received from Messrs. Dorman Long and Co., Middlesbrough.

The pieces were stated to be from opposite ends of the same plate.

JJJ 1750.—Piece marked A, 18½ by 16 inches by 7/16ths inch thick. One edge was part of a circumferential joint fractured through the rivet holes, which were of 13/16ths inch diameter and two inches pitch; the other edges had been cut by a blowpipe, except for a length of four inches on one longitudinal edge which had been sawn. The piece was not flat and on the concave face there were a number of cracks near the fractured edge, most of them originating at the rivet holes.

JJJ 1751.—Piece marked A1, 17 by 21½ inches by 7/16ths inch thick. One edge was part of a circumferential joint which was cracked in places but not completely fractured; the rivet holes were of 13/16ths inch diameter and 2 inches pitch. An adjacent edge was part of a longitudinal joint fractured through the rivet holes, which were of 13/16ths inch diameter and 2¾ inches pitch. The other two edges had been cut by a blowpipe, except for a length of four inches on each which had been sawn. The piece was not flat; the cracks in the region of the circumferential joint were on the concave face, and those near the fractured edge of the longitudinal joint were on the convex face.

These two pieces of plate and the positions of the various test pieces which were cut from them, are shown in Plate 3, and the results of the mechanical tests are given in our report of 31st May, 1927. Those results were so closely similar for the two pieces of plate that only one analysis was considered necessary; for this purpose equal parts of chips from A and A1 were taken. The results were given in our report of 3rd June, 1927.

Visual and microscopical examination of the plate yielded the following information:—

The longitudinal riveted joint is parallel to the longitudinal direction of the plate. This is contrary to ordinary boiler practice, but may be usual in drums of water tube boilers on account of their dimensions.

The rivet holes were drilled.

The material is mild steel, of ordinary quality except as regards the yield point which is unusually high for this class of material. There is no notable segregation, and only an ordinary degree of lamination; one rather large laminar defect was observed at about mid-thickness of the plate in the neighbourhood of the fractured longitudinal joint.

No extensive signs of plastic deformation of the metal were detected in the regions of the riveted joints and it is inferred that the high yield point was a characteristic of the material before it was put into use.

In addition to the readily observable cracks at the edges of the rivet-holes and between the holes, there were numerous fine cracks in the same regions which were revealed when the skin was just removed. The finer cracks were almost entirely intergranular, Figs. 1 and 2, and the coarser cracks had numerous fine branches which were also intergranular, Figs. 3 and 4. At a few positions along some of the larger cracks there were signs of distortion of the metal.

Most of the fine cracks were filled with oxide. The larger cracks were bordered with oxide, but they were not filled; many of these larger cracks appeared to have been wrenched open, no doubt as a result of the explosion, and as a further result it is likely that an oxide filling of such a crack would be in a great degree detached. We are of opinion that the cracks have developed slowly during a considerable time.

The faces which showed cracks were all inner faces of joints, though they were opposite faces of the plate for longitudinal and circumferential joints. The unbroken circumferential joint showed evidence of much working; the holes which were nearly circular on the outer face of the joint, were elongated $\frac{1}{8}$ inch in a longitudinal direction on the inner face of the joint. There was evidence of a good deal of caulking along all the joint edges and around the rivet heads of the circumferential joints.

We understand that the internal diameter of the drum was 36 inches and that the boiler pressure was 165 lbs. per square inch. The average working stresses in the plate, calculated in the ordinary manner, were therefore 9,800 lbs. per square inch at the longitudinal joint, and 5,800 lbs. per square inch at the circumferential joint. There is no apparent metallurgical reason for the failure of the longitudinal joint, except that we should regard the plate as being cut in the wrong direction, but this only makes more remarkable the simultaneous failure of the circumferential joint, at which the stress was so much less. We are of opinion that the above stresses are not likely by themselves to have caused failure of the plate.

DAVID KIRKALDY & SON.

Election of Members.

List of those elected at Council Meeting held on Monday, July 8th, 1929:—

Members.

Robert Adamson Baxter, Milldens, Graham Street, Montrose, Scotland.

Andrew Thomson Bowden, University of Western Australia, Perth, Western Australia.

Francis Stuart Savours David, Harbour Engineers' Dept., Colombo, Ceylon.

John Joseph Giblin, Point Road, Dundalk, Ireland.

Thomas Laws Mackie, 90, South View West, Newcastle-on-Tyne.

Henry Giles Martin, 44, Beach Avenue, Whitley Bay, Northd.

John Stiles Martin, *c/o* T. W. Greenwell & Co., Ltd., South Dock, Sunderland.

John Mitchell, Eng.-Lt., R.N., ret., 31, Broomhill Road, Goodmayes, Essex.

Eric George Davis, 121, Clonmore Street, Southfields, S.W.18.

James Roberts Henderson, Dunvale, Maxwelltown, Dumfries, Scotland.

Norman John Gillespie MacKay, *c/o* Cooper, Allen & Co., Cawnpore, India.

Companion.

Robert Arthur Hornell, Rear-Admiral, D.S.O., ret., Wellington House, Strand, W.C.2.

Associate-Members.

William Hunter Barr, 51, Lorne Street, Leith, Scotland.

Carl Jacob Lamb, Westinghouse Elec. & Mfg. Co., South Philadelphia Works, Lester, Pa.

Windsor Martin, Hoel Las, Llansamlet, Swansea, Glam.

Associate.

Allan Hubert Abraham, 163, Queens Road, Buckhurst Hill, Essex.

Andrew Cecil Kennedy, 10, Waterloo Road, Hakin, Milford Haven.

Graduates.

Albert Berry, 23, The Oval, Firth Park, Sheffield.

George Albert Westlake, 26, King Street, Pelaw-on-Tyne.

Transferred from Associate Member to Member.

S. B. Jackson, 9, Maldon Road, Acton, W.3.

Kenneth Carlisle Lawson, 45, Lincoln Street, Barrow-in-Furness.

Thomas Charles Tippin, 54, Linden Road, Gillingham, Kent.

Transferred from Associate to Associate Member.

Thomas Durant Shilston, East View, Stockton Road, West Hartlepool.

Transferred from Graduate to Associate-Member.

Leonard A. Nightingale, 17, Springfield Road, Thornton Heath.

Board of Trade Examinations.

List of Candidates who are reported as having passed examination for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

For week ended 8th June, 1929:—

NAME.	GRADE.	PORT OF EXAMINATION.
Evans, William V.	1.C.M.E.	Glasgow
Nicol, Edmund	1.C.M.E.	,,
Barnes, George W.	1.C.M.E.	London
Atkin, George E.	1.C.M.E.	Liverpool
Cowie, John	1.C.M.E.	,,
Harrison, Ronald T.	1.C.M.	,,
Marks, George R.	1.C.	,,
Martin, Reginald	1.C.	,,
McCallum, David	1.C.	,,
Pattinson, James	1.C.	,,
Sharpe, Frederick A.	1.C.	,,
Ellis, Mathew J.	2.C.	,,
Rennie, William	2.C.	,,
Williams, Harold L.	2.C.	,,
Whitehead, Francis A. A. ...	2.C.	Dublin
Mowforth, Norman C.	2.C.	Hull
Pearson, Sidney	2.C.	,,
Woodmansey, William H. W. ...	2.C.	,,
Banning Arthur	1.C.	,,
Bell, George E.	1.C.	,,
Coy, Norman	1.C.	,,
Duncan, Arthur B. C.	1.C.	Glasgow
Miller, William M.	1.C.	,,
Phillips, John B.	1.C.	,,
Clare, Clifford C.	1.C.	London
Dalrymple, Horace T.	1.C.	,,
Stratton, Thomas	1.C.	,,
De La Mare, Harry W.	2.C.	,,
Golder, John S.	2.C.	,,
Miller, William	1.C.M.	,,
Allen, Albert F.	1.C.	North Shields
Forster, William R.	1.C.	,,
Slassor, Robert	1.C.	,,
Flaws, Laurence J.	2.C.	,,
Shout, Alfred	1.C.M.	,,
Hagan, John L.	1.C.M.E.	,,
Sanderson, John	1.C.M.E.	Sunderland
Taylor, Edward C.	1.C.M.E.	,,
Pallett, William S.	1.C.	,,
Rowntree, John	1.C.	,,
Cowe, Henry A.	2.C.	,,
Dales, Albert	2.C.	,,
Dodds, Gordon, A. F.	2.C.	,,
Herdman, Reginald	2.C.	,,
Hird, John W.	2.C.	,,
Percy, Reginald H.	2.C.	,,
Stockdale, William K.	2.C.	,,

For week ended 15th June, 1929:—

Ennels, Louis J.	1.C.M.E.	London
Jones, Thomas R.	1.C.M.E	,,
Bryan, Ernest V. A.	2.C.M.E.	,,
Smith, Robert B.	1.C.M.E.	,,

For week ended 15th June, 1929—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Bull, Frederick G.	1.C.M.E.	Cardiff
Lawrence, Frederick S.	1.C.M.E.	,,
Lashford, Bernard F.	1.C.	,,
Rogers, John L. C.	1.C.	,,
Angus, Stuart P.	2.C.	,,
Beard, David N.	2.C.	,,
Gaskin, Frederick E.	2.C.	,,
Cook, John D.	1.C.	Glasgow
Gaskill, Robert G.	1.C.	,,
McMillan, George B.	1.C.	,,
Storry, Reginald	1.C.	,,
Watson, Archibald C. B. ...	1.C.	,,
Barbour, Robert H.	2.C.	,,
MacLachlan, Alexander ...	2.C.	,,
Hair, David	1.C.M.E.	,,
Reid, Alexander S.	1.C.M.	,,
Dickson, Jameson	2.C.	Leith
Young, John S.	2.C.	,,
Hartley, Arthur P.	1.C.	Liverpool
Mort, John	2.C.	,,
Lawson, Kenneth C.	1.C.M.	,,
Clayton, Harold R.	1.C.	London
Cook, Horace C.	1.C.	,,
Robertson, William H. H. ...	1.C.	,,
Washington, Frank	1.C.	,,
East, Arthur S.	2.C.	,,
Hine, Percival H.	2.C.	,,
Wilkinson, Joseph	2.C.	North Shields
Berlin, John H.	2.C.M.	,,
Johnston, James B.	1.C.	Southampton
Cole, Alfred	2.C.M.	,,
Rawlinson, Albert	1.C.M.E.	,,

For week ended 22nd June, 1929 :—

Gibson, Alfred T.	1.C.M.E.	London
Vella, Joseph	1.C.M.E.	,,
Davis, Eric G.	1.C.	,,
Godsiff, Ralph	1.C.	,,
Day, Reginald S.	2.C.	,,
Flory, John H. G.	2.C.	,,
Ferrier, Archibald	2.C.	,,
McKenzie, Hugh A. S.	2.C.	,,
Nicoll, George	1.C.	Glasgow
Blakeley, George F.	2.C.	,,
Cradock, William E.	2.C.	,,
McIntyre, Donald	2.C.	,,
McLean, Daniel	2.C.	,,
Cotton, Harold	1.C.	Liverpool
Hall, Donald B.	2.C.	,,
Harrison, William N.	2.C.	,,
MacKay, Colin H.	2.C.	,,
Appleton, Ronald	2.C.M.	,,
Scarisbrick, Charles W. ...	1.C.E.	,,
Keyworth, Egerton L.	1.C.M.E.	,,
Bode, Stanley	2.C.M.E.	,,
Edmondson, Ernest	1.C.M.E	North Shields
Marsh, Andrew	2.C.	,,
Whittle, Dudley F.	2.C.	,,
Farrell, David D.	1.C.M.	,,
Littler, John J.	1.C.M.	,,
Chambers, John H.	2.C.M.	,,

For week ended 22nd June, 1929—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Alton, William A.	1.C.	Sunderland
McMaster, Herbert	1.C.	,,
Kelleher, Edward H.	2.C.	,,
Richardson, Henry D.	2.C.	,,
Singleton, Donald H.	2.C.	,,
Allinson, George P.	1.C.M.E.	,,
King, Charles A.	1.C.M.E.	,,
Reed, George T.	1.C.M.E.	,,

For week ended 29th June, 1929:—

Forrester, William	1.C.M.E.	Glasgow
Smart, William E.	1.C.M.E.	North Shields
Humble, John G. R.	1.C.M.E.	,,
Harvey, John	1.C.	,,
Butchart, Robert	2.C.	,,
Frost, Walter S.	2.C.	Belfast
Russell, William L.	1.C.M.	,,
Allen, Robert B.	2.C.M.	,,
Beynon, Aubrey	1.C.	Cardiff
Henderson, Frederick M. ...	1 C.	,,
Wide, Ernest R.	1.C.	
Ewer, Percy S.	1.C.M.E.	,,
Keer, Frederick K.	1.C.M.E.	,,
Edwards, Thomas J.	2 C.	,,
Kilpatrick, Charles	2.C.	Glasgow
Kinney, John	2.C.	,,
McDonald, Walter B.	2.C.	,,
McMillan, Archibald H. ...	2.C.	,,
Watson, David G.	2.C.	,,
Duncan, Arthur B. C.	1.C.M.E.	,,
Houston, Robert	1.C.E.	,,
Currie, Charles S.	1.C.	,,
McLean, Ian C.	1.C.	,,
Miller, Thomas	2.C.M.	,,
Potts, Robert C. D.	1.C.	Leith
Brand, Robert M.	2.C.	,,
Brown, Alexander McI.	2.C.	,,
Davidson, Charles	2.C.	,,
Duff, William	2.C.	,,
Stewart, John F.	2.C.	,,
Bond, George C.	1.C.	Liverpool
Forshaw, Charles G.	1.C.	,,
Frank, William	1.C.	,,
Jennions, William	1.C.	,,
Kinghorn, John E.	1.C.	,,
Montgomery, George V.	1.C.	,,
Clear, Noel T.	2.C.	,,
Constable, James D.	2.C.	,,
Egan, John	2.C.	,,
Griffith, Thomas A.	2.C.	,,
McKee, Stanley R.	2.C.	,,
Musker, Henry	2.C.	,,
Sowden, Frederick J.	2.C.	,,
Wilkie, Samuel D.	2.C.	,,
Daniels, Alfred J.	2.C.	London
Pizzardi, Emanuel C.	2.C.	,,
Ryan, William L.	2.C.	,,
Fayrer, Cyril E. V.	1.C.	Southampton
Weller, Maurice W. W. ...	2.C.	,,