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Developments in Machinery of Cross-Channel Vessels.

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Chairman: Sir Amos L. Ayre, K.B.E., D.Sc. (President).

Synopsis.

The general requirements and limitations imposed on the machinery of cross-Channel vessels to suit the requirements of the service are discussed.

The earlier types of machinery for paddle-engined vessels are briefly touched on, and illustrations are given of some of their more notable features. A brief reference, with particulars, is made to the early direct-driven turbine steamers, but the main portion of the paper is concerned with geared-turbine and Diesel-engined vessels from 1913 onwards.

Illustrated comparisons are given of the early and latest types of propeller thrust blocks, and of coal-fired and oil-fired water-tube boilers, and reference is also made to mechanical stokers. Curves of speed and power of a number of vessels, together with tables of representative geared-turbine, turbo-electric, direct-Diesel and Diesel-electric vessels, are given, as well as illustrations of machinery arrangements and propelling machinery. The latest types of turbines, gearing, condensers and manœuvring gear are discussed, and illustrations are given. Improvements in high-pressure boilers, economisers and air heaters are illustrated and discussed, while electrical requirements, auxiliaries, feed systems and auxiliaries generally are considered and illustrations given of outstanding types.

The problem of machinery for cross-Channel vessels is a somewhat special one, as owing to the limits imposed on the size of the vessel by the facilities and depth of water at the terminal ports, the length, draught and displacement have to be curtailed to suit. Usually the vessels have to run to a fixed timetable made to suit the rail connections on either side, and the speed of the vessel has to be modified to suit. As the speed required is generally fairly high, the problem of squeezing a quart into a pint pot results in the inevitable compromise.

In the case of vessels on a daily run, the problem of accommodation is not so acute. A reasonable space can therefore usually be allotted to the machinery. For vessels engaged on a night service, the requirements of cabin accommodation make things much more difficult, for passenger berthing accommodation requires much more space, and there is a tendency to restrict the engineers' space in the interests of the passengers. This tendency has been accentuated by the new Ministry of Transport regulation regarding the provision of separate accommodation for the members of the crew, who formerly could be accommodated in a common space, either fore or aft. This has led to the practice of having accommodation on the lower decks, in a position which the engineer could formerly count as his own, and necessitates the provision of elaborate sewage systems. Fire equipment has also been greatly increased, and where formerly a few hoses or fire buckets were considered sufficient, elaborate sprinkler systems, pumps and tanks are now required.

While these all make the vessels safer, the demand of all these services, coupled with the limitations on length, beam and draught, causes the naval architect to look with covetous eyes on the largest non-paying spaces available, which were formerly ear-marked for the engineers. The depth to the main deck is usually restricted and this makes the question of overhaul somewhat awkward, especially with the growing practice of wholly or partly enclosing the machinery spaces, notably with the geared turbines and underslung condensers usually fitted in accordance with modern practice. To accommodate Diesel engines at all, these must be of the high-speed type such as the trunk piston engine, with minimum overhauling height.

The increased demand for more elaborate and luxurious accommodation and higher speeds, leads to further demands on power requirements and adds further to the difficulty of the engineers.

The above is a brief summary of the limitations imposed on the engineer by the requirements of the service.

These and other considerations in connection with the design of cross-Channel vessels have been dealt with more fully by Sir Maurice Denny in his Presidential Address to the Institute in 1935.

The high speeds required involve demands for large powers as shown in Fig. 1. This curve indicates how rapidly the power increases with the speed.

It is well known that very large powers can be accommodated in small machinery spaces, notably in destroyers, but these cases are not exactly parallel, as in destroyers economy can be sacrificed to power. In any case destroyers

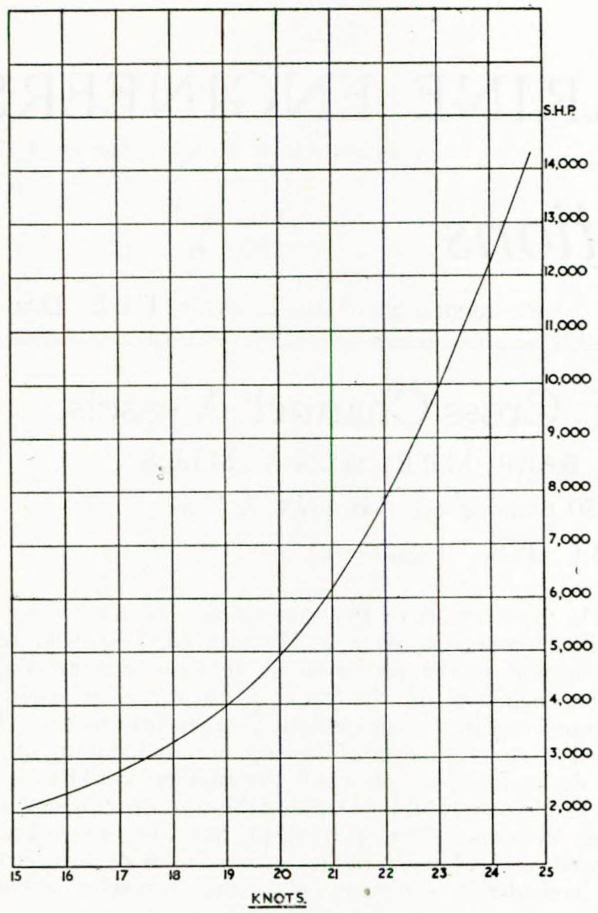


FIG. 1.—*Curve of speed and horse power.*

are only expected to run at full power for a short period, especially in peace time, and can have a large number of skilled engineers on watch. In the case of Channel steamers, full power is demanded almost as soon as the vessel has cast off and has to be maintained until the vessel is tied up, and that in all weather conditions.

The question of fuel economy is a vital one and must be given full consideration; also the number of engineers required needs careful consideration in order to reduce expenses to a minimum if the service is to be a paying proposition. Reliability of machinery is of course another vital factor, and the requirements of the M.o.T. have to be met. Consideration of cost precludes the use of very expensive light alloys, the material chosen being generally of the best quality although not necessarily the lightest and most expensive.

The cross-Channel steamer type goes a long way back, and several notable machinery installations have been made in the past. It is proposed to touch only briefly on some of the earlier types.

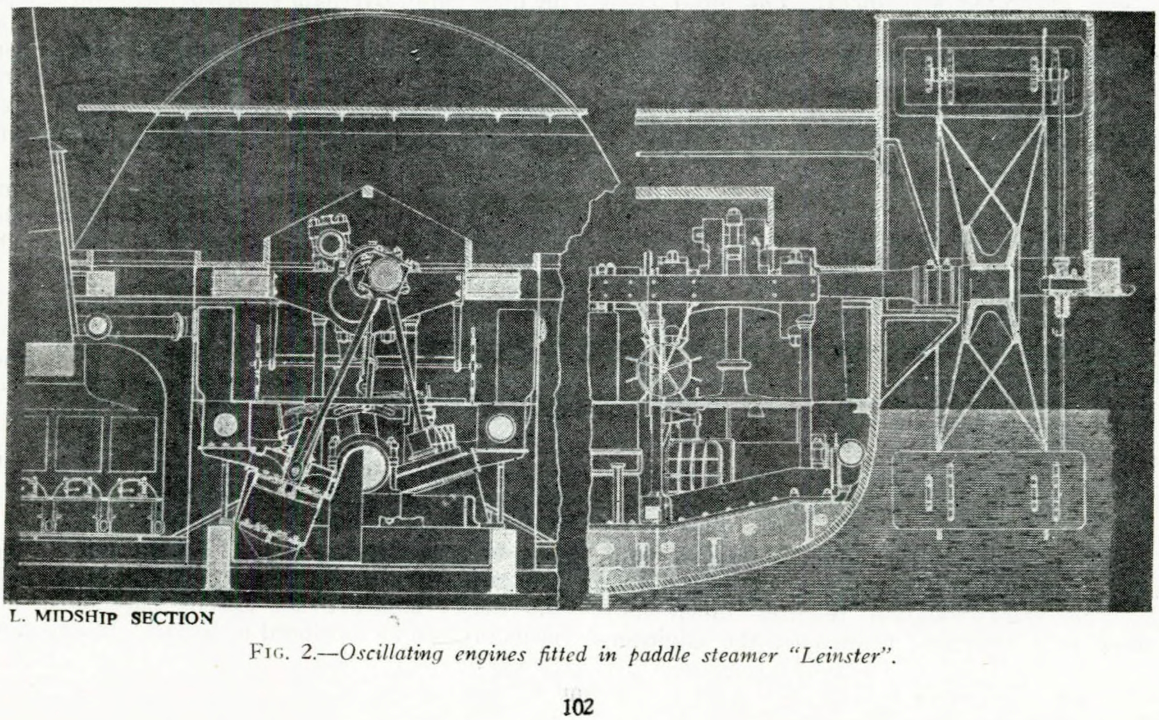
An early example is the machinery fitted in the *Leinster* which had originally a pair of oscillating engines and a haystack-type boiler, operating at 20lb. per sq. in. with jet condensers, driving two paddle wheels with feathering floats. This set is illustrated in Fig. 2.

An interesting feature of this set is that eighteen men were required for manœuvring the engines, all firemen and greasers presumably lending a hand.

In the illustration it will be noted that a pair of spoked wheels is connected to the valve gear of each pair of cylinders. Each wheel was manned by four men, with a seventeenth at the jet condenser and the chief engineer at the stop valve.

Another interesting example is the *Banshee,* fitted with "steeple"-type triple-expansion engines having cylinders 44in., 70in. and 108in. with a stroke of 78in. These were built by Messrs. Cammell, Laird & Co., Ltd. The boiler pressure was 155lb. per sq. in., and the engines developed a total of 4,200 i.h.p. at 35 r.p.m., to give the vessel a speed of 21·17 knots.

A sectional illustration through the L.P. cylinder of this set is shown in Fig. 3, and it will be noted that the cylinder is fitted with two piston rods, a balanced slide valve and triangular connecting rods. Six cylindrical Navy-



L. MIDSHIP SECTION

FIG. 2.—*Oscillating engines fitted in paddle steamer "Leinster".*

type boilers were fitted, burning coal on the enclosed-stokehold system of forced draught.

Some of the earlier paddle vessels developed quite large powers. A typical example of one of these is the *Leopold II,* built by Messrs. Wm. Denny & Bros. in 1893 for the Belgian Government to run on the Dover-Ostend route. This vessel was fitted with compound diagonal paddle engines having 59½in. and 101¼in. diameter cylinders and a stroke of 6ft. 9in. Eight cylindrical coal-fired boilers, operating at a pressure of 110lb. per sq. in. and working on an enclosed-system of forced draught, supplied the steam. A total i.h.p. of 8,500 at 51·5 r.p.m. was developed on trial for a speed of 22 knots.

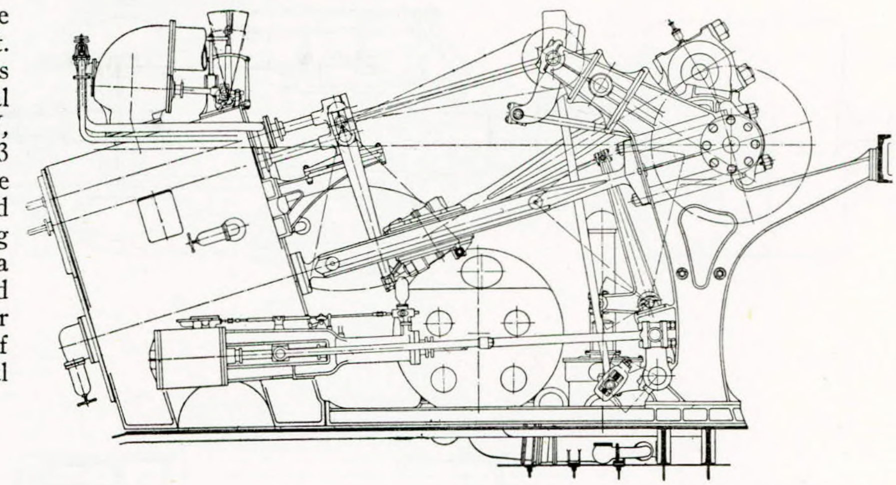


FIG. 4.—*Arrangement of diagonal engines fitted in paddle steamer "Leopold II".*

An illustration of this set is shown in Fig. 4.

This forms an interesting comparison with the Diesel engines fitted in the latest type of Ostend-Dover vessel, the *Prince Baudouin,* referred to later in the paper.

Space does not permit any further examples of these very interesting types of earlier cross-Channel vessels. For those interested, further examples can be found in previous papers on this subject.

Of the direct-driven turbine steamers it is not proposed to say much, other than to give a few brief particulars of the *King Edward* which, in the year 1900, was the first vessel to be fitted with Parsons' turbines.

This was a triple-screw vessel fitted with an H.P. turbine on the centre shaft and an L.P. turbine on each wing shaft, with condensers in the wings, and supplied by steam at 150lb. per sq. in. by a double-ended Scotch boiler burning coal on the enclosed-system of forced draught. Astern turbines were fitted in the L.P. turbine only.

The machinery developed a total of 4,200 s.h.p., giving a speed of 20·5 knots on a total machinery weight of 285 tons, *i.e.* a ratio of 14·7 s.h.p. per ton.

This pioneer vessel was followed by a long succession of highly-successful direct-driven turbine vessels, nearly all coal-fired and fitted with Scotch or water-tube boilers.

As all modern Channel vessels are now driven by geared turbines or Diesel engines, it is not proposed to give any further examples of direct-driven turbine installations.

Before the year 1912 the machinery fitted in cross-Channel steamers was mostly of the reciprocating type, either diagonal paddle engines, compound or triple vertical reciprocating steam engines, driving single or twin screws, or direct-coupled steam turbines. The steam generators were cylindrical Scotch, Navy type, or straight-tube water-tube boilers. These types of machinery have already been briefly dealt with above, as well as in several informative papers read before the various technical societies.

The coming of the geared turbine, oil fuel and high-pressure boilers, and the advent of the Diesel engine, have all added their problems and also their quota of improvements. It is with these changes that it is proposed to deal.

A problem with the earlier turbine steamers was that of astern power as, in an endeavour to reduce idle weights, the astern power was curtailed and often found to be

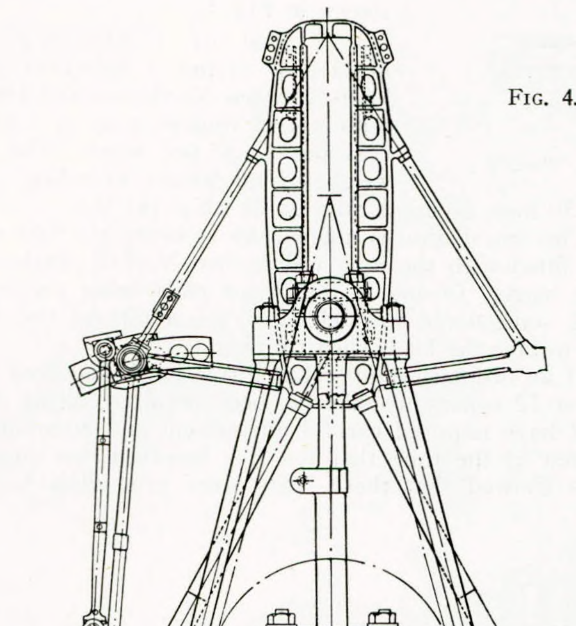


FIG. 3.—*Sectional arrangement of low-pressure cylinder fitted in paddle steamer "Banshee".*

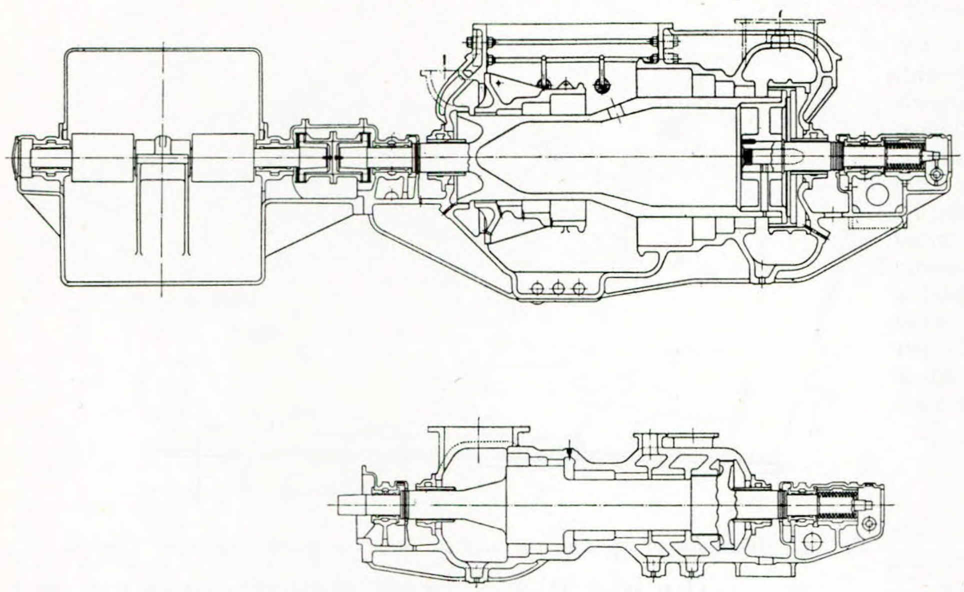


FIG. 5.—*Sectional arrangement of turbines and gearing fitted in t.s.s. "Paris".*

insufficient. The expression of astern power as a percentage of the ahead power was apt to be misleading. In the case of a 20,000 s.h.p. vessel 50 per cent. astern power would be 10,000 s.h.p., which would give double the power fitted for ahead going in many large ocean-going steamers of more than twice the length. A more satisfactory basis would be to express the astern power as a percentage of the ahead going revolutions. On this basis a figure of 90 per cent. of the ahead revolutions for astern purposes can easily be obtained. Few trials have been made under measured mile conditions of vessels running astern. The question of running astern at high speed is largely governed by the ability of the vessel to steer astern in a straight line, and for this purpose bow rudders are usually necessary.

In the case of Diesel engines the same power astern as ahead can be provided.

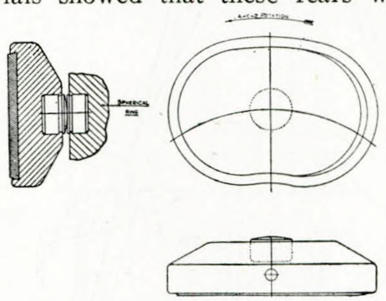
The first vessels to be fitted with geared turbines were the *Normania* and *Hantonia,* built in the year 1912 by The Fairfield Shipbuilding & Engineering Co., Ltd. for the London & South Western Railway Co. These vessels were fitted with compound turbines driving twin screws through gearing. A maximum of 5,780 s.h.p. at 326 r.p.m. was developed on trial and a speed of 20·16 knots was obtained. One double-ended and one single-ended Scotch boiler were fitted, the working pressure being 160lb. per sq. in., burning coal on the enclosed system of forced draught. On a six hours' trial a total of 4,980 s.h.p. at 310 r.p.m. was attained for a speed of 19·7 knots with a coal consumption of 1·35lb. per s.h.p. The total machinery weight including water was 490 tons, giving at ratio of 11·8 s.h.p. per ton at maximum power.

One of the earliest vessels fitted with geared turbines was the *Paris,* built by Messrs. Wm. Denny & Bros. in the year 1913. She was fitted with twin screws and compound turbines running at 2,600 and 1,900 r.p.m. for H.P. and L.P. respectively, coupled by helical gearing to the propeller shafts which ran at 430 r.p.m. Eight Yarrow-type water-tube coal-fired boilers were fitted, working at a pressure of 200lb. per sq. in. For purposes of comparison with later types of machinery, sectional arrangements of the turbines and gearing are shown in Fig. 5.

A total of 13,300 s.h.p. was developed, giving a speed of 24·73 knots between Newhaven and Dieppe, with a fuel consumption of 1·4lb. of coal per s.h.p. per hour. The total weight of machinery including water was 530 tons, giving a ratio of 25 s.h.p. per ton.

This installation is noteworthy as being the first vessel to be fitted with the now well-known Michell single-collar thrust block. Owing to the thrust pads being pivoted off centre, some doubt was felt about the ability of the thrust block to take the load when running astern.

If an ordinary multi-collar thrust block had been fitted at least 12 collars would have been required, all of which would have required careful adjustment and attention. It was felt at the time that the risk involved was justified. Trials showed that these fears were groundless and the



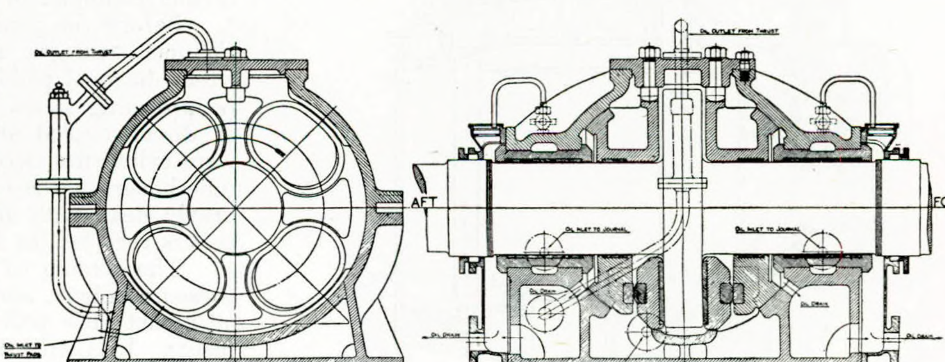


FIG. 6.—*Michell propeller thrust block fitted in t.s.s. "Paris".*

Michell thrust blocks gave no trouble whatever.

As a matter of interest the propeller thrust block as fitted in the *Paris* is shown in Fig. 6. The thrust pads were kidney-shaped and made of gun metal with a comparatively thick facing of white-metal. Each pad had a hardened-steel disc at the back with a rounded face which engaged with a similar hardened-steel disc, thus getting point contact for the pivoting of each pad. The retaining rings were of the spherical-seated type to give some measure of self-alignment, although this did not act in service as expected.

For comparative purposes a drawing of the latest type of Michell thrust block is shown in Fig. 7. As will be seen the principal differences are:—The thrust pads are now sector-shaped and are usually made of cast-iron with thin white-metal faces. Steel inserts in pads are no longer fitted. Instead of pivoting on adjoining steel point, a stop is machined at the back and the thrust pad pivots on the edge so formed. This is termed a line-pivoted pad.

The spherical retaining rings have been superseded by a shoe, on the face of which the line pivots of the pads bear, and on the back are fitted adjustable liners. The shoe transmits the whole of the thrust load to the bottom half of the casing only, and as the top half carries no load it can be made of light construction.

The thrust blocks need not now be coupled to the forced-lubrication service. In the majority of cases they work with their own self-contained bath lubrication, with the oil level when stationary well below the bottom of the shaft. A cupro-nickel cooling coil is fitted in the oil bath. Glands are no longer fitted at the ends of the blocks, these being replaced by oil deflectors.

In regard to loads and speeds, there has not been much change in the loading of thrust pads of marine thrust blocks since the time of the *Paris*. In changing from multi-collar thrust blocks of the pre-Michell thrust block era, which carried a maximum of 40 to 45lb. per sq. in., it was found possible to take all the thrust load to be carried on one block, at 250lb. per sq. in., on a single collar, and consequently there was little call to increase this loading.

That this is a very conservative loading is shown by the fact that in special cases where a very small thrust block is desired, principally on warships, the thrust loading has been increased up to 500lb. per sq. in., and in land turbine thrust blocks 500lb. per sq. in. is now established practice. Even this figure has been greatly exceeded and designs of normally-finished line-pivoted pads have been run at loads of as high as 4,000lb. per sq. in.

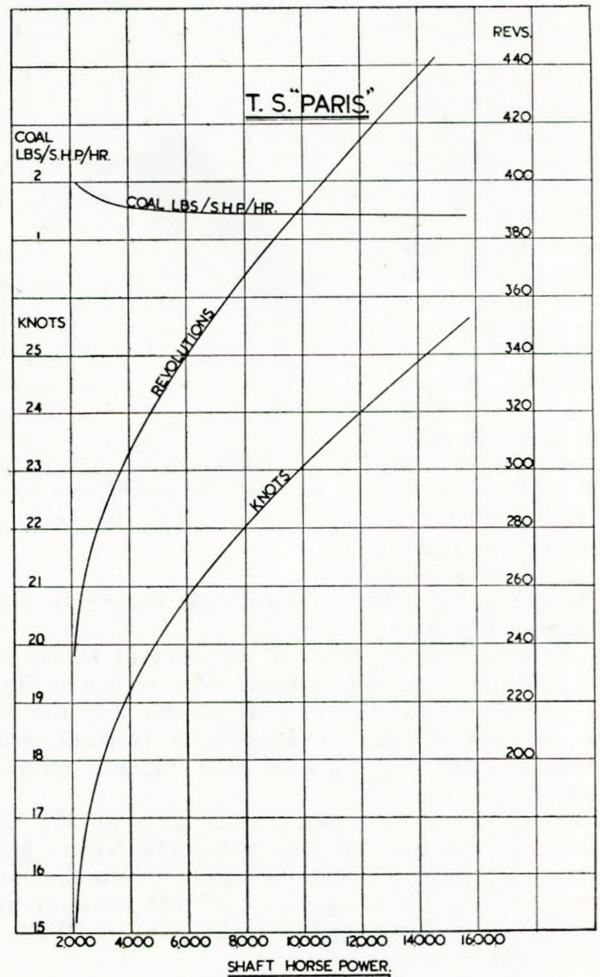
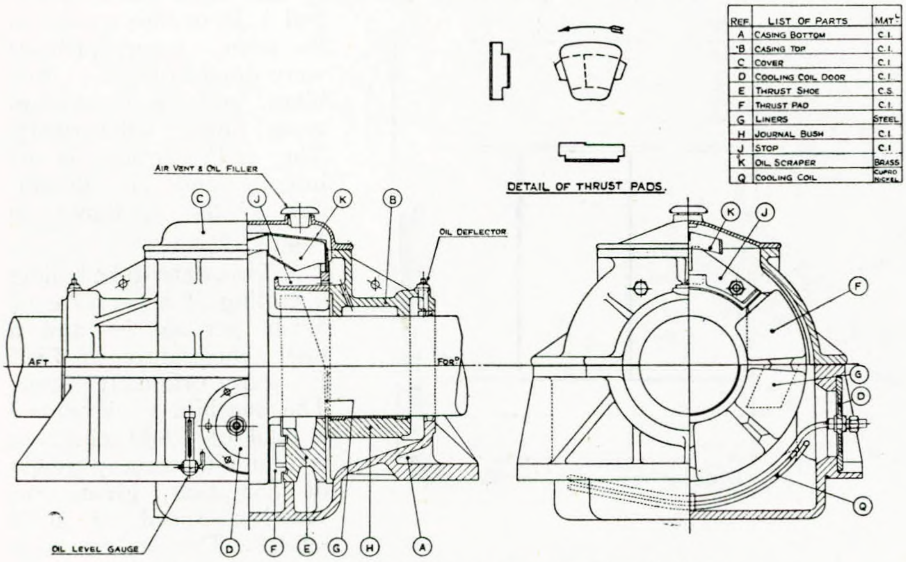


FIG. 8.—*Curve of power and speed of t.s.s. "Paris".*

A graph showing the power, revolutions, speed and steam consumption of the *Paris* is shown in Fig. 8.

The coal-fired water-tube boilers gave no trouble, except to the stokers. The machinery had to be brought up to full power in about five minutes, maintain full power till the end of the run and then shut down suddenly. With about a ton of coal burning fiercely on each grate, the only way to get rid of the heat, after shutting off the fans, was to draw the flaming mass on to the stokehold floor plates and to turn the hose on it. The conditions in the boiler room at the end of the run were, to say the least, very far from pleasant.

After about 19 years it was considered desirable to fit oil fuel, and new boilers of the same type were fitted but the number was reduced by exactly half, four oil-fired boilers being fitted in the same space as the original coal-fired



REF.	LIST OF PARTS	MAT'L
A	CASING BOTTOM	C.I.
B	CASING TOP	C.I.
C	COVER	C.I
D	COOLING COIL DOOR	C.I.
E	THRUST SHOE	C.S.
F	THRUST PAD	C.I.
G	LINERS	STEEL
H	JOURNAL BUSH	C.I
J	STOP	C.I
K	OIL SCRAPER	BRASS
Q	COOLING COIL	CUPRO NICKEL

FIG. 7.—*Latest type of Michell propeller thrust block.*

boilers, and were capable of giving the same output.

The water-tubes of the original boilers were found to be in very good condition indeed, a tribute to the efficiency of the engineers and to their care and skill in operating these boilers under very arduous conditions. This is the more notable when it is considered that at that time very few merchant vessels were fitted with water-tube boilers, and many of these were far from successful.

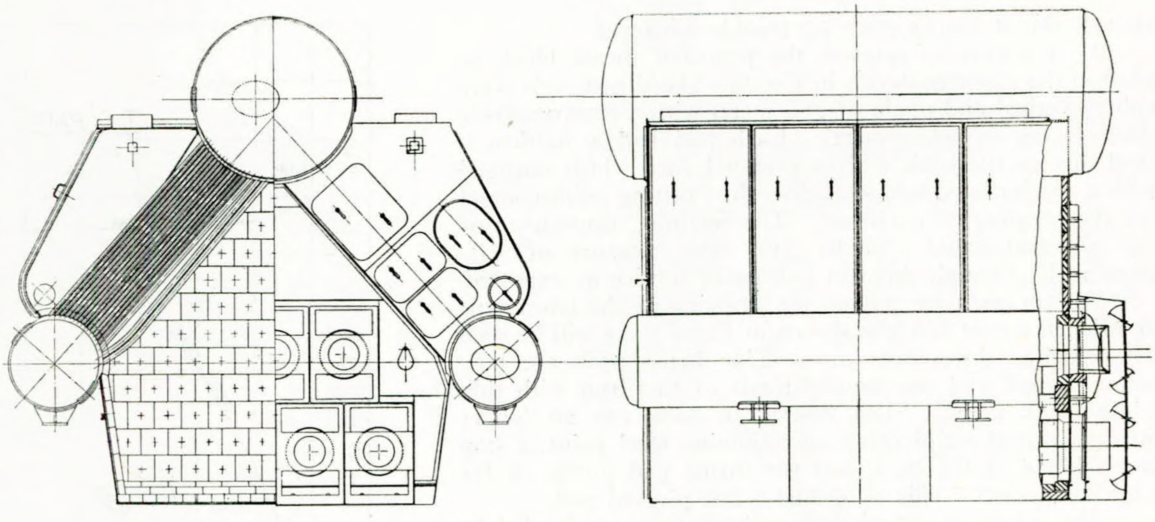


FIG. 10.—*New oil-fired Yarrow-type boilers fitted in t.s.s. "Paris".*

The original coal-fired Yarrow-type water-tube boilers are shown in Fig. 9.

For comparison the oil-fired Yarrow-type boilers fitted in 1932 when the vessel was re-boilered are shown in Fig. 10.

A similar vessel, the t.s.s. *Worthing* for the same service was built in 1928, and drawings of turbines, gearing and boilers, shown in Figs. 11 and 12, are given for comparison.

The machinery developed 15,400 s.h.p. at 373 r.p.m. with four Yarrow-type oil-fired water-tube boilers having a working pressure of 250lb. per sq. in. saturated, on a machinery weight including water of 531 tons, giving a ratio of 29 s.h.p. per ton, and a fuel rate of 0·92lb. per s.h.p. per hour.

As the boiler pressure is only slightly increased and no superheat supplied, no great reduction in fuel consumption is to be expected.

An interesting example of a modern set of machinery is the *Princess Maud,* fitted with geared turbines and four Babcock & Wilcox boilers with mechanical stokers. One of the boilers fitted with these stokers is shown in Fig. 13.

The steam consumption of the turbines is about the same as in the previous example and the fuel rate, burning low calorific value coal, about 1·5lb. coal per s.h.p. per hour. The weight of machinery is of course considerably increased and works out at 10·9 s.h.p. per ton.

Coal, even with mechanical stokers, has not been altogether satisfactory in cross-Channel steamers, owing to the short voyages and their frequent starting and stopping. It is a fairly safe prophecy that oil fuel will become universal for these conditions, but great credit is due to the engineers and boilermakers for overcoming more or less successfully the difficulties and disappointments in burning solid fuel.

This vessel was later converted to oil fuel and the weight saved increased the power/weight ratio to 11·9 s.h.p. per ton.

High pressure and temperatures have been slow to find sponsors for these services, owing to the short period of running—in some cases as short as one hour.

The pioneer high-pressure and superheat vessel was the *King George V* built in 1926 by Messrs. Wm. Denny & Bros. and engined by The Parsons Marine Steam Turbine Co., Ltd. The machinery, as originally installed, comprised seven turbines arranged with an H.P. 1st and 2nd I.P. and L.P. turbine geared to one shaft, and a 1st and 2nd I.P. and L.P. turbine geared to the other. Astern turbines were fitted in the L.P. turbines, and the condensers were fitted athwartship. The H.P. turbine is of interest and an illustration of this is shown in Fig. 14.

Two water-tube boilers operating at a pressure of 575lb. per sq. in. and a total temperature of 750° F. were originally fitted. The machinery developed a total of 3,800 s.h.p. on trial on a machinery weight of 233 tons, giving the vessel a speed of 20·78 knots. The boilers were arranged to burn coal

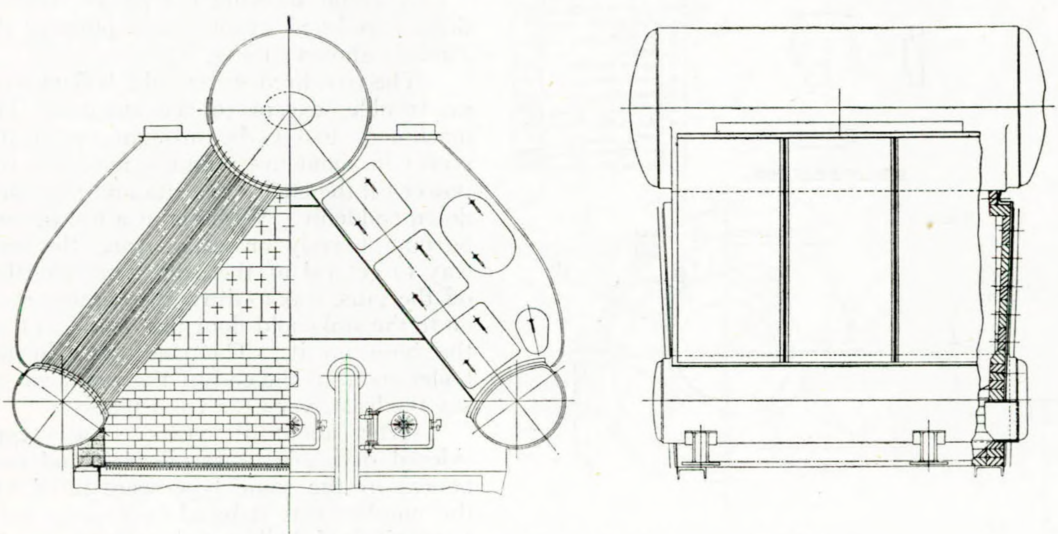


FIG. 9.—*Original coal-fired Yarrow-type boilers fitted in t.s.s. "Paris".*

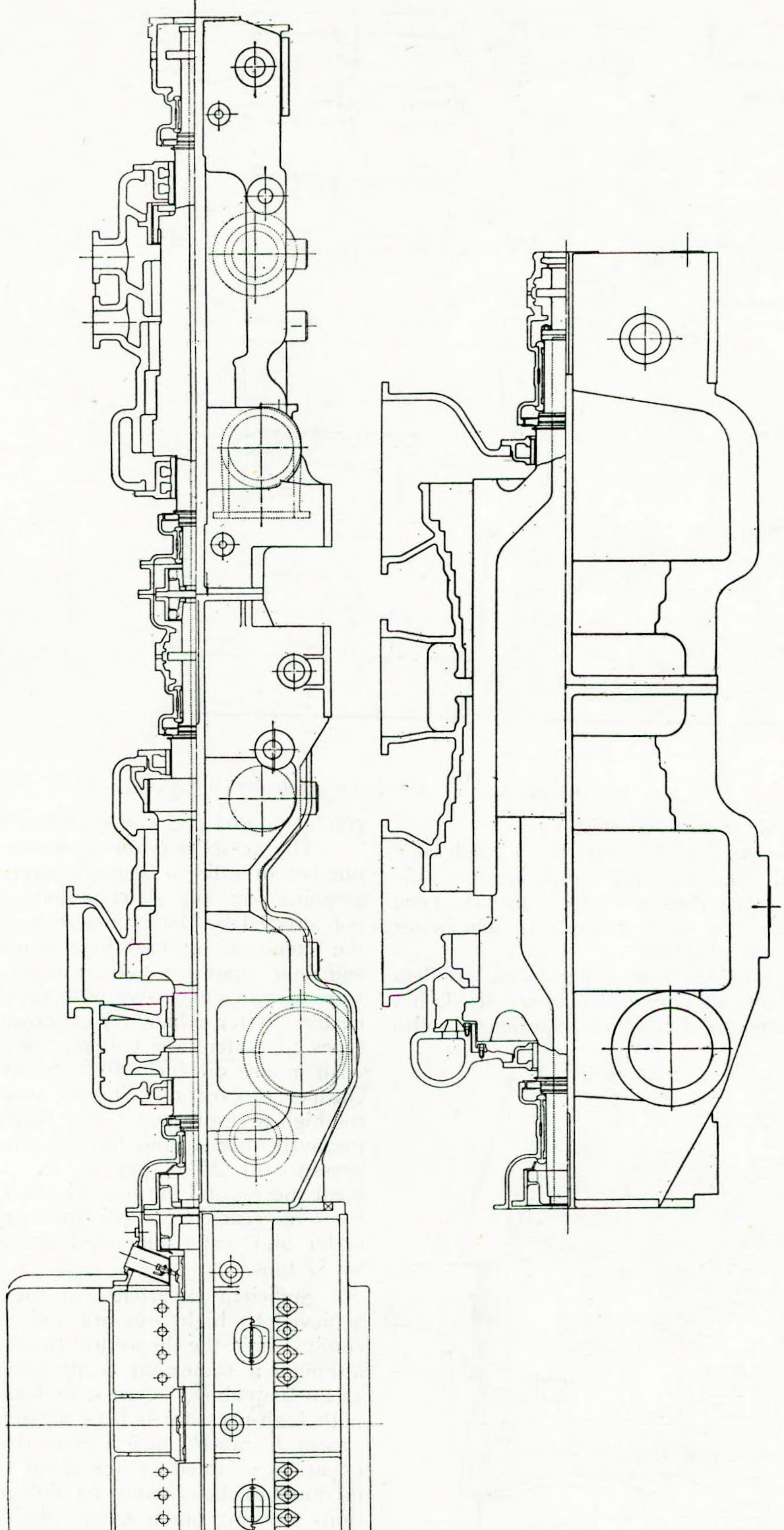


Fig. 11.—*Sectional arrangement of turbines and gearing fitted in t.s.s. "Worthing".*

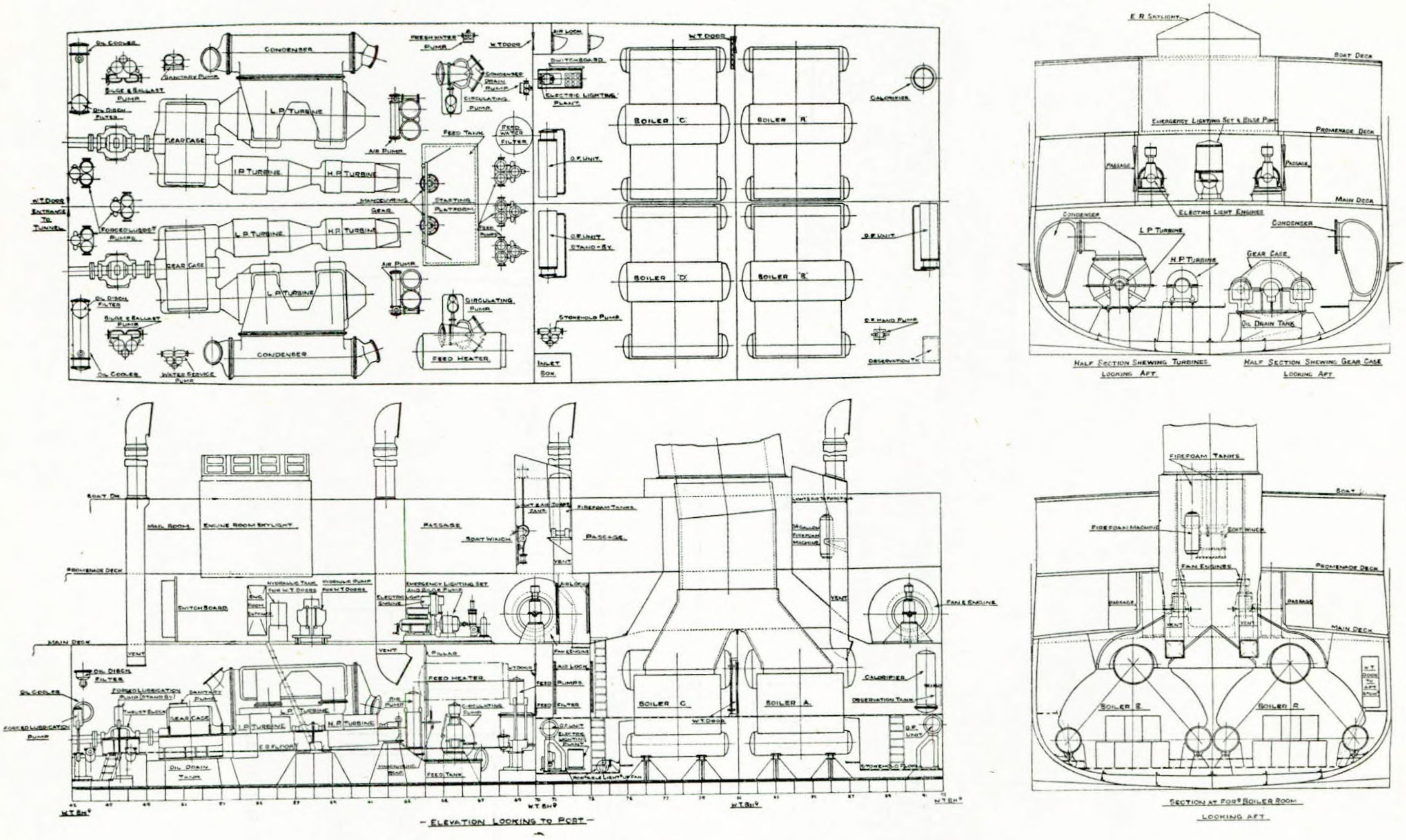


FIG. 12.—*Arrangement of machinery fitted in t.s.s. "Worthing".*

under enclosed-stokehold forced draught.

The machinery ran very well indeed but considerable trouble was experienced from the high temperature, as the probable loss from this cause does not appear to have been anticipated. This trouble was easily remedied when better insulating material became available.

Considerable boiler troubles were experienced. Boilers supplied by two well-known boilermakers were tried, but had to be removed owing to difficulties experienced with combustion of fuel and superheater troubles.

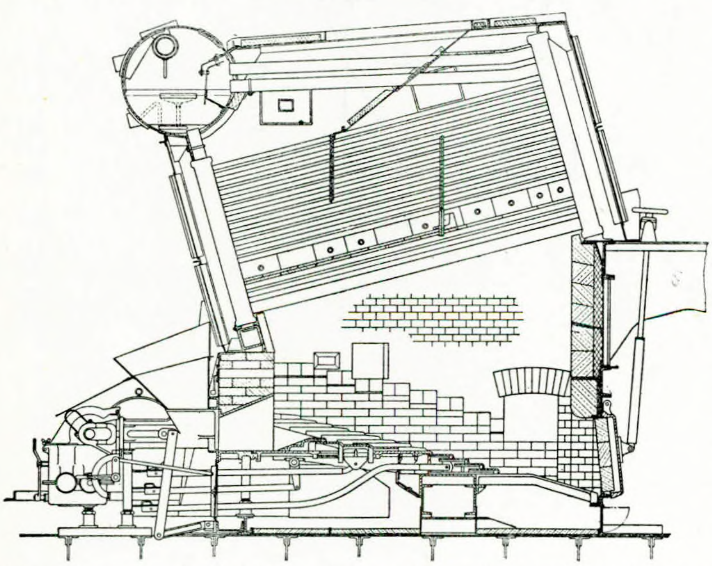


FIG. 13.—*Babcock & Wilcox boiler fitted with mechanical stoker installed in t.s.s. "Princess Maud".*

The vessel was on a service which demanded a large number of calls to be made over quite short distances and stopping for only short periods. While the turbines were not affected by the excessive manœuvring, with coal firing the combustion conditions could not be adjusted with sufficient rapidity to suit, and the superheated temperatures were at times excessive with eventual damage to the superheater. After exhaustive experiments with the two different types of water-tube boilers, and since the owners did not wish to use oil fuel (for coal at that time was much the cheaper proposition), it was eventually decided to remove the high-pressure water-tube boilers, together with the high-pressure turbine, and fit a double-ended Scotch boiler at a pressure of 200lb. per sq. in. The conversion proved a great success and the vessel has been on daily summer service for some years now. It is interesting to note that the Scotch boiler and water increased the weight of the installation by 57 tons.

Sufficient experience of the economy which could be achieved by high pressure and temperature was gained to confirm fully the theoretical predictions, and the experiment, although a somewhat costly one, could only be described as an unqualified success, and all subsequent vessels fitted with high-pressure boilers, including the *Queen Mary* and *Queen Elizabeth,* owe a good deal of their success to the experience gained on the *King George V*. There is now no doubt of the economy of high-pressure superheat installations working under more suitable conditions with oil fuel and water-tube boilers.

A modern arrangement of machinery fitted in the t.s.s. *Falaise* is shown in Fig. 15.

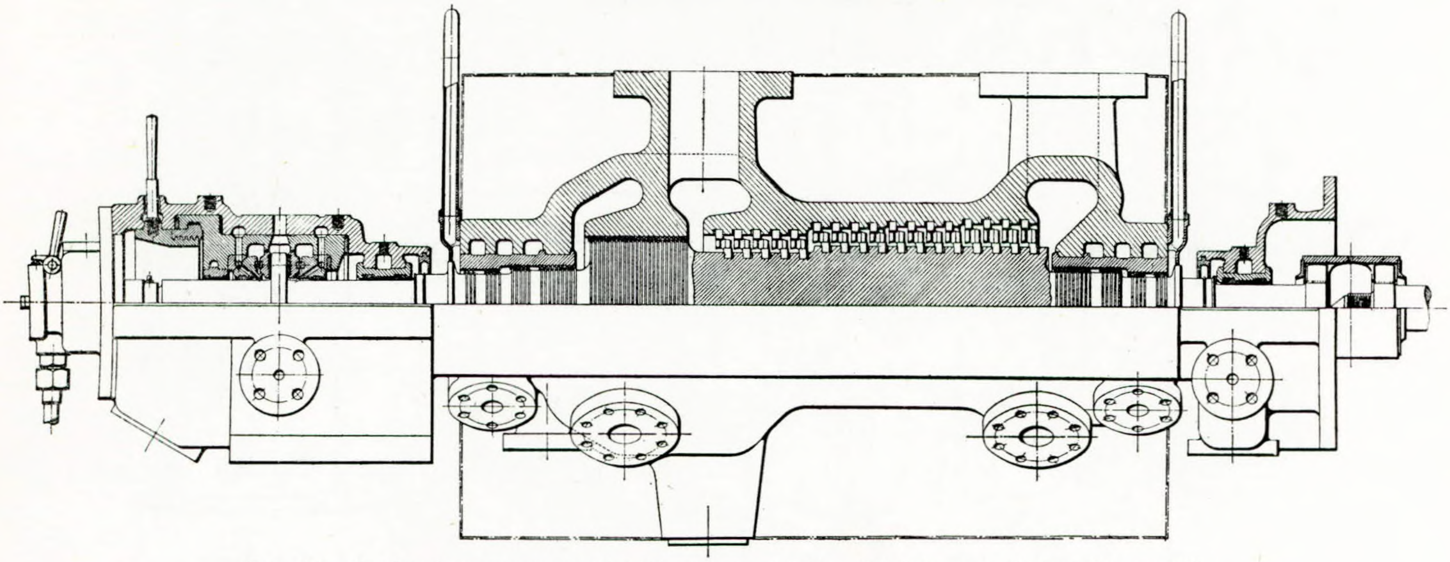


FIG. 14.—*Sectional arrangement of high-pressure turbine fitted in t.s.s. "King George V".*

From the machinery layout, it will be noted that all the auxiliaries are independent of the main engines and either turbine or electrically driven. The engine room is almost totally enclosed and the glands steam condensers should considerably improve the habitability of the engine room. Compound impulse geared turbines with end-tightened reaction blading are fitted, with underslung condenser, closed-feed system and glands steam condensers. Two Foster-Wheeler water-tube boilers working at a pressure of 450lb. per sq. in. and a total temperature of 750° F. are fitted. One of these is shown in Fig. 21.

The manœuvring gear is of great interest and, as it is

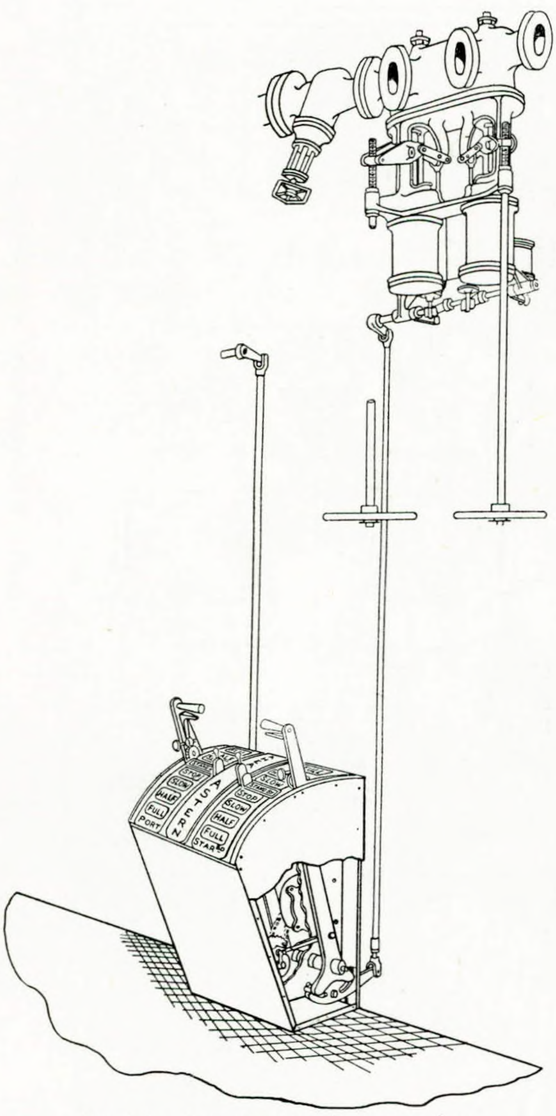


FIG. 16.—*Arrangement of manœuvring gear fitted in t.s.s. "Falaise".*

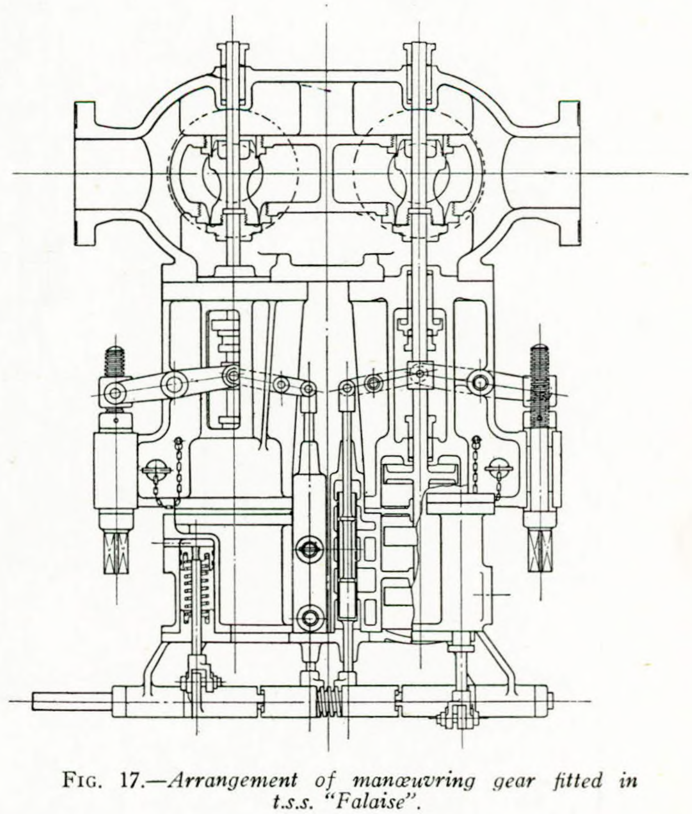


FIG. 17.—*Arrangement of manœuvring gear fitted in t.s.s. "Falaise".*

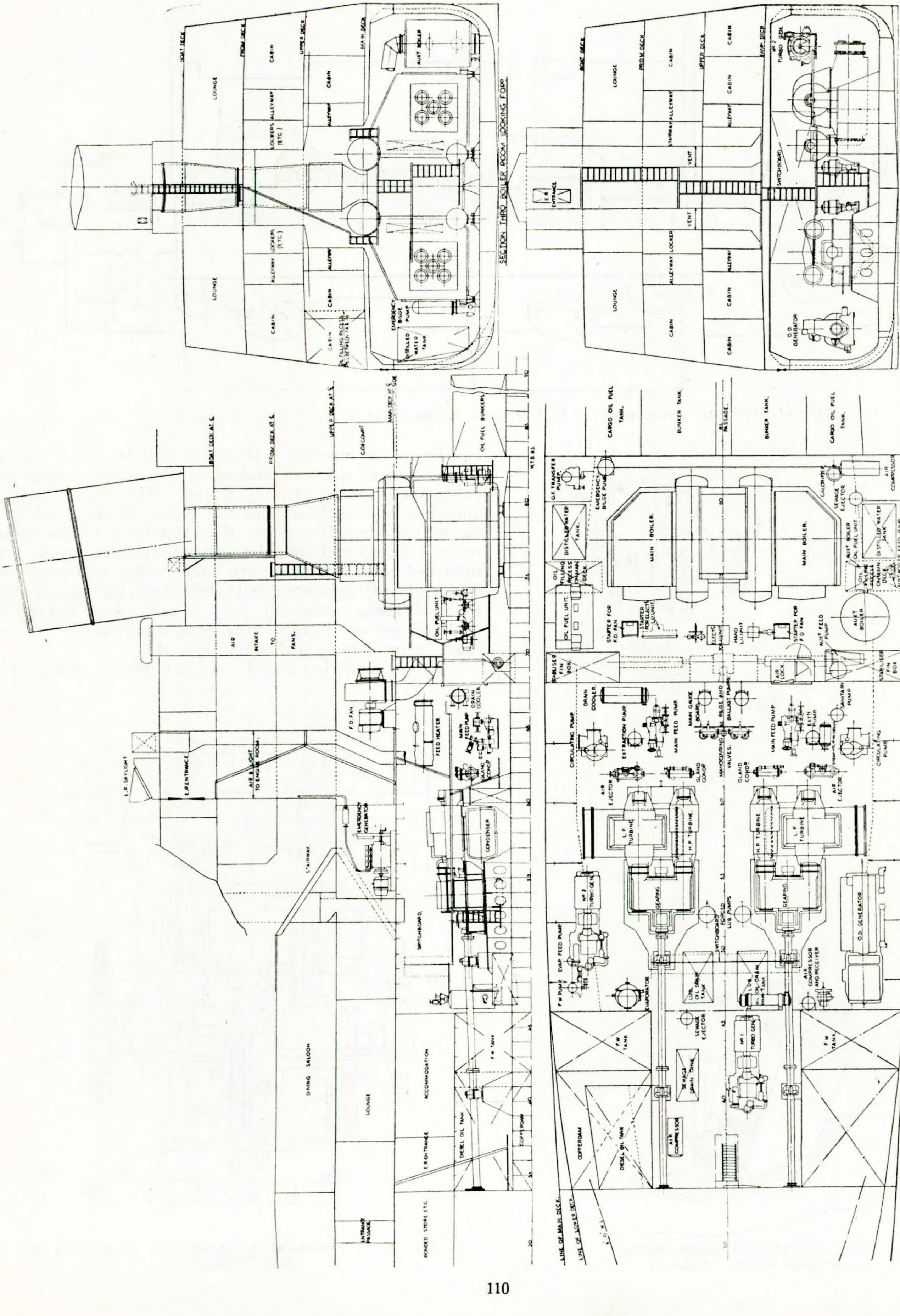


FIG. 15.—*Arrangement of machinery fitted in t.s.s. "Falaise".*

TABLE I

PARTICULARS OF REPRESENTATIVE TURBINE VESSELS.

YEAR	1912	1913	1919	1920	1924	1925	1926	1928	1928	1929	1929	1930	1932	1934	1937	1946	1947	TURBO ELECTRIC 1946
NAME.	NORMANNIA	PARIS.	ANTWERP	ANGLIA	DINARD	ST JULIAN	KING GEORGE V.	WORTHING	DUKE OF LANCASTER	CANTERBURY	VIENNA.	LADY OF MAN.	ISLE OF SARK	PRINCESS MAUD.	FENELLA	INVICTA	FALAISE	HINEMOA
OWNERS.	SOUTHERN RLY	SOUTHERN RLY	L.N.E. RLY	L.M.&S RLY	SOUTHERN RLY	G.W. RLY	DAVID MACBRAYNE	SOUTHERN RLY	L.M.&S. RLY	SOUTHERN RLY	L.N.E.RLY	I.O.M STEAM PKT	SOUTHERN RLY	L.M.&S RLY	I.O.M STEAM PKT	SOUTHERN RLY	SOUTHERN RLY	UNION STEAMSHIP
BUILDERS.	FAIRFIELD	DENNY	JOHN BROWN.	DENNY	DENNY	JOHN BROWN	DENNY PARSONS	DENNY	DENNY	DENNY	JOHN BROWN	VICKERS-ARMSTRONG	DENNY.	DENNY	VICKERS-ARMSTRONG	DENNY	DENNY	VICKERS-ARMSTRONG
DIMENSIONS - LENGTH.	290'-0"	300'-6"	320'-0"	387'-0"	321'-6"	280'-0"	260'-0"	306'-0"	347'-9"	335'-0"	350'-0"	360'-0"	301'-6"	325'-0"	310'-0"	340'-0"	301'-0"	400'-0"
BREADTH.	36'-0"	35'-6"	43'-0"	45'-0"	41'-0"	40'-0"	32'-0"	38'-6"	53'-0"	47'-0"	50'-0"	49'-0"	42'-0"	49'-0"	46'-0"	50'-0"	48'-0"	58'-0
DEPTH	23'-6"	15'-9"	26'-6"	18'-6"	16'-0"	24'-8"	11'-0"	15'-9"	19'-6"	17'-9"	27'-0"	26-6"	16'-0"	17'-0"	18'-0"	17'-9"	17'-6"	29'-0"
DRAUGHT	12'-10½	9'-1"	15'-0"	12'-9"	12'-1½	13'-0"	6'-8	9'-7"	13'-8"	11'-3"	15'-3"	12'-6"	12'-0"	10'-8"	12'-3"	12'-2½	12'-6	17'-0⅝
DISPLACEMENT TONS	2000	1510	3220	3130	2270	2250	770	1,800	3,320	2,520	4,000	3300	2190	2600	2,650	2890	2,825	6,445
S.H.P. TOTAL	4980	13,300	9,500	15,000	5480	4350	3800	15,400	8,590	8,960	9,500	11,500	5,230	7,100	8,000	11,300	8,500	13,000
SPEED KNOTS	19·69	24·73	21·5	24·74	19·8	18·75	20·78	24·4	21·58	22·36	21·5	22	19·72	20 84	21	22·2	20	21
R.P.M. OF PROPELLERS	310·3	433·7	275.	290	253.	250	582.	373·6.	263	268	275	275.	254.	268·6	275	271·3	270	220
BOILERS. NO AND TYPE	1-D.E. 1-S.E CYLINDRICAL	8-YARROW	5-CYLINDRICAL	9-B.&W.	1-D.E 1-S.E CYLINDRICAL	4-CYLINDRICAL	2-YARROW	4-YARROW	6-B.&W.	4-B.&W.	5 CYLINDRICAL	2-D.E 2-S.E CYLINDRICAL	2-YARROW 1-S.E CYLINDRICAL	4-B.&W.	3-B.&W.	2-YARROW	2 FOSTER WHEELER	4 YARROW
PRESSURE LBS/□"	160	200	200	200	180	230	575	250	225	225	215	220	250	225	250	250	450	425
TEMPERATURE °F	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	750	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	SAT^D	750	725
TOTAL HEATG SURFCE ☐'	10,221	24,640	14,405	33,916	9,825	9,300	5,100	19,440	19,770	17,072	15,033	18,746	10,000 2,470	15,400	13,560	15,000	13,900	28,420
TYPE OF DRAUGHT	C.S.	C.S	C.S.	C.S.	C.S	HOWDEN	C.S	C.S.	C.S.	C.S.	C.S.	HOWDEN	C.S	C.S.	C.S.	BALANCED DRAUGHT	C.S.	BALANCED DRAUGHT
FUEL	COAL	COAL	COAL	COAL	OIL	OIL	COAL	OIL	COAL	OIL	COAL	OIL	OIL	COAL	OIL	OIL	OIL	OIL
FEED SYSTEM.	OPEN	OPEN	OPEN.	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN	OPEN.	OPEN.	OPEN.	OPEN.	OPEN	OPEN.	OPEN	CLOSED	CLOSED.
ELECTRIC GENERATORS NO AND TYPE.	2-STEAM RECIPS	2-TURBO	2-STEAM RECIPS	2-TURBO	2-STEAM RECIPS	2-STEAM RECIPS	1-STEAM RECIPS	2-STEAM RECIPS	3-TURBO	1-STEAM RECIPS 1-DIESEL	3-TURBO	2-TURBO	2-STEAM RECIPS	2-TURBO	2-TURBO	2-TURBO	2-TURBO 1-DIESEL	3-TURBO
OUTPUT EACH K.W.	50	20	100	50	60	50	10	30	60	80	125	130	60	125	150	150	200	350
TOTAL WT. OF MACHINERY TONS	411	478	715	847	439	510	220	490	598	557	759	835	425	605	570	574	455	1,074
WT OF WATER & LUB. OIL TONS	79	52	133	68	98	85	13	41	42	41	142	171	50	38	33	46	40	62
TOTAL PROPULSIVE WT. OF MACHY. TONS.	490	530	848	915	537	595	233	531	640	598	901	1,006	475	643	603	620	495	1,136
FUEL CONSUMPT. LBS/S.H.P.	1·35	1·4	1·4	1·31	0·935	1·1	1·085	0·92	1·4	1·01	1·4	0·897	0·929	1·5	0·875	0·88	0·78	0·74

NOTE :- THE OWNERS GIVEN ARE THOSE PRESENTLY OPERATING THE SERVICE.

rather novel, details are shown in Fig. 16. It will be noted that the valves are operated by oil pressure supplied from the main lubricating oil pumps, and the gear is designed to prevent the engines being operated the wrong way. The engineer has only to move the manœuvring valve lever in the same direction as the telegraph pointer, which moves in a sector along side as clearly shown in Fig. 16.

The total weight of machinery in this installation is about 495 tons. Figures of power, weight, fuel consumption, etc. of this and other geared-turbine cross-Channel vessels are given in Table I.

Boilers.

The faithful friend of the marine engineer, the robust and reliable cylindrical boiler, popularly known as the Scotch boiler, which has given such good service in a very large number of successful steamers, and which is still fitted where space, power and weight limitations permit, has now largely been superseded by the water-tube type of boiler, as this possesses very many advantages for this service especially when oil fired. In cases where high pressures are desired, the water-tube boiler of course becomes a necessity.

There are many suitable types of water-tube boilers, and all the well-known types have been fitted at some time or other, as they all possess individual advantages. The type eventually fitted is largely a matter of the owners' choice, although on occasion one or other type may be found more suitable on account of the space available, or to meet a particular set of conditions.

Examples of the Yarrow-type of water-tube boilers are given in Figs. 9 and 10, and while these are for comparatively low pressures they illustrate the general features of the design. Space does not permit any further examples of this type of boiler, but later designs have been considered with superheaters and air heaters.

The question of whether superheaters, air heaters and

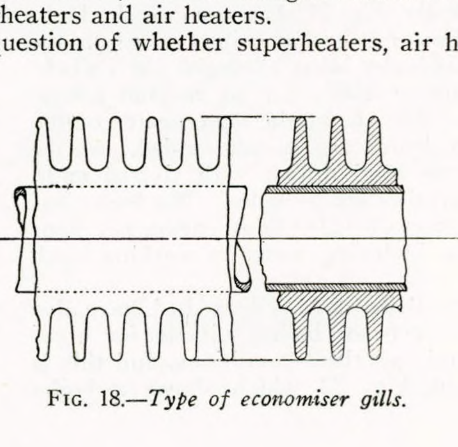


FIG. 18.—*Type of economiser gills.*

economisers should be fitted involves a delicate balance between the weight and space available and it hardly seems possible to allow for them all. Tubular air heaters alone give a reasonable amount of economy by heating the combustion air and reducing the funnel temperature, but the lighting up condition requires careful consideration to prevent gases being cooled below the dewpoint, and the uptakes have to be carefully arranged to prevent the formation of any soot pockets.

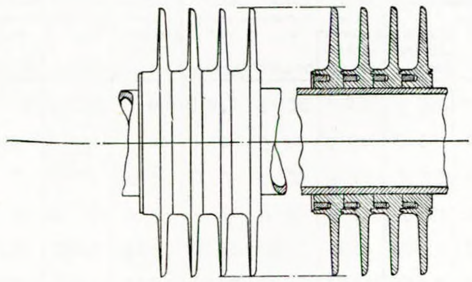


FIG. 19.—*Type of economiser gills.*

In many cases it will be found that the best compromise is obtained by fitting economisers alone, as these really become a secondary feed heater and have the additional advantage of reducing the funnel gas temperature. The type of economiser fitted in merchant vessels is a very robust affair and comprises a series of cast-iron rings pressed on steel tubes, the rings being finned to provide the maximum heating surface. Pressing on the rings gives good metallic contact with the tube, and the material of the rings is not so readily affected by the under-cooled gases when lighting up. The economisers fitted in Admiralty vessels are a very much lighter but more elaborate affair, using aluminium finned rings pressed on to the tubes. Where weight is of greater importance than cost, this type of economiser would be fitted.

Types of economisers are illustrated in Figs. 18, 19 and 20.

The types of economiser gills shown in Figs. 18 and 19 have been developed by Messrs. Foster Wheeler, Ltd. in conjunction with their designs of boilers. Messrs. Babcock & Wilcox have developed a stud type of economiser for the same purpose, which comprises a series of metal stud bars flash-welded direct on to the economiser tube. This type is shown in Fig. 20.

As an illustration of a type of high-pressure boiler, Fig. 21 shows one of the high-pressure Foster-Wheeler boilers fitted in the *Falaise,* this boiler being arranged for a working pressure of 450lb. per sq. in. and a temperature of 750° F. at the superheater outlet. The steam drums are fusion welded, and the water drums solid drawn with riveted ends. Circulating tubes are provided. The boiler has an evaporation of 42,000lb. of steam per hour and weighs, including water to working level, 64 tons.

Messrs. Babcock & Wilcox, Ltd. have also developed a type of boiler suitable for high-pressure and superheat conditions, and this is indicated in Fig. 22 which shows a boiler for a proposal, with an evaporation of 100,000lb. per hour, the steam condition in this case being 400lb. per sq. in. pressure and 750° F. temperature at the superheater outlet. The weight including water to working level is 76 tons. It is interesting to note that the now familiar square-shaped headers and straight-type tubes have disappeared from this design. Messrs. Babcock & Wilcox have by no means abandoned square headers and straight tubes for high-pressure work, as several boilers of this type have been fitted in merchant vessels to suit these pressure conditions, but the weight of this type renders it unsuitable for cross-Channel work except in special cases.

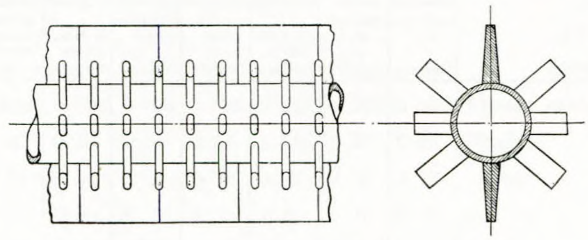


FIG. 20.—*Type of economiser gills.*

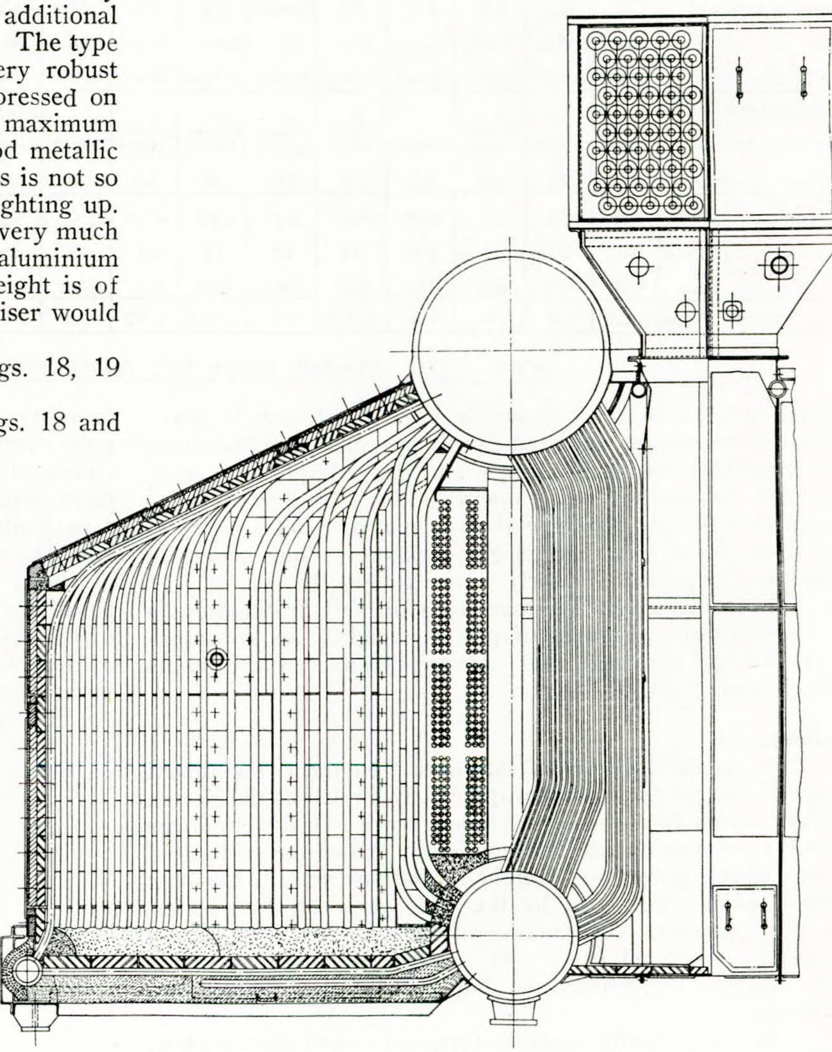


FIG. 21.—*Foster Wheeler high-pressure boiler fitted in t.s.s. "Falaise".*

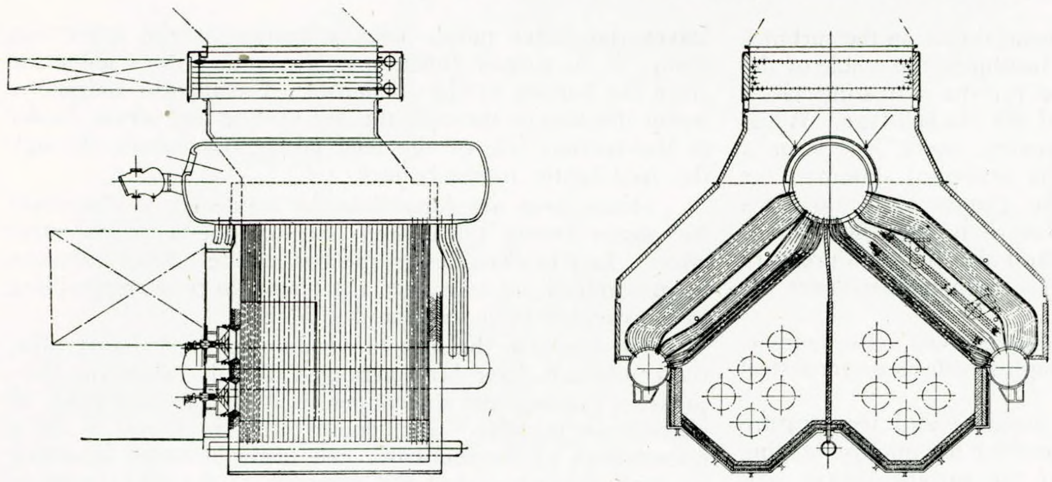


FIG. 22.—*Babcock & Wilcox high-pressure type boiler.*

Other types of high-pressure boilers have been considered for this class of work, *i.e.* Thornycroft, Sulzer Monotube, and La Mont forced-circulation types of boilers. So far none of these types of boilers has been fitted for this service, and it therefore does not seem necessary to make any further comment on them, except to remark that there appear to be no technical reasons why they should not prove satisfactory.

Turbo-electric and Diesel-electric drives for the propelling machinery have only been fitted to a few vessels, although they can be shown to be an economical proposition where weight is not too serious a limitation.

An interesting example of the turbo-electric drive for a larger vessel is the t.s.s. *Hinemoa*, recently built by Messrs. Vickers - Armstrongs Ltd. for the Union Steam Ship Co. of New Zealand. This vessel, although perhaps not really a cross-Channel steamer, approaches these vessels so closely that it was felt that some particulars would be of interest. The main propelling machinery comprises two double unit synchronous propulsion motors each of 6,500 s.h.p. at 220 r.p.m., 3,150-volts 3-phase, and two 5,120-kW. 3,150-volts 3-phase turbo-alternators running at 3,080 r.p.m. The electrical equipment was supplied by the British Thomson-Houston Co., Ltd. Steam is supplied by four Yarrow-type boilers at a pressure of 425lb. per sq. in. and a temperature of 725° F. at the superheater outlet. Three self-contained turbo-generators, each of 350kW. 220-volts, are fitted for auxiliary purposes. The layout of the machinery is shown in Fig. 23 and other details are given in Table I.

Turbines.

In regard to turbines, the principal improvement in blading has been the fitting of better corrosion- and erosion-resisting materials such as stainless steel and Monel metal, and the fitting of end-tightened and segmental blading.

End-tightened blading enables a large tip clearance to be arranged in the high-pressure turbines, where the leakage is most serious owing to the small specific volume of high-pressure steam, and at the same time provides for small axial clearances. Sometimes the axial clearance is made adjustable to enable a large clearance to be provided when manœuvring, but it is doubtful if this refinement is worth while.

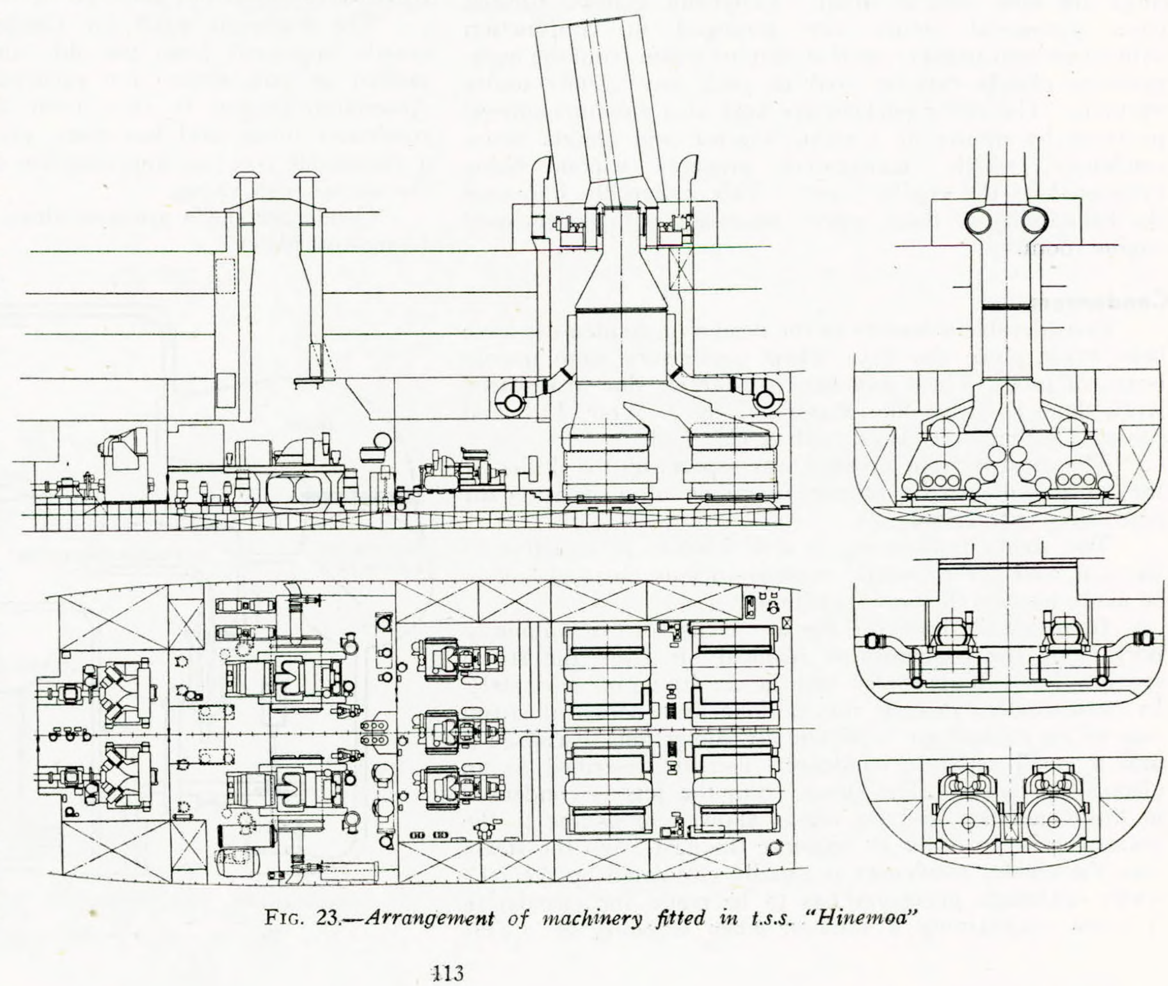


FIG. 23.—*Arrangement of machinery fitted in t.s.s. "Hinemoa"*

Dummies for balancing the steam thrust on the turbines have been dispensed with in some instances, the whole of the steam thrust being taken by the turbine adjusting block which is now almost universally of the Michell type. While this practice has proved satisfactory, there has been a tendency recently to revert to the fitting of dummies, as this reduces the pressure on the glands and minimizes leakage. For high-pressure turbines it is now the practice to make the casings of cast steel, and also the high-pressure portion of the astern turbine where high temperatures are concerned.

High-pressure turbine joints have given some trouble, and it is now the practice to fit high-tensile non-creep steel bolts at the high pressure end.

Modern practice with high pressure and temperature steam indicates that the nozzle boxes for the impulse blading should be fitted independently of the turbine casing, and be free to expand in all directions independently of the main turbine casing. This is particularly important for the astern turbine, as the windage of the astern blades running ahead when the turbines are going ahead can increase the temperature considerably, and it is now considered desirable to fit an indicating thermometer to the astern turbine.

Lagging has also secured some attention, especially at the high pressure and temperature end, and it is now common practice to fit Newtempheit high-temperature insulation and magnesia blocks to the maximum thickness possible commensurate with the space available.

Glands have also received attention and carbon rings are now seldom fitted. Labyrinth glands, formed from gun-metal strips, are arranged in conjunction with a common receiver, so that surplus steam from the high-pressure glands can be used to pack any glands under vacuum. The outer pockets are kept at a sub-atmospheric pressure by means of a steam ejector and glands steam condenser, which arrangement prevents vapour being exhausted to the engine room. This materially improves the habitability of these spaces, especially with an enclosed engine **room.**

Condensers.

Considerable advances in the design of condensers have been made since the days when condensers were mainly boxes of tubes. These advances are largely due to research work done by firms like Messrs. G. & J. Weir, Ltd. and Messrs. Richardsons Westgarth & Co., Ltd.

The most notable advance was separating the duties of the air pump into its proper functions of a separate air and water extraction.

The steam turbine, as is well known, is sensitive to vacuum, and for economic reasons various changes had to be made to meet the new conditions.

In order to draw off the air at its lowest volume, a portion of the condenser is blanked off from the steam space to form an air cooler, and the air drawn off separately. In most modern designs this is done by a series of steam jets which extract air from the air cooler and discharge it into a small separate condenser, usually described as an ejector condenser. The steam from the jets is condensed in this condenser and the air is allowed to escape to the atmosphere. In order to conserve the heat from the steam jets, the ejector condenser is usually circulated by the feed water, although provision has to be made for circulating it when maintaining a vacuum when standing by. This leaves the water pump, usually known as the extraction pump, to its proper function of extracting the condensate from the bottom of the condenser. Usually the extraction pump discharges through the air ejector and drain cooler to the suction side of the feed pump and thence through the feed heater to the boilers.

Steam lanes are formed in the condenser to distribute the steam evenly throughout and to give a regenerative effect. In a modern design the condensate temperature can be guaranteed not to exceed the temperature corresponding to the vacuum by more than 2 to 3° F.

To minimize the loss of vacuum in the exhaust pipe, the condensers have been arranged directly below the low-pressure turbine, and the condenser itself has been made as shallow as possible. Incidentally, this is found to be a convenience as the condenser can easily be tested by filling up with water to cover the top row of the tubes without flooding the low-pressure turbine. To support the weight of the condenser, and to allow for expansion of the L.P. turbine, the condenser is supported on springs.

As with many other items associated with the machinery of cross-Channel steamers, a compromise has to be made between the highest vacuum possible with the sea-water temperature available and the maximum permissible by considerations of weight and space available. Usually it is not found to be practicable to maintain a higher vacuum than 28½in. of mercury with a 30in. barometer and a sea-water temperature of 65° F. To maintain this, the ratio of sea-water circulated to steam condensed has to be about 80 to 1.

The materials used for condenser tubes have been greatly improved from the old Admiralty mixture which proved so satisfactory for vacuums not exceeding 27in. Aluminium-bronze is now used almost exclusively for condenser tubes, and has given very great satisfaction at a reasonable cost; no apprehension need be felt concerning the use of high vacua.

Condenser shells are now almost exclusively fabricated from steel plates.

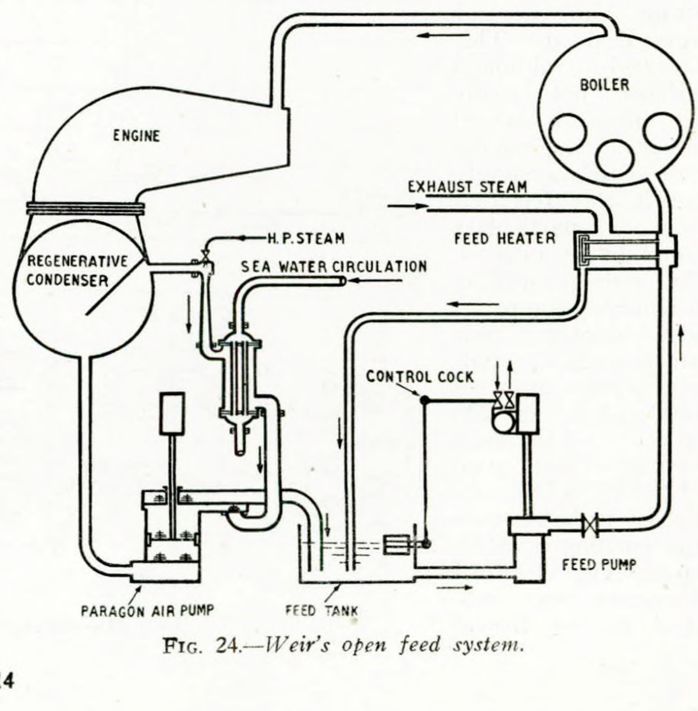


FIG. 24.—*Weir's open feed system.*

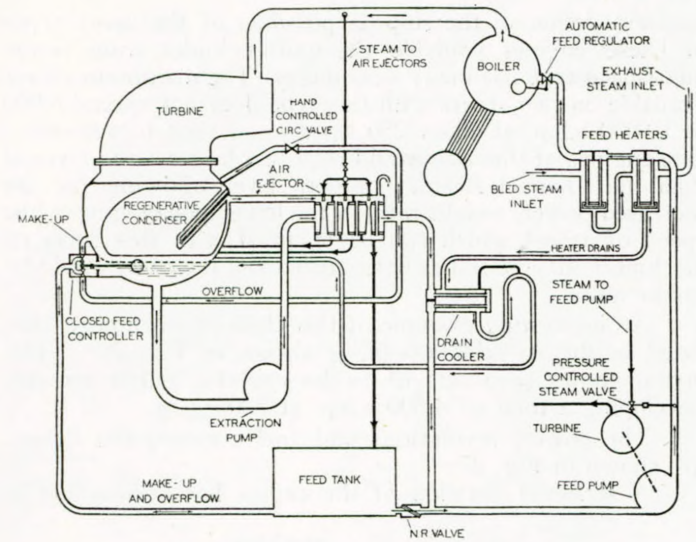


FIG. 25.—*Weir's closed feed system.*

Another notable advance in connection with condensing plant was the introduction of the closed-feed system. Formerly water was removed from the condenser by the air or extraction pump and discharged to an open feed tank. This system is shown diagrammatically in Fig. 24, which illustrates a sort of half-way stage between the combined air and extraction pump and the latest closed-feed system.

The latest arrangement of Weir's closed feed is shown diagrammatically in Fig. 25.

The condensate is kept in a closed circuit and led through the air ejector and drain cooler to the suction side of the feed pump, whence it is delivered via the feed heater and economisers to the boilers. The feed water is never allowed in contact with the air, and all air and corrosive gases are removed in the condenser. All make-up feed in this system has to pass into the condenser and be de-aerated there.

Gearing.

While the design of gearing has been improved in detail, the general appearance and materials remain much the same as fitted in earlier vessels, nickel-steel pinions and forged-steel rims shrunk on to cast-iron centres being the same. Small improvements such as chamfering the ends of the teeth and thinning at the extremities have been made, while great attention has been paid to the accuracy of the tooth form and to improvement of the gear hobbing machines. The practice of boring the gear housings from accurately set up boring bars has been adopted to ensure accurate meshing of the gear teeth over the whole width of face.

The involute form of tooth originally adopted remains the same, although in some cases the all-addendum type of tooth has been adopted. Vickers, Bostock and Bramley enveloping type of tooth has also been fitted in a few cases.

The helix angle of 45° originally adopted has now given place to a 30° angle which makes for a smoother-running gear. Double-reduction gearing is seldom fitted in cross-Channel vessels, as the propeller revolutions are usually such that the necessary reduction between turbine and gearing can easily be attained in one step.

Flexible couplings now only differ in small detail from the original design. Several designs have been tried to give greater flexibility and to make allowance for mal-alignment, but failed to receive general approval. It is now the usual practice to concentrate on accurate alignment of turbines and gearing and to leave the flexible coupling to provide for axial movement only.

It is now usual to pay more attention to the lubrication of flexible couplings and separate oil feeds are provided. Most pinions are fitted with central bearings, owing to the small diameter and great width of face necessary to suit the power conditions. Where possible, a narrower face width with a larger diameter of pinion bearing provides greater rigidity and should be adopted when conditions permit, although no trouble has been experienced with well-fitted centre bearings set up with a mandril in true alignment.

Very great care is now taken in setting up gearing to ensure good meshing and correct alignment, and oversize, and size for size, mandrils are freely used for this purpose during erection.

The practice of lubricating the working tooth faces by means of oil sprayers remains the same, and in most cases it is now considered good practice to fit half the number of ahead sprayers to the astern faces, although there are many cases running quite successfully with no sprayers fitted for the astern faces.

TABLE II.

GEARING PARTICULARS.

YEAR	1912	1913	1919	1920	1924	1925	1928	1928	1929	1929	1930	1932	1934	1937	1946	1947
NAME	NORMANNIA.	PARIS.	ANTWERP.	ANGLIA.	DINARD.	ST. JULIAN.	WORTHING.	DUKE OF LANCASTER	CANTERBURY	VIENNA.	LADY OF MAN.	ISLE OF SARK.	PRINCESS MAUD.	FENELLA.	INVICTA.	FALAISE.
GEAR	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.	S.R.
TYPE.		NORMAL INVOLUTE.		NORMAL INVOLUTE.	NORMAL INVOLUTE.		NORMAL INVOLUTE.	NORMAL INVOLUTE.	NORMAL INVOLUTE.		V. B. B. TEETH.	NORMAL INVOLUTE.	NORMAL INVOLUTE.	V. B. B. TEETH.	ALL ADDENDUM INVOLUTE.	ALL ADDENDUM INVOLUTE.
PINIONS.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. & L.P.	H.P. & L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. L.P.	H.P. & L.P.
PITCH DIA. D.INS.	9·4 13·6	9·34 13·24	6·64 8·14	9·09 11·17	6·64	6·64	8·14 11·35	7·28 11·57	7·28 11·57	9·2 11·6	7·5 12·21	6·64 7·07	7·28 11·57	7·28 11·78	8·36 13·93	6·43
R.P.M.	2015 1390	2530 1780	2650 2150	2232 1817	2800	2800	3106 2227	3090 1945	3208 2020	2690 2150	2930 1800	2800 2630	3184 2005	3130 1935	3100 1850	3700
TOTAL WIDTH OF FACE	20"	36"	33"	49"	22"	20"	34"	30"	30"	24"	28"	22"	30"	20½"	23½"	27"
GAP.		17"	3"	17"	12½"	3"	16"	14"	14"	3"	12¼"	12½"	14"	2½"	3"	11¼"
SPEED AT PITCH LINE. FT/SEC.	82·4	103	77	88·5	81·1	81	110·3	98·13	101·5	108	95·8	81	101·2	100	113	104
LOAD PER INCH P. LBS.	396	482	480 550	460 460	401	370	532 532	397 397	408 408	470 540	530 647	384 416	362 363	497 608	537 604	417
L/D. WIDTH COEFFICIENT		3·86 2·72	5·42 4·42	5·4 4·39	3·32	3·46	4·18 2·99	4·12 2·59	4·12 2·59	2·93 2·33	3·73 2·29	3·31 3·11	4·12 2·59	3·16 1·95	3·17 1·9	4·2
P/D. LOAD "	42·1 29·1	51·7 36·4	72·2 67·5	50·6 41·2	60·4	55·7	65·3 46·8	54·5 34·3	56 35·3	51 46·5	70·6 53·5	57·9 58·8	49·7 31·4	68·3 51·6	64·2 43·4	64·8

NOTE:- WIDTH COEFFICIENT. L = TOTAL FACE WIDTH WHEN A CENTRE BEARING IS FITTED.
L = TOTAL FACE WIDTH + GAP WHEN THERE IS NO CENTRE BEARING.

The lubricating oil from the bearings and sprayers drains to a sump in the bottom of the gear case, and it is now led, if at all possible, to a separate drain tank. This prevents the dipping of the gear wheel rim into the oil when the vessel is rolling. Lubricating oil tanks are preferably made separate from the hull structure to prevent possible contamination of the oil from leaky rivets or the vessel grounding.

Particulars of gearing are given in Table II.

Diesel Engines.

The application of direct-driven Diesel engines has been gradually making headway, and the low fuel consumption is making this type of machinery a serious competitor with geared steam turbines which have hitherto held the field almost exclusively.

Owing to the limitations of deck heights and to the natural desire of the owners to get as much passenger accommodation in the ship as possible, of the many types of Diesel engines available, the multi-cylinder trunk-piston high-speed type has many advantages. The maximum power available on two shafts with this type does not exceed 8,000 to 10,000 b.h.p. at about 250 r.p.m., and even to accommodate engines of this size would require a larger size of vessel than the Channel steamer proper. Even allowing for the increased power/weight ratio in the lower power ranges, the speed of vessel which can be obtained with this form of machinery may be somewhat reduced and the costs would be rather more.

An interesting example of this class of machinery, that fitted in the *Royal Daffodil,* is shown in Fig. 26. The layout shows twin sets of twelve-cylinder Sulzer engines developing a total of 4,500 b.h.p. at 320 r.p.m.

The power, revolutions and fuel consumption figures are shown in Fig. 27.

A sectional drawing of the engine has been added in

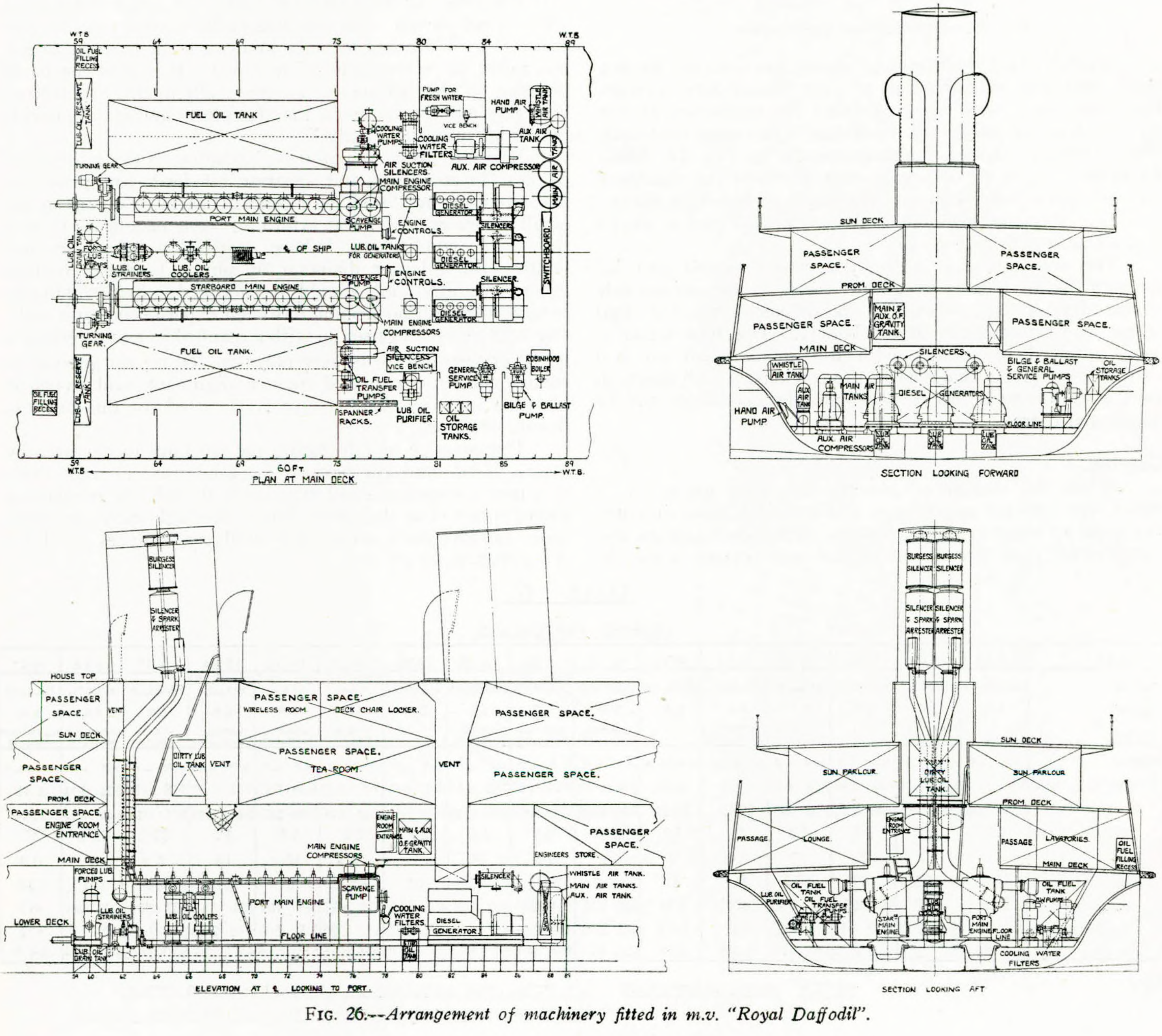


FIG. 26.—*Arrangement of machinery fitted in m.v. "Royal Daffodil".*

Fig. 28 to illustrate the low head room required for this type of engine.

Of the larger type of cross-Channel motor vessels, mention should be made of the *Prince Baudouin* for the Dover-Ostend service. The arrangement of machinery is shown in Fig. 29.

A sectional view of the engine fitted in the *Prince Baudouin* is shown in Fig. 30.

The *Prince Baudouin* was built in 1934 by Cockerill, Belgium, for the Dover-Ostend service. This vessel is propelled by two sets of Sulzer crosshead two-cycle single-acting type Diesel engines, each having 12 cylinders 580 mm. bore and 840 mm. stroke. They developed a total of 16,000 b.h.p. at 253 r.p.m. on trial, giving a speed of 25·23 knots. The normal b.h.p. developed on service is 15,000 at 256 r.p.m., giving a speed of 23·5 knots. Scavenge air for the engines is supplied by three motor-driven scavenge blowers, each requiring 448 kW. and supplying 13,000 cubic feet of air per minute at a pressure of 18lb. per sq. in. when running at 2,320 r.p.m.

For supplying current for the scavenge blowers and other services, four sets of Sulzer four-cycle single-acting Diesel engines are fitted, each having eight cylinders 310 mm. and 400 mm. stroke and developing 680 b.h.p. at 550 r.p.m. with an output of 480 kW.

The auxiliary engines and the scavenge blowers are fitted in a separate compartment at the forward end of the engine room.

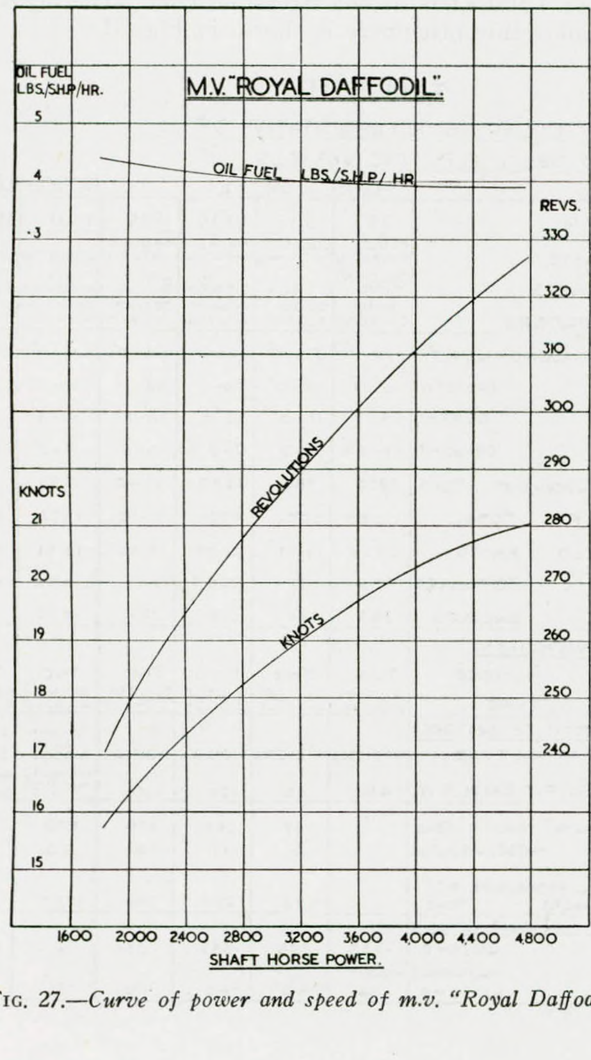


FIG. 27.—*Curve of power and speed of m.v. "Royal Daffodil".*

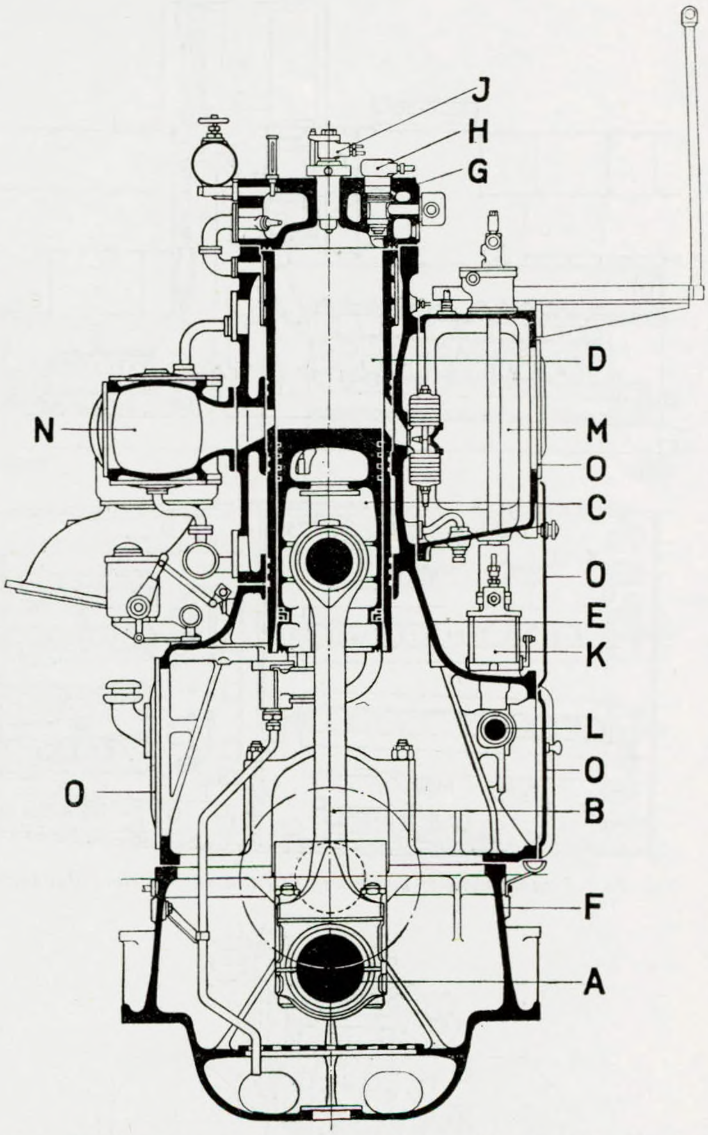


FIG. 28.—*Sectional arrangement of Sulzer Diesel engine fitted in m.v. "Royal Daffodil". (A) crankshaft; (B) connecting rod; (C) piston; (D) cylinder liner; (E) cylinder block; (F) bedplate; (G) cylinder cover; (H) starting valve; (J) fuel valve; (K) fuel pump; (L) camshaft; (M) scavenging air receiver; (N) exhaust manifold; (O) removable lagging.*

A later vessel, the *Prins Albert,* is fitted with similar machinery, but in order to reduce the size of the auxiliary generating sets and to dispense with the large scavenge blowers and motors, the main engines are arranged to supply their own scavenge air, each cylinder being fitted with its own scavenge pump driven from the working piston by a rocking beam.

Only three auxiliary Diesel generators, each of 200 kW., are required for the auxiliary and hotel services.

This forms an interesting comparison with the paddle steamer *Leopold II* mentioned earlier in the paper.

Other notable motor vessels are the *Royal Ulsterman* and *Royal Scotsman* built by Messrs. Harland & Wolff Ltd. for the Irish cross-Channel service, and the *Princess Victoria* built in 1947 by Messrs. Wm. Denny & Bros. for the L.M. & S. Larne and Stranraer route. Particulars of these and other vessels are given in Table III.

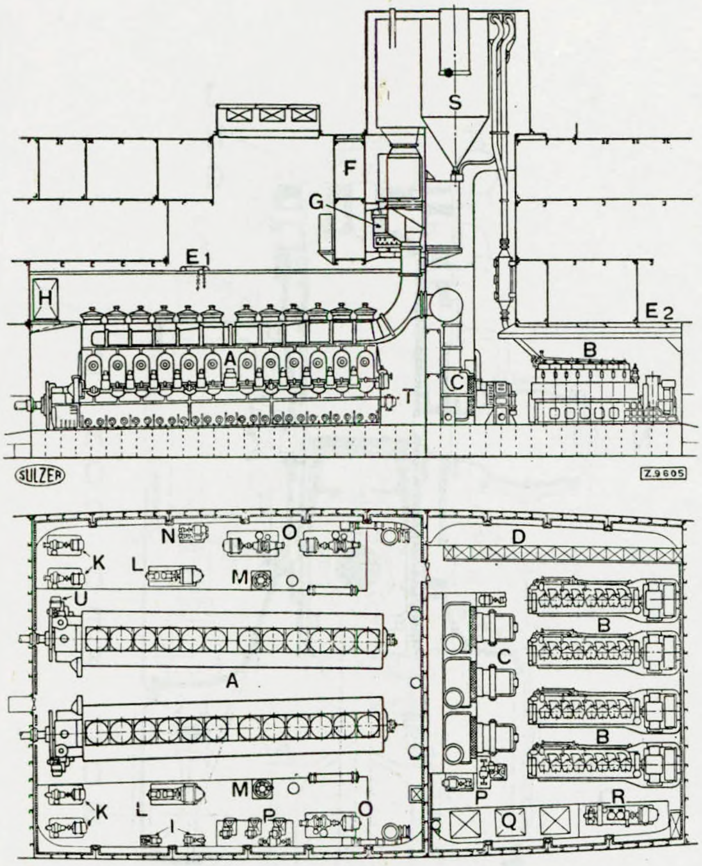


FIG. 29.—*Arrangement of machinery fitted in m.v. "Prince Baudouin".*

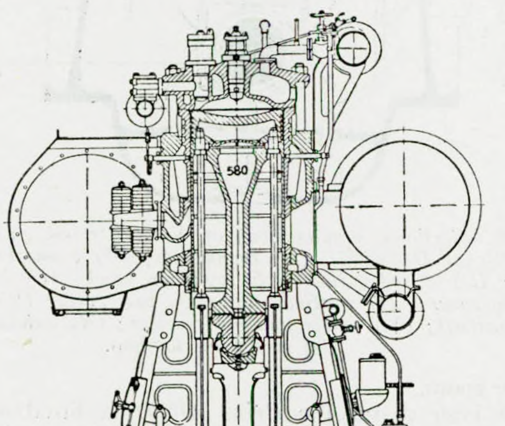


FIG. 30.—*Sectional arrangement of Sulzer Diesel engine fitted in m.v. "Prince Baudouin".*

Considerable trouble was experienced in earlier Diesel installations due to vibration. The subject of torsional vibration has been exhaustively studied and no difficulties are likely to be experienced due to this cause. In any case, unless when passing through a critical, torsional vibration is not likely to be transmitted to the hull. Free vibrations, whether caused by primary and secondary forces or couples due to the reciprocating and rotating masses, can cause a great deal of trouble in a light structure, especially if synchronism happens to exist. The only cure is for almost perfect balance to be obtained in the main engine. So far naval architects do not appear to have found a simple method of finding the period of vibration of a complicated structure like the hull of a ship. With multi-cylinder engines very good balance can be obtained, but it is not desirable to have fewer than six-cylinder engines fitted in a light hull.

Diesel-electric machinery has been fitted in a number of vessels, and it possesses several advantages in cases where the space can be provided. The cost and power/weight ratio is more than the Diesel direct-driven machinery. A number of interesting vessels have been fitted with this system such as the *Lochfyne* and *Lochnevis* which, while perhaps not coming exactly into the category of cross-Channel vessels, are nevertheless interesting examples of much power compressed into small bulk.

The *Lochfyne* was fitted with Paxman engines and Metropolitan-Vickers electrical equipment, and developed a total of 1,300 s.h.p. at 435 r.p.m. on trial. The layout of this interesting machinery is shown in Fig. 31.

TABLE III

PARTICULARS OF REPRESENTATIVE DIESEL AND DIESEL ELECTRIC VESSELS

		DIRECT DIESEL				DIESEL-ELECTRIC	
YEAR		1934	1935	1939	1939	1931	1934
NAME.		PRINCE BAUDOUIN	QUEEN OF THE CHANNEL	ROYAL DAFFODIL	PRINCESS VICTORIA	LOCHFYNE	LOCHNEVIS
OWNERS.		BELGIAN GOVT.	C.S.N.COY.	G.S.N.COY.	L.M.S. RLY. COY.	DAVID MACBRAYNE	DAVID MACBRAYNE
BUILDERS.		JOHN COCKERILL	DENNY SULZER	DENNY SULZER	DENNY SULZER	DENNY-PAXMAN METRO VICK	DENNY-PAXMAN-GEC
DIMENSIONS	LENGTH	370'-9"	255'-0"	304'-0"	315-0"	214'-6"	175'-0"
	BREADTH	45'-11"	34'-0"	50-0"	48'-0"	30'-0"	31'-0"
	DEPTH	24'-9"	11'-6"	12'-6"	16'-6"	10'-3"	10'-6"
	DRAUGHT	11'-1¾"	7'-0"	7'-9½"	10'-6"	7'-2"	7'-0"
DISPLACEMENT.	TONS	2800	780	1265	2140	643	560
S.H.P.	TOTAL.	16 000	3050	4760	4850	1350	1010
SPEED.	KNOTS.	25 23	19 81	21 09	19·62	16·51	15·11
R.P.M.	PROPELLERS.	253	323 3	326·5	259	440	402·7
	ENGINES.	253	323 3	326·5	259	332	505
MAIN ENGINES.							
	NUMBER.	TWO	TWO	TWO	TWO	TWO	TWO
	TYPE.	SULZER 2-CYCLE	SULZER 2-CYCLE	SULZER 2-CYCLE	SULZER 2-CYCLE	PAXMAN 4-CYCLE	PAXMAN 4-CYCLE
ELECTRIC GENERATORS.							
	No AND TYPE.	4-DIESEL	3-DIESEL	3-DIESEL	3-DIESEL	2 MAIN 3 AUXY. DIESEL	2 MAIN 3 AUXY. DIESEL
	OUTPUT EACH K.W.	480	50	100	110	MAIN 540 AUX. 2-45 1-22	MAIN 420 AUX 48
TOTAL WT. MACHY.	TONS		167	268	370	170	135
" " WATER & LUB OIL	TONS		6	11	16	3·3	4·0
TOTAL PROPULSIVE WT. OF MACHY.	TONS.		173	279	386	173·3	139·0
FUEL CONSUMPTN. ENGS. ONLY.	LBS/B.H.P.	·363	·385	·385	·381	-	-
ALL PURPOSES	LBS/B.H.P.	ABOUT ·4	·40	·40	·405	·51	·52

A curve of the speed, revolutions and fuel consumption of this vessel is shown in Fig. 32.

The *Lochnevis* also had Paxman Diesel engines running at 500 r.p.m. with General Electric Company electrical gear, and developing a total of 1,000 s.h.p. at 400 r.p.m., the layout of the machinery being similar to that for the *Lochfyne*. Both vessels were arranged for control of the machinery from the bridge, but the opinion of the deck officers regarding the value of this is somewhat conflicting. Many captains prefer that the control of the machinery should be by the engineers obeying the telegraph order from the bridge.

Particulars of these and other Diesel-electric vessels are given in Table III.

With the later designs of machinery, a definite trend has been to arrange the main engines for propulsion only and to have all auxiliaries independently driven. With the exception of the main feed and circulating pumps, which are usually turbo-driven, especially in vessels with high pressure and temperatures, the auxiliary pumps are usually electrically driven. With the increased demand for lighting, heating and hotel services, the size and output of the electric generators has increased considerably, from two to ten times that provided in earlier vessels, and three sets each of 200 to 300 kW. are now being fitted. Where steam is available these are usually turbo-driven either direct coupled or geared, with a Diesel-driven set for harbour use when the boilers are shut down, as is usually the case as soon as the passengers are ashore. The larger turbo-generating sets are often made self-contained with their own underslung condenser and closed-feed system. The condensate and extraction pumps are driven direct from the turbine, which provides a most economical unit. The number and diversity of electrical connections has grown very considerably from the days when a small 10 to 15 kW. steam set was sufficient

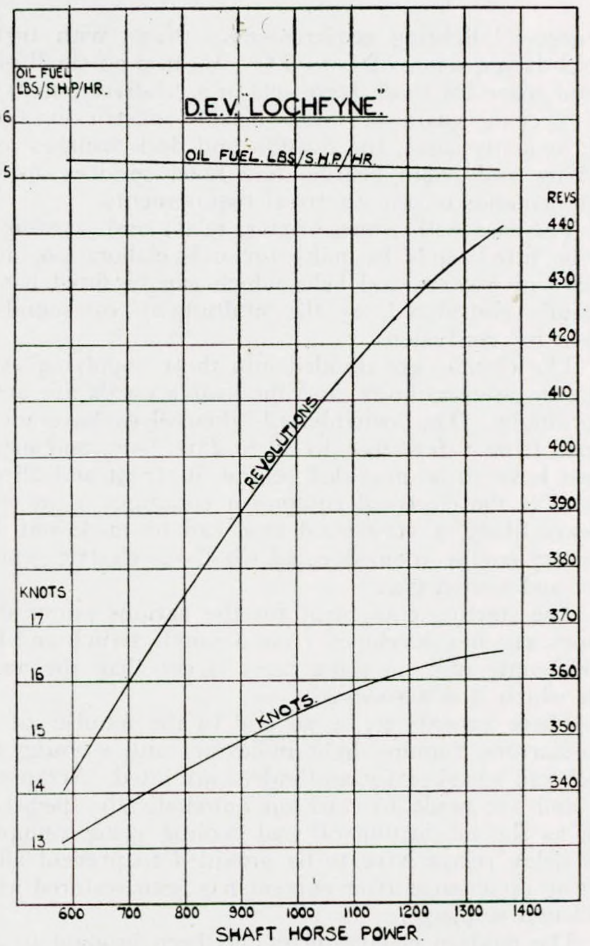


FIG. 32.—*Curve of speed and power of D.e.m.v. "Lochfyne".*

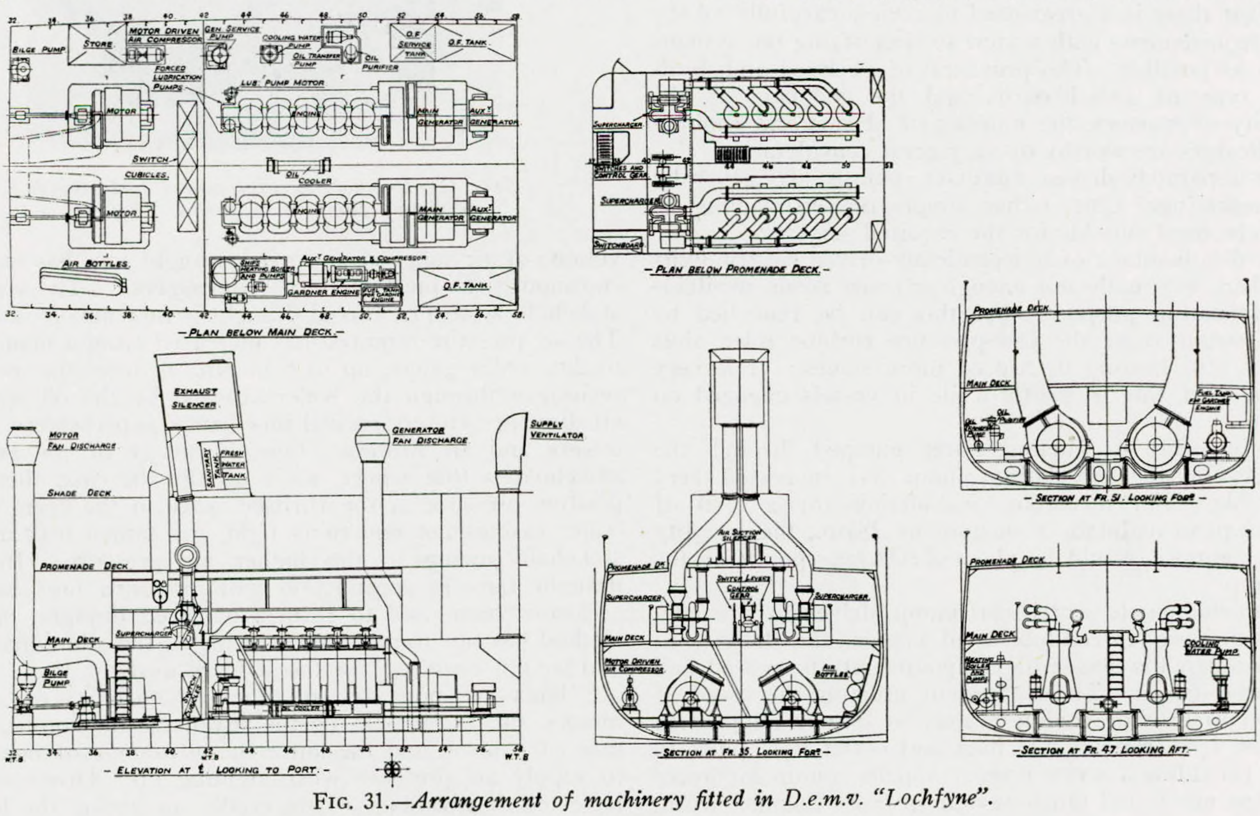


FIG. 31.—*Arrangement of machinery fitted in D.e.m.v. "Lochfyne".*

to meet all lighting requirements. Now, with turbo- or Diesel-driven sets of 200 to 300 kW., it is no small problem to find space for these large sets in a relatively small vessel.

Steering gears are now usually electrically operated and, in many cases, the capstan and deck winches as well. Cooking and cabin heating and hotel services also make large demands on the electrical requirements.

The ease with which alarms, relays and warning lights can be fitted tends to make for over-elaboration, and the variety of hooters and bells which can be fitted has to be carefully considered, as the multiplicity of sounds only makes for confusion.

The circuits are divided into those supplying essential and non-essential units, and the switchboards are arranged accordingly. The switchboards themselves have increased in size from a few feet, to 20 to 25ft. long, and means of access have to be provided behind, in front and all round. Indeed if the electrical equipment continues to increase as appears likely, a very good case can be made out for an auxiliary engine room devoted wholly to electric generating plant and switch gear.

The starting equipment for the various pump and fan motors, etc. has developed from a simple switch and fuse to an elaborate unit, in some cases larger than the auxiliary with which it is associated.

There appears to be no end to the number of relays auto-starters, running light indicators and warning alarms which can be asked for and indeed are fitted. Arrangements can and are made to start up automatically special units, such as the lubricating oil and cooling water pumps, and time delay relays have to be provided to prevent all units starting up at once after current has been restored after an accidental stoppage.

The modern electric plant has been brought to a high pitch of reliability despite its complexity, and it would now appear that there is a great need to review carefully all the various requirements with a view to simplifying the systems as much as possible. The provision of enclosed and dead-fronted type of switchboards and the reducing of the complexity of starters, the number of alarms and running light indicators are worthy of very great consideration.

The separately-driven auxiliary pumps are generally of the centrifugal type, either simple or self-priming as found to be most suitable for the required service.

One disadvantage of independently-driven electric units is that there is usually not enough exhaust steam available for feed heating purposes, but this can be remedied by bleeding steam from the low-pressure turbine inlet, thus providing feed heating in two or more stages. It is very questionable if this is worth while in vessels engaged on short runs.

The quantity of cooling water pumped through the condensers by the circulating pump has increased very considerably. For a turbine installation for a total of 10,000 s.h.p. to maintain a vacuum of 28½in., the quantity of water pumped would be about 2,300 tons per hour for each pump.

From the simple centrifugal pump, driven by a single-cylinder enclosed forced-lubricated engine, the design has passed through the stages of compound sets to geared and direct turbo-driven. The method of utilizing the speed of the vessel to provide cooling water, so largely adopted in destroyers, by arranging the inlet and outlet flow pipes to suit and providing a screw-type of impeller pump for lower speeds, has not found much favour in cross-Channel work, largely on account of space required and lower speeds involved. Pumps are now mostly driven by vertical or horizontal, direct or geared turbines, or electric motors. An illustration of a vertical geared turbo set by Messrs. Drysdale & Co., Ltd. is shown in Fig. 33. This type was adopted largely on account of the small space occupied, the turbine drive proving the most suitable for high pressure and temperature steam.

Like the circulating pumps, the size, pressure and volume of air supplied by forced-draught fans has increased enormously to meet modern requirements. The enclosed-stokehold system of forced draught is now almost universal. The air pressure required has increased from a modest 1in. to 2in. water gauge, up to 6 to 8in., to meet the increased resistance through the boilers caused by the oil sprayers, air directors, closely-packed tube banks, superheaters, economisers and air heaters. One advantage of the enclosed stokehold is that where, as is usually the case, there is a positive pressure in the furnace space in the event of the boiler casings not remaining tight, gas cannot leak into the stokehold owing to the higher air pressure. Induced-draught fans in conjunction with pressure fans have on occasions been used to form a balanced draught, but this method has not found favour owing to the additional space and weight required for the induced-draught fans.

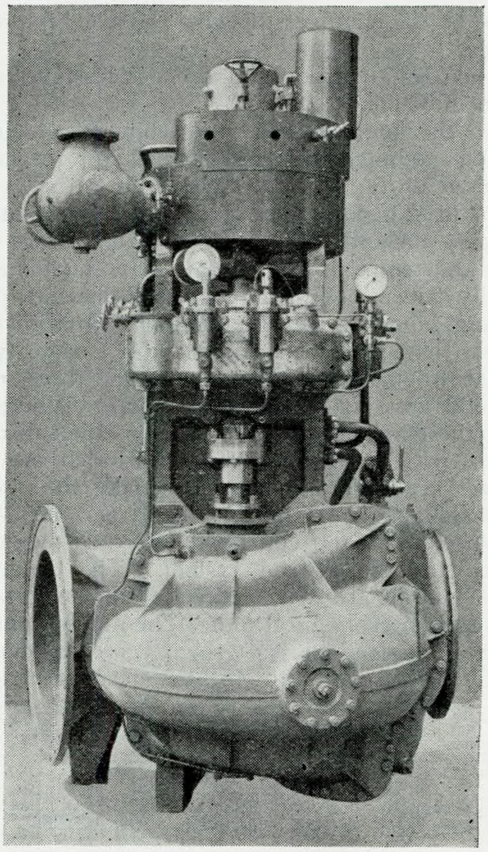


FIG. 33.—*Drysdale vertical geared turbo-driven circulating pump fitted in t.s.s. "Falaise".*

Fans are now driven either by turbines or electric motors, the former having the advantage of simplicity and ease of control, and the latter the advantage of being able to supply air pressure when lighting up. However, they have the disadvantage of materially increasing the load on the electric generators, and the final choice is largely a matter of opinion. With electrically-driven fans special arrangements have to be made to obtain a very large range of speed control.

Owing to limitations of deck heights previously mentioned, usually it is not possible to fit a gravity lubricating oil system, so the pressure system with duplicate lubricating oil pumps and coolers is usually fitted. Greater care is now paid to oil filtering and purification, and suction and discharge filters are fitted. The magnetic type of filter is now also coming into more general use. It is now common practice to provide lubricating oil purifiers, and arrangements are made for continuous and bulk oil purification.

Cut-out governors are provided on the turbines to shut off steam in the event of the turbine overspeeding or failure of oil pressure, and they can be arranged to operate on the ahead manœuvring valve only, thereby allowing the astern valve to be manually operated to bring the turbine quickly to rest by admitting astern steam. The type of governor commonly fitted is illustrated in Fig. 34.

The governor acts purely as a cut-out governor and operates only in the event of the turbines overspeeding due to any cause. It has no effect otherwise on the revolutions of the turbines which are controlled by the extent to which the manœuvring valve is opened. The governor is fully lubricated from the lubricating oil system, and depends for its action on centrifugal force acting on the spring-loaded valves in the centre of the governor causing them to open, thus reducing the oil pressure. This in turn opens a steam valve on the manœuvring valve and causes the main valve to close. Arrangements can also be made on the governor to indicate the fore and aft movement of the turbine rotor.

In the event of a shut down of the turbines due to the failure of lubricating oil or overspeeding in the ahead direction, if the governor is arranged to operate on both ahead and astern manœuvring valves, then it is not possible to bring the turbines quickly to rest by opening up the astern steam valve. In some cases to enable this to be done, the governor is arranged to operate on the ahead manœuvring valve only.

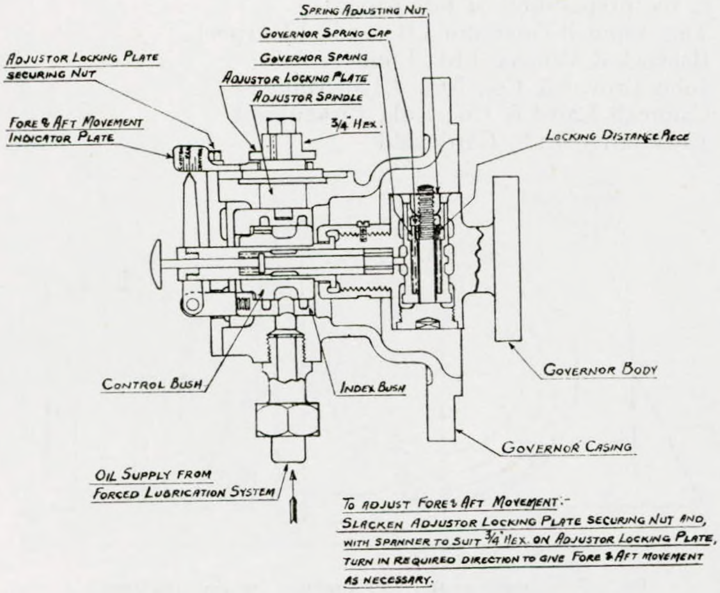


FIG. 34.—*Aspinall governor fitted in t.s.s. "Falaise".*

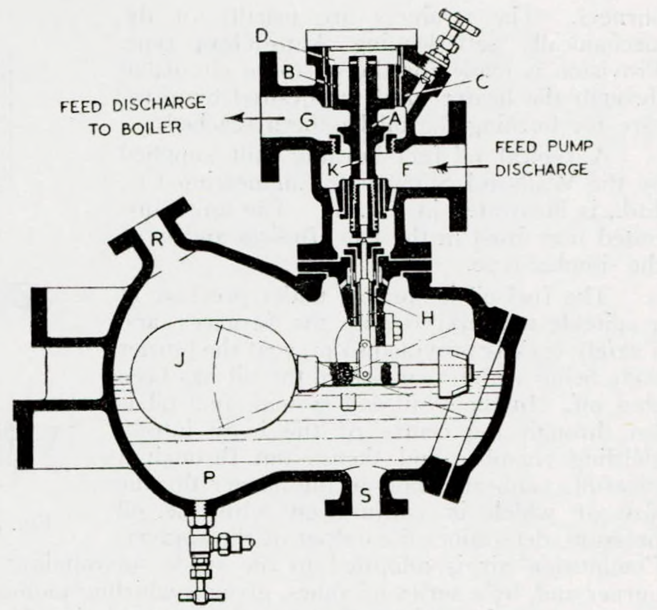


FIG. 35.—*Weir's latest type of robot feed water regulator fitted in t.s.s. "Falaise".*

With high-pressure boilers, pure distilled feed water is essential and a closed-feed system most desirable. Evaporators are now provided for the purpose of distilling the make-up feed water, it being usual to distil raw fresh water carried in the reserve feed tanks. Sea water is used only in an emergency. With these precautions it is doubtful if any further special treatment of the feed water is necessary.

The introduction of the closed-feed system appears to complicate matters, but the system is now well tried and gives the minimum of trouble.

The maintenance of a steady level of feed water in the boilers is most important. While the general principal of the original Mumford feed-water regulator remains the same, the present day type of regulator has been very much improved and under normal conditions is a very reliable instrument.

A sectional view of Weir's latest Robot-type regulator is shown in Fig. 35.

Feed heaters fitted in earlier vessels were usually of the straight-tube type, and were virtually condensers in reverse with ferrules and cotton cord packing, although several types of fibre and metallic packing were tried with varying degrees of success. In some cases the tubes were expanded into a tube plate at one end, and at the other into a header which was free to expand. This design was abandoned for high-pressure work in favour of the hairpin type of tube arranged for multi-flow, in which the tubes with a return bend are expanded into a tube plate, and the flows arranged at the header end. This type of feed heater is simple and gives great satisfaction in service.

No spectacular changes have been made in oil-fuel burning, but there has been a steady stream of minor improvements. A common type of oil-fuel burning plant comprises a steam-heated oil fuel heater of the hairpin type, pumps, and suction and discharge strainers. The units are usually mounted on a common tray, and may be either simplex or duplex to suit the space available, one unit acting as standby to the other. The fuel pumps, which may be either steam or motor driven, draw the fuel from the bunker tanks and discharge through the strainers and heaters to the burners. The strainers are usually of the mechanically self-cleaning Auto-Klean type. Provision is made for the oil to be circulated through the heater until the desired temperature for burning the oil has been reached.

A typical oil-fuel burning unit supplied by the Wallsend Slipway & Engineering Co., Ltd., is illustrated in Fig. 36. The unit illustrated was fitted in the t.s.s. *Invicta* and is of the simplex type.

The fuel oil is sprayed under pressure at a suitable temperature into the furnaces, and a safety cock is provided to prevent the burner body being withdrawn before the oil has been shut off. In the Wallsend system, fuel oil is led through the centre of the body into a swirling chamber and thence out through a carefully calibrated hole in the burner tip, the size of which in conjunction with the oil pressure, determines the output of the sprayer. Combustion air is admitted to the space surrounding the burner and, by a series of vanes, given a whirling motion to ensure a complete mixture of the oil spray and air. Means are provided for controlling the air supply separately to each burner.

For lighting up, a special unit with electrical or paraffin heaters, and motor driven or hand pumped, is provided.

For keeping boiler heating surfaces clean, soot blowers are being increasingly used and have a marked effect on maintaining the efficiency of the boilers; they may now be considered as standard practice. The positioning of the blowers and the drainage of the steam pipes connecting them have to be carefully considered if the best effect is to be obtained. Most types of blowers are semi-automatic, and for convenience in operation the blower should complete its cycle of operations by simply turning one handwheel. The gun type of blower in which the nozzle is withdrawn from the furnace when not in operation is the most effective and is generally used for the fire-row tubes. Tubular-nozzle type blowers may have to be used for economisers and air heaters.

Electric type salinometers are also provided to give warning of any contamination of the feed water by salt. They are arranged in the form of cells fitted at various points such as the main and auxiliary condensers, coolers, etc. The connections from the cells are led to a common instrument, and arrangements are made whereby each point can be switched on in turn to read the degree of salinity in grains per gallon. Warning lights and bells can also be provided for each circuit to give visual and audible warning of an excessive amount of contamination.

For Diesel engines it is now considered almost essential that the cylinder jackets of main and auxiliary engines should be cooled by fresh water circulating in a closed circuit with independent pumps and coolers. This prevents the possibility of overheating due to narrow passages being silted up. Separate lubricating oil pumps, coolers and strainers are also provided.

Amongst other improvements provided are the fitting of Michell bearing blocks to the propeller shafting. In some cases roller bearings have been fitted with satisfactory results.

An interesting design of roller bearing is the Cooper split roller bearing, which is self-aligning and can be fitted to shafts with solid couplings. This design is illustrated in Fig. 37.

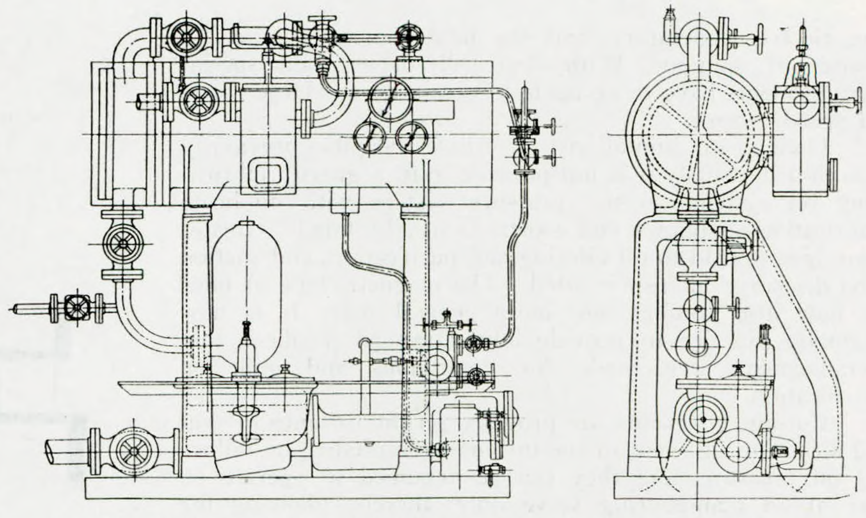


Fig. 36.—*Wallsend Simplex oil-fuel burning unit fitted in t.s.s. "Invicta".*

Numerous other fitments, such as depth gauges, distant reading thermometers, etc., are now considered essential to the safe and proper working of the machinery.

Elaborate arrangements for prevention of fires with oil fuel are now fitted, and CO_2 fire foam or sprinkler installations are a requirement of the Ministry of Transport.

In a review of this nature it is not possible to cover every improvement made over the past 34 years, but it is felt that attention has been drawn to the principal changes made in the machinery.

Nothing has been said regarding future development as it is dangerous to prophesy, but there are several interesting possibilities regarding the machinery of cross-Channel vessels and the one most likely to make its influence felt in the near future is the gas turbine, of which there are several experimental units already built or building.

Acknowledgments.

The authors acknowledge with grateful thanks their indebtedness to the following firms for permission to use much of the information and many of the illustrations used in the preparation of this paper :—

The Aspinall Governor Co., Ltd., Liverpool.
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Cammell Laird & Co., Ltd., Birkenhead.
Cockburns, Ltd., Cardonald.

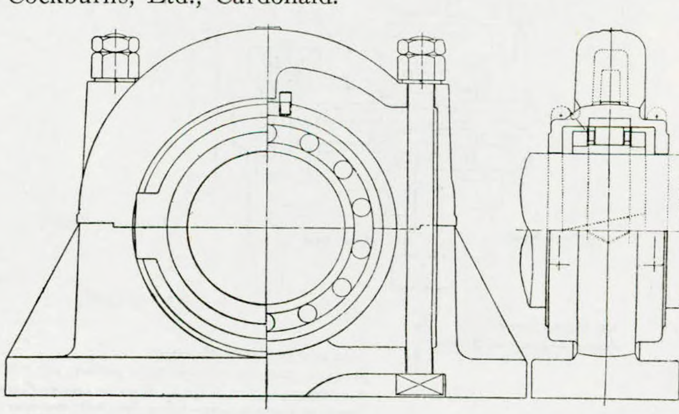

Fig. 37.—*Cooper split roller bearing for line shafting.*

Cooper Roller Bearings, Ltd., Kings Lynn.
Wm. Denny & Bros., Ltd., Dumbarton.
Drysdale & Co., Ltd., Glasgow.
The Fairfield Shipbuilding & Engineering Co., Ltd., Glasgow.
Harland & Wolff, Ltd., Belfast.
Michell Bearings, Ltd., Newcastle-on-Tyne.
The Parsons Marine Steam Turbine Co., Ltd., Wallsend-on-Tyne.
Sulzer Bros., Ltd., London.
The Wallsend Slipway & Engineering Co., Ltd., Wallsend-on-Tyne.
G. & J. Weir, Ltd., Glasgow.
Vickers-Armstrongs, Ltd., Barrow.
The Model Engineering Publishing Co. for illustrations of the *Leinster* and *Banshee*.

Discussion.

Mr. J. P. Campbell (Member), opening the discussion, said that he was rather sorry that the authors had not gone back a little further in history than 1913, because one of his colleagues who was interested in historical records had informed him that ships of the type under discussion were being built in 1813, although it was not actually until the year 1817 when what might be called the first cross-Channel vessel, the "Rob Roy", built by the authors' firm, was put into operation on a regular service, and their firm had specialised in building this class of vessel ever since that date. The type of paddle steamer then built appeared to have had a reasonably long life, carrying on until the year 1851, when the first single-screw steamer started on the Newhaven-Dieppe run, and in 1886 the first twin-screw steamer appeared on the same run.

The authors had summed up the position existing on cross-Channel boats admirably, no doubt due to their long experience. Mechanical stokers had been mentioned and they had given wonderful service over a period of years, but in the national interest, owing to fuel shortage, it had been necessary to dispense with them in favour of oil fuel. An interesting feature regarding the conversion from mechanical stoking to oil fuel was that induced-draught fans could be dispensed with.

Reference was made to the first geared turbine vessel, the "Hantonia". That vessel, still in service, was now 35 years old—it still had its original main wheels although he understood that the pinions had been renewed. It still averaged its trial trip speed with the greatest comfort.

It was of interest to note in Table 1 that the weight of machinery in the "Normannia" in 1912 was given as 490 tons, and that a comparable vessel, the "Falaise", which was being built at the present time, had 70 per cent. additional shaft horsepower although its machinery weight was only 5 tons heavier.

With regard to the question of astern power, he had the records of one vessel which had recently been converted from mechanical stoking to oil fuel. The specification called for astern revolutions equivalent to 85 per cent. of the ahead power, but on the measured mile 86 per cent. had actually been attained. The interesting part was that full ahead revolutions were 271 and full astern revolutions were 234. The ahead revolutions corresponding to the shaft horsepower going astern, which was 6,440, would give an ahead speed of 19·5 knots, but on full astern with the same revolutions only 16·2 knots were obtainable, so it would appear that the additional propeller slip when going astern was in the neighbourhood of 16·7 per cent.

The relevant trial particulars of that vessel were as follows:—

4,190 G.R.T.
Vessel fitted with bow rudder.
Length 348ft. 0in. o.a. Breadth 50ft. 0in. (mld.).
Depth 17ft. 9in. (mld.).

Actual trial conditions 9/10/46:
Draft 11ft. 11in. for'd. 12ft. 6in. aft. 12ft. 2¼in. mean.
Displacement 2,886 tons. Coeff. 0·52.
Midship area 539 sq. ft. Coeff. 0·942.
Wetted surface 15,330 sq. ft.

	R.p.m.	S.h.p.	Speed, knots.
Full ahead	271	11,300	22·16
Full astern	234	6,440	16·2
Percentage difference of astern to ahead	86	57	73

The only way to overcome the problem of space in connection with the possible installation of direct-Diesel propulsion would be to have a great number of cylinders and make a complicated multiple-cylinder job, but that would require a lengthy engine room. Furthermore, high-speed Diesel engines were inclined to be noisy, and from the passenger point of view that was undesirable.

It was stated in the paper that the fitting of electric alarms tended to make for over-elaboration, but he was not altogether in agreement with that, because automatic alarms were essential as an insurance against accidents and, from the travelling public's point of view, they helped to prevent possible grounds for complaints.

The authors had mentioned superheated steam, and he would like to know when, in the authors' opinion, the fitting of superheated steam was justified in that class of vessel.

Mr. D. J. Harris (Member) said that he had read through the paper with great interest, having had a pretty long connection with cross-Channel vessels, and he had come to the conclusion that the paper was factual and historical; therefore, there would be very little controversy in the discussion. However, Mr. Denny had almost contributed a second paper and there were a number of interesting points upon which to comment.

In the author's opening remarks reference had been made to squeezing a quart into a pint pot, and although the speaker would not mention any particular ship, there were cases to which that phrase applied. He had in mind one vessel of about 3,600 gross tons which carried something in the region of 800 head of cattle, 400 tons of cargo, and 1,500 passengers. Passengers and cattle would not appear to be a very good mixture, and he advocated the policy of keeping cattle in the cargo-carrying ships and passengers in ships which only carried passengers.

He was particularly interested in the description of the "Banshee" engine which, he believed, was the old L.N.W. Railway ship. When he had been in Holyhead he had frequently listened to words of praise about her performance.

With regard to the "King Edward", he corroborated all the authors said about that ship. She had given no trouble, and only a few years ago her boilers were retubed for the first time.

He considered that the Michell single-collar thrust block was one of the greatest inventions ever made, and all too little had been written or said on its behalf. It was noted that glands were done away with now, which was a great improvement because the packing used in those glands wore the journals severely; it was many years ago that he had taken the packing out of glands and had fitted deflectors. The grooving was also severe on the tunnel shaft journals which were fitted with Michell bearings.

With reference to the "Princess Maud" and the mechanical stokers which were fitted to her four boilers, those were of the Erith Roe type and gave good results. Their removal and replacement by oil-burning equipment was in no way due to mechanical defects or inefficiency. It was a politic move. She originally burned coal called "washed smalls" which used to cost 10s. 6d. per ton and was most economical, but in a year or so the price had risen to that of ordinary steam coal. Incidentally, it was proved that for the flying start from Stranraer the head of steam was maintained more steadily with the coal grates than with the oil burners. Whilst one could agree with the authors' prophecy that oil-fuel burning would become universal in cross-Channel steamers, from a financial point of view he considered it to be most uneconomical, although the worsening coal situation in the country might result in the balance ending in favour of oil.

As to the "King George V", no one could but give credit to Messrs. Wm. Denny & Bros. and Parsons Marine Steam Turbine Co., Ltd., and to Captain Williamson for the great and valuable pioneer work carried out by them in the installation of high pressure and superheat in that vessel.

The description of the machinery installed in the "Falaise" was of great interest and typical of what should be in an up-to-date turbine high-speed passenger vessel. Of particular interest was the design of the manœuvring valves and gear. It was, he imagined, somewhat similar to that fitted to the Southern Railway train ferries, and he had hoped to copy it in vessels under his supervision. Ease in operating manœuvring valves and the positive closing of them, particularly the tightness of the astern valve when under full power ahead, was most essential. One of the cross-Channel vessels mentioned in the paper stripped considerable blading in the astern turbine due primarily to a leaky astern manœuvring valve. Afterwards the precaution was taken of fitting a pyrometer to the astern turbine in all that particular company's turbine vessels. These had proved invaluable in detecting a leaky astern manœuvring valve.

As to water-tube boilers, he had had, over the past 28 years, considerable experience of these. They had all been of the Babcock straight-tube header type with saturated steam of pressures ranging from 180 to 225lb. Two of those vessels built in 1920-21 were still running with the same boilers and most of the original tubes, and the make-up feed water was drawn from town supply. He could not speak too highly of that class of boiler, which was now looked upon as the low-pressure type. For higher pressures and superheat, Babcock and Wilcox also supplied a two-drum boiler much the same in design as the Foster Wheeler boiler shown in Fig. 21.

With regard to turbines, the improvement in blading material, the end-tightened and segmental method of manufacture, and the care taken in the brazing had made the failure-free life of the turbine almost endless and its maintenance negligible.

As far as condensers were concerned, the fitting of aluminium-brass tubes had been a great boon to marine engineers, and he could not recall one tube failure since first fitting them in about 1932.

The Weir closed-feed system or its equivalent was definitely necessary in turbine vessels.

The authors' remarks on Diesel engines were interesting. The considerable trouble experienced with earlier Diesel installations mentioned by the authors still continued in present-day installations, despite all the intricate calculations on torsional vibration. Much had been done to reduce vibration, in particular by Messrs. Harland & Wolff, Ltd., by seating the engine bedplates on rubber-lined chocks, but he felt that Diesel engines and vibration would be bedfellows for all time, the vibration being a penalty the owners and their advisers had to accept for their choice when fitting Diesel engines. Apart from the main engines, most of the noise and much of the vibration was caused by the Diesel-driven generators.

The "Royal Daffodil" did great service during the war, and much of the credit for her successful running must be given to Mr. Coulthard who supervised the construction of the engines on behalf of the owners, and subsequently ran her as Chief Engineer for some years, including many trips during the evacuation of Dunkirk, for which service he was awarded the D.S.C.

With a service such as cross-Channel operations one had to be conservative. In regard to astern power, on the Holyhead-Kingstown route the ship was running right across the main line of traffic from and to Liverpool, particularly on a Saturday night, and it was very essential to have large astern power. There had been collisions, and points particularly concerning astern power, the time or distance in which a vessel could be brought up, were main factors considered in the Admiralty Court. Then again, cross-Channel boats went into fairly narrow harbours at good speed and had to pull up quickly.

He doubted whether a suitable return was obtained from the heavy extra cost of the installation of high-temperature power, and the responsibility which was thrown upon the engineers.

Mr. J. Calderwood, M.Sc. (Member) said that there was very little in the paper with which to argue, but he did desire to raise one point in connection with astern power. It appeared to him that it was all wrong to talk about astern power. It was not astern power that was wanted but astern torque in order to pull up the machinery quickly and get the propeller stationary, this being the condition to give the greatest braking power of the ship.

An interesting experiment was carried out some years ago on a turbo-electric job. Astern trials were run under various conditions and records were carefully made of the time required to stop the ship; if his memory served him aright, the ship was pulled up in the shortest distance by bringing the propeller to a stop and holding it there. It seemed, therefore, that the ability of machinery to develop high power in reverse was of secondary importance compared to its capacity to produce high reverse torque while still turning ahead.

With regard to the future of gas turbines, he believed it must be at least five years before any could be installed in cross-Channel ships, not because it would not be possible from a technical point of view, but simply because he did not think any firm could undertake to manufacture a gas-turbine installation for this purpose for delivery in much less than five years. The greatest difficulty on cross-Channel ships would be the question of reversal. Unless an electric drive were put in there were no means of reversing—at any rate none had yet been thoroughly tried out in service—and that would be a disadvantage in cross-Channel ships more than for other services, because an electric drive was heavy in weight.

However, it should be possible to arrange a gas turbine even with an electric drive with a weight as light or possibly lighter than that of a modern steam turbine installation. If a simple type low-efficiency turbine was acceptable, and this might well be the case for the short cross-Channel trips, then the gas turbine should show a considerable advantage in weight over any steam installation. Such a simple gas turbine would, of course, have a lower efficiency at sea than a steam turbine but would more than counter-balance this by savings in harbour consumption. For the longer services the high-pressure high-efficiency gas turbine would show savings over the steam turbine both at sea and in port, but such an installation would not show any marked advantage in weight unless used with a reversing gear or reversible pitch propeller, neither of which was yet fully developed.

Mention was made of starting up a gas turbine in six minutes. That might be possible, but quite frankly he would not like to do it regularly because the same problems of local stressing and possible distortion arose in a gas turbine as in a steam turbine during heating up, and no operating engineer would regularly put a steam set on load in a few minutes.

With regard to the question of the Diesel type of engine, he did not think the difficulty with that type of engine on very high-powered cross-Channel boats concerned weight so much, because he imagined the weight was about the same as for a steam turbine installation. What would appear to be the main factor was the question of head room. The number of cylinders which could reasonably be used was limited; this settled the cylinder diameter required for a given output, which in turn determined the stroke and hence the height of the engine. Among the higher-powered cross-Channel ships, this question of head room did not present any difficulty in ships such as the "Prins Albert" (Dover-Ostend service), but might make it difficult though not impossible to adopt Diesel engines for certain runs such as Dover-Calais where ship dimensions were more restricted. For most services, however, where power was not so high in relation to ship dimensions, the Diesel engine should show to advantage in arrangement of the accommodation due to the saving of the space required for the large boiler uptakes of a steam job.

Major W. Gregson, M.Sc. (Eng.), M.I.Mech.E. (Member) said that he had listened to the paper with great interest, as he had been associated with the cross-Channel type of vessel in a minor way over a period of some 30 years. He had served in them as well for some little time, of which incidentally he had enjoyed every minute and had learned a great deal. The machinery of cross-Channel ships covered every type of marine propulsion and in his time he had seen the phase which was marked in its earliest stages by the passing of the last of the paddlers right down to present-day conceptions of Diesel and modern steam propulsion.

The authors' main difficulty in keeping the paper within reasonable length must have been in deciding what to leave out, but as it was they had mentioned most of the high spots in the fascinating story of the development of cross-Channel ship machinery. He (Major Gregson) would like to mention two other outstanding incidents of the pre-1914 era.

The authors had mentioned the "King Edward" as the first turbine-driven passenger vessel. Her development was due largely to the vision and energy of the late Sir Charles Parsons and the firm of Messrs. William Denny & Bros., Ltd., but she only served in the Clyde area. The first real cross-Channel steamship to be propelled by turbines was "The Queen" of the old S.E. & C. Railway Co. followed by the "Brighton" of the old L.B. & S.C. Railway Company (both Denny-built vessels). The performance of these ships on difficult services definitely established the turbine for marine usage. The second point of interest was the series of ships built for the then new Heysham-Belfast service of the old Midland Railway, where two reciprocating-engined ships were in competition with two turbine-driven vessels. Here an absolutely fair comparison of the two types of propulsion was available and the honours went to the turbine steamers. The superintendent engineer of the Midland Railway was then Mr. Scott, who might be remembered by some of the older members of the Institute as one of the great marine engineers of his day.

The paper mentioned the subject of mechanised coal-burning. Up to the recent war the mechanically-stoked cross-Channel ship was doing good service, as with home supplies of coal and good bunkering facilities this system possessed many advantages, but the present state of coal supply—both cost and non-availability—now completely discounted coal burning. Mechanical firing reached its zenith just before the outbreak of the war and he (Major Gregson) would instance, as examples additional to those mentioned in the paper, the Harland & Wolff-built "Duke of York" for the L.M.S. Heysham-Belfast service, where the coal was carried in 'tween-deck bunkers so that it gravitated down to the stoker hoppers (see Fig. 38).

Other outstanding examples of mechanised coal firing with gravity-fed stoker hoppers were the three Southern Railway cross-Channel ferries ("Twickenham Ferry", "Shepperton Ferry" and

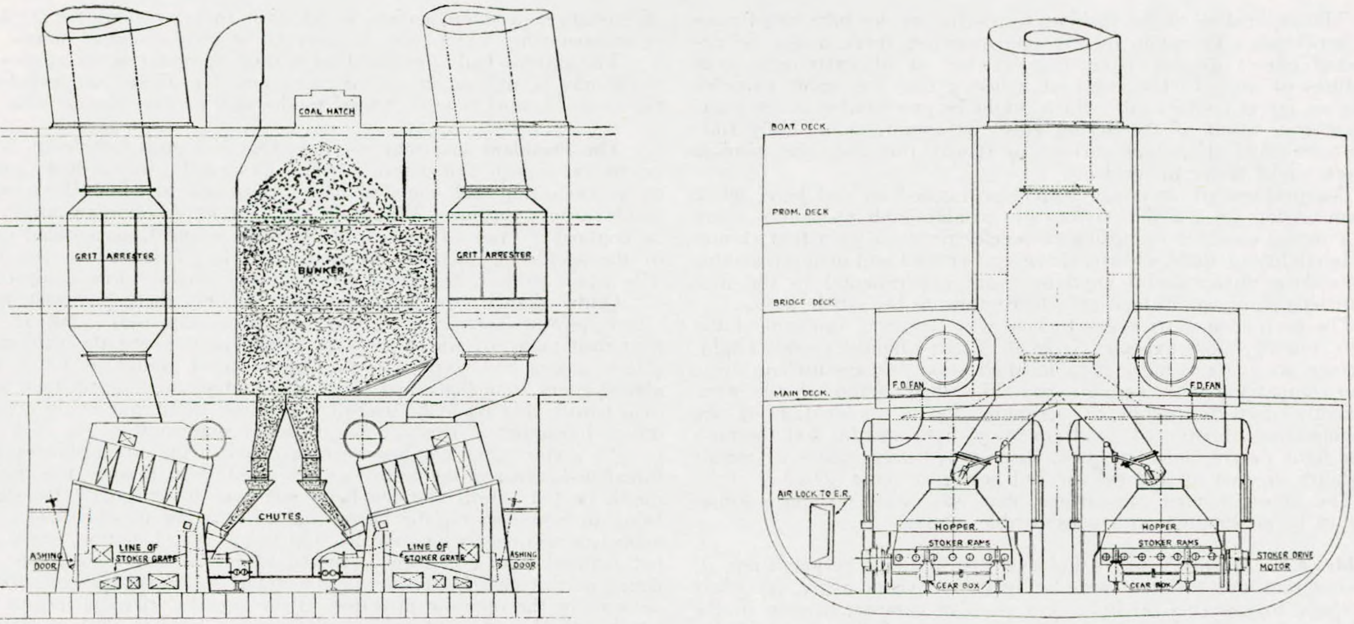

FIG. 38.—*Boiler room of the t.s.s. "Duke of York".*

"Hampton Ferry") built by Messrs. Swan, Hunter & Wigham Richardson, Ltd. for the Dover-Dunkirk through rail service.

On page 112 the authors stated that "Babcock & Wilcox have by no means abandoned square headers and straight tubes for high-pressure work, as several boilers of this type have been fitted in merchant vessels. . . . . ". It would have been more correct if the authors had stated "several hundred" rather than "several". It was of interest to note that of the nine cross-Channel passenger/mail (i.e. fast) steam packets ordered since the war ended, six had the header type of boiler.

He (Major Gregson) had rather taken the line that for cross-Channel ships the machinery should be simple, of appropriate weight and reasonably economical, but that economy must not be sought for at the expense of increased maintenance and first costs, and above all that the number of days per annum when the ship was at sea should be the absolute maximum. Ships of this type were expensive in first cost—they really were the "Rolls-Royces" of the sea, and a little saving in fuel could easily be discounted by an increase in days out of service. In pre-1940 days the total fuel cost of an average mail steamer of the type under review was of the order of 14 per cent. of the *total* operating cost, but of course the present-day fuel situation might now make this very much higher.

He was interested in the authors' remarks on the possibility of the gas turbine for the cross-Channel type ship, and he believed (as such vessels were based on home ports) that they offered a very opportune case for trying out this method of propulsion. In the present state of the art—metallurgical as well as purely mechanical—a good case could be made, but he would like to have the authors' views on the best method of manœuvring, as this was so vital in cross-Channel services which in many cases used difficult ports; they also sailed right across the main lines of ocean-going shipping.

No paper and discussion on the subject under review was really complete without some reference to the personnel who operated and serviced our cross-Channel vessels. The service seemed to breed a first-class type of man—both engineer and deck—grand fellows all. The man in the street who travelled aboard these ships had no idea of the amount of thought, care and experience which made for the perfection of running thereof.

Mr. E. G. Warne (Member) said that the paper invited a consideration of the question of fuel. With the disappearance of the coal-fired steamer for home services, more oil must be imported to run ships with alternative types of machinery. Was it suggested that the oil-fired steamer could compete with the Diesel-engined ship on the basis of present or future costs of fuel?

This was to be doubted, for the consumption of fuel with any oil-fired steam-engined cross-Channel boat would be about 0·75lb. per b.h.p. per hour and that of a corresponding Diesel-engined vessel about 0·37lb. per b.h.p. per hour. Therefore, the owners must rest assured that the price of boiler oil would be about half that of Diesel fuel. At the present time, Mr. Warne mentioned, the price of boiler oil was 80 per cent. of that of Diesel fuel.

Apart from the matter of price, every oil-fired steamer bunkering in this country made a demand on ocean-going tanker tonnage of double that required by the Diesel-engined vessel. Perhaps the actual quantity was not very great, but the authors of the paper might care to express an opinion on this matter.

Mr. R. J. Welsh, Wh.Ex. (Member) said that Mr. Calderwood had pointed out that in most cases astern torque was more important than astern power, but it might be further pointed out that the provision of astern torque (down to zero propeller speed) did not necessarily require the delivery of any power whatever from the main engines. The necessary torque could be provided equally well by any form of shaft brake—either a mechanical brake, or a suitably-arranged hydraulic coupling or magnetic coupling, or the like.

If a brake be used to hold the shaft stationary, and thus gave what was believed to be the maximum retarding effect to the ship, until the ship speed had dropped to a little under half, then an extra power of about 10 per cent. of full ahead power would be enough to complete the manœuvre by providing a substantial astern speed on the propeller and ultimately something approaching 40 per cent. speed astern. This solution to the astern power problem might be worth serious consideration for any form of prime mover unsuitable for direct reversal.

The authors had drawn attention to the fact that eighteen men were required for manœuvring the "Leinster", whereas the two engines of the "Falaise" were arranged so that both could be manœuvred simultaneously by one man. It was difficult to avoid speculating whether this trend would not continue to its logical conclusion, with all engines controlled from the bridge and the engine-room merely an unmanned compartment of self-sufficient machinery. The space under the bonnet of an ordinary motor car might be considered as an engine room with a main engine and several auxiliaries, including circulating water pump, fuel transfer pump, float-controlled service tank, power-driven fan, auxiliary electric generator, etc., all of which ran for relatively long periods without anyone on watch. The modern aeroplane was, perhaps, an even better example of the same thing, since the powers involved were more nearly of the same order as those of cross-Channel vessels.

He neither recommended nor condemned the principle of unmanned engine rooms, but merely suggested it as food for thought regarding the direction in which they appeared to be moving.

In regard to gas turbines, he agreed with the authors and with previous speakers, that it was likely to be five years before a cross-Channel vessel would be in service with this form of machinery. It might well be even longer.

Quite apart from manufacturing difficulties under the present conditions of power-station priority in all turbine work, it had to be remembered that there was as yet not even an experimental gas-turbine vessel afloat. The equivalent of the "Turbinia" had not yet put to sea.

The application of gas turbines to marine service introduced many new problems. To quote merely one example, there might be unexpected effects arising from the drawing in of extremely large quantities of air. In the event of a heavy fog, the water particles in the air might contain salt, which might be precipitated in the compressor as a result of the drying effect of compression. Only full-scale tests could show how serious, or trivial, this and other similar matters might prove in service.

The problem of reversing had been touched on and here, while acknowledging the possible virtues of variable-pitch propellers, there was a strong case for regarding turbo-electric drive as a first choice. The reliability of turbo-electric drive was proved and unquestionable; to introduce unnecessarily anything more experimental in the first gas turbine ships would tend only to complicate the whole issue.

The performance of a gas turbine was largely a function of the life in running hours expected from it. Cross-Channel vessels ought, therefore, to prove a most suitable application for gas-turbine drive as—in comparison with, say, a cargo ship—their running hours were sufficiently short to permit of designing for a combination of the desirable characteristics of good efficiency, light weight, and (because of the light weight and consequent absence of heavy masses of metal) the ability to start up and deliver full power at short notice.

The cross-Channel gas-turbine ship was most definitely something to be anticipated with considerable interest.

Mr. A. C. Howe (Visitor) said that it would be a serious thing if, knowing that gas turbines were at least five years away, no effort was made to use fuel oil in a very popular manner, namely in the Diesel engine. The Diesel engine had a great deal to be said for it in many directions. He recalled a paper read some short time ago in which it was stated that the Diesel engine of modern type, by reason of its small bulk and light weight, could be arranged almost anywhere in the ship, even on shelves carried from the bulkheads or the hull itself. This was possibly going a little far ahead, but the possibility was always there. The size of the modern Diesel engine did lend itself to easy stowage, and the weight itself was such as could be compared favourably with any other installation.

Other speakers having mentioned the problems of vibration and noise, Mr. Howe stated that modern methods using resilient mountings and sound insulation, could amply deal with these problems. As regards torsional vibration, calculations connected with this problem were no longer a mystery to reputable Diesel constructors, and should not present any difficulty. Furthermore, it was not always the Diesel engine itself which vibrated; what was felt by the passengers was quite often sympathetic vibration on the part of the ship itself, and he recalled the case of a ship which was well known to Mr. Denny, which vibrated in sympathy with the engine but which was rapidly cured by the introduction of equipment generating the necessary contrary forces.

The modern tendency to couple two, four or even more engines to one propeller shaft facilitated the application of large power into a small space.

Diesel-electric application lent itself very ably to sensible distribution in the ship, which would do much to facilitate the organization of passenger accommodation in addition to improving the problem of manœuvring, which was so essential in cross-Channel ships.

The authors had intimated that in their opinion electric application could only be utilized in special cases, and Mr. Howe suggested that the cross-Channel type of Diesel might well be that special case.

The President said that one item that had been prominent in the discussion was that of astern power. During the war it had cropped up in connection with the simplified turbine sets in which there was a single astern turbine. Whatever the determined amount might be, he doubted if even an appreciable increase would have avoided many of the accidents, such as collisions, that had occurred in the past. The whole subject, he considered, required further close analysis.

Quite often it had been said that "If only there had been more astern power, something would not have happened", but if one examined many of the Admiralty Court cases where the subject of astern power had come into the argument, it would be found that almost every time there had been other complications, and these were of a nature that could be usefully examined by marine engineers and others interested in this special aspect of manœuvring.

As a rule when engines were reversed in the circumstances of a threatened collision, the helm was also used. For instance, the engines might be put astern and the helm put over to starboard, the desire being to take way off the vessel and to turn her to starboard. The helm was so used as long as the ship had forward motion, but it was not realized that a moment occurred when the astern propeller race acting on the back (port side) of the rudder had a relative and greater velocity in the opposite direction to the vessel's forward motion and acted with the effect of turning the vessel's head to port in spite of her forward motion. In such a case, which had sometimes seemed to be mysterious, a lack of astern power had been wrongly blamed as the cause of the accident, which really occurred because the colliding vessel, in moving over to port, caught up with the other which otherwise might have got clear. He hoped that someone would take up the subject and analyse this complication of helm action when using astern power.

They had listened to an intensely interesting paper which had dealt with that aristocrat of merchant ships, the cross-Channel ship. Relatively speaking she was the fastest of merchant ships, and certainly an example of putting a quart into a pint pot.

A debt of gratitude was owed to Messrs. Wm. Denny & Bros. and to all the other firms mentioned by the authors in the acknowledgments which they had made at the end of the paper, for allowing such an interesting treatise on cross-Channel ships to be made available to us; particularly interesting was the data given in Table I.

Mr. J. Calderwood, M.Sc. (Member of Council), proposing a vote of thanks to the authors, mentioned that the paper had been prepared at extremely short notice to fill a gap which had occurred in the programme. The efforts of the authors in presenting this extremely interesting and well-written paper would be warmly appreciated.

Mr. A. F. C. Timpson, M.B.E. (Member of Council) seconded the vote of thanks, which was carried with acclamation.

The Authors' Reply to the Discussion.

The authors, in reply, said that Mr. Campbell went back a little further than they had, to the "Rob Roy" in 1817, but the ships mentioned in the paper were a little better known.

Mr. Campbell had referred to the question of mechanical stokers. Where fitted these had been very successful. The trouble with mechanical stokers was not their actual functioning so much as the difficulty at the present time in getting supplies of coal at a reasonable cost for the stokers to burn.

A comparison was made between the weight of the "Hantonia" (490 tons) and the weight of one of the later vessels, and the difference was only 5 tons; but it was only fair to state that the "Hantonia" was fitted with Scotch boilers, which made a tremendous difference to the weight of machinery. The weight of water alone in a Scotch boiler could be about 50 tons, which made a big difference in the weight of the machinery.

In referring to astern power, Mr. Campbell mentioned that in going astern there was greater slip, but that was largely influenced by the shape of the blades. The astern thrust of the propeller was not taken on a nice smooth helical surface as when going ahead, as for constructional reasons the shape of the back of the blade taking the astern thrust was not so good as the ahead face. The ahead surface was in many cases especially treated in order to give a nice easy flow, but in the reverse direction the surface was not so good and a higher slip was the result.

It was agreed that braking effect was most important. It was for that reason that very many companies, notably the Southern Railway, in arranging their manœuvring valves had the cut-out gear for the governors arranged so that it operated only on ahead valve. In the event of a failure in lubrication, if the ahead turbine were shut down steam could be given astern to bring the machinery quickly to rest.

Immediately an order was given for full speed astern, while the vessel was still travelling ahead, astern steam was applied to bring the vessel to the stop as soon as possible, and under those conditions, considerable braking was obtained with the propeller.

The question of astern power had been brought up in a large number of Admiralty court cases, and the cause of collision might be a misunderstanding at the time the order was given. The navigating officer would often say that the cause of an accident was that the machinery was not worked to orders; consequently the question of astern power was sometimes confused with the fact that orders were not given correctly or were given so rapidly that there was no opportunity for them to be carried out. (Here Mr. Barr mentioned that he had been on the starting platform when the order had been received to go ahead, then the order "Half Astern" was received and before sufficient time had elapsed to touch the wheels down came the order "Half Ahead", and although nothing happened everybody seemed to be quite happy!)

Mr. Campbell also raised a point concerning induced draught. That was a very nice way of running boilers, and the only thing which could be said against it was the amount of space taken up, because induced-draught fans had to be put in the spaces which were normally reserved for accommodation. It was worth mentioning in this connection that the passenger department had a very big say in the space available for machinery. They did not care very much where the machinery was put. All they were concerned about was maximum accommodation for passengers; consequently the machinery space had to be cut down very much indeed.

Mr. Harris referred to very congested engine rooms, and the authors were very sympathetic; but if he were being pushed by shipbuilders who in turn were being pushed by passenger service departments he would have the same difficulty in obtaining more space for machinery.

He also mentioned that cattle and passengers did not mix very well, but cattle often received better treatment than passengers. To attempt in small ships to make passenger space and cattle space do alternate duties was extremely difficult and like all compromises was seldom satisfactory.

Reference was also made to the Michell thrust bearing. The authors entirely agreed that it was one of the few inventions which came out absolutely complete. There had been practically no alteration in the original design brought out by Michell, which was rather remarkable. Most things were a steady growth, but the Michell thrust was an instance of an entirely new idea being evolved which had necessitated very little modification right up to the present time.

The manœuvring gear of the "Falaise" was mentioned. This was not the first vessel to be fitted with that type of gear. It worked very satisfactorily, but it might not be too popular with captains and navigation officers because it was another of those schemes which took away the excuse that the engines were not worked to orders. In the gear there were two sectors, side by side, one of which was operated by telegraph order from the bridge and all the engineer had to do was to bring his operating lever pointer over in line with the telegraph pointer so that he could not possibly make a mistake in direction.

Manœuvring valve leakage could give trouble. A leakage into the astern turbine could raise a very high temperature by increasing the density of the medium in which the astern turbine was rotating and trouble would be experienced.

As regards the mounting of Diesel engines on rubber blocks, that might be a difficult problem, because the Diesel engine, in common with the turbine, had to take the thrust from the propeller, and the thrust block had to be mounted very solidly so that the thrust of the propeller could be transmitted to the ship. It was also doubtful whether rubber chocks were really of any advantage, because a flexible mounting could not very well be placed on something solid without trouble ensuing.

The authors agreed with Mr. Calderwood's estimate of the time which would elapse before gas turbines were likely to be used for cross-Channel work. They were all in favour of gas turbines and were looking forward with interest to the first to be put into service.

As to the question of reversing with gas turbines, there was of course the hydraulic coupling method of reversing the propeller as well as the electric drive method. It was of interest to note that the Parsons Marine Steam Turbine Company had considered a hydraulic coupling method, and that Harland & Wolff had taken out a patent for the reversing propeller. It indicated that the particular form of reversing gear which would be adopted eventually had still to be thrashed out, but that was only one of the problems which would have to be solved in connection with gas turbines.

The authors agreed with the comments regarding the head room required for Diesel engines. It was a feature of cross-Channel ships that tall engines could not be installed, otherwise they would be sticking through the deck.

Mr. Warne gave certain figures of fuel consumption of Diesel engines as compared with oil burned in boilers. Those figures were substantially correct, and the only reason the authors could give for Diesel engines not being used far more than they were, was largely on account of the difficulties of getting them into the space available. When very high power was required, one could not get Diesel engines running fast enough, light enough or small enough in the space available.

Mr. Welsh spoke about astern power and bridge control. All captains were not in favour of bridge control; they seemed to prefer a division of responsibility. The usual skipper seemed to think that he had enough to do pushing the telegraph about from ahead to astern. If he were controlling the ship himself and drove it up against the quay, he could not blame it on to anyone else, which might be one of the reasons why engine-room control was preferred.

With regard to the question of salt being deposited in the compressor in the event of gas turbines being used, the conditions which obtained at the present time in connection with boiler fans were similar, because if the gas turbine had to compete with the steam turbine and, incidentally, with the Diesel engine, then the total fuel consumption would have to be about the same and, consequently, the quantities of air should be similar.

Mr. Howe referred to vibration in ships. The shipbuilder said that vibration must be due to the engines because the ship would not vibrate on its own accord, and that assertion was a difficult one to refute. The only solution appeared to be for the Diesel-engine builders to make their engines, if it were possible, so that they did not vibrate at all.

The President referred to the question of astern power and helm effect, and the matter would be referred back to the experiment tank.

A point had been raised about whether superheated steam was a good thing or not and the authors hoped soon to be in a position to say something more about that after running tests in a ship for a short period.

Mr. Harris was thanked for his remarks about the authors' firm. Some of the speakers had been kind enough to make complimentary remarks about the paper, and the authors felt that anyone wishing to read a comprehensive survey of the subject should refer to Major Gregson's classic Thomas Lowe Gray lecture to the Institution of Mechanical Engineers.

Everybody would endorse Major Gregson's remarks concerning the personnel of the cross-Channel services. They were a fine body of people who were doing a difficult job exceedingly well.

In conclusion the authors desired to thank the members of the Institute for the way in which the paper had been received and for the interest shown by the various contributors.

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Published by Metal Information Bureau Limited, Princes House, 39, Jermyn Street, London, S.W.1. 224pp. 5s. post free.

The Nickel Bulletin.

Bound Volume 18, 1945. The Mond Nickel Company, Limited, Grosvenor House, Park Lane, London, W.1.

The Ships and Seamen of Britain.

By Michael Lewis, M.A., F.R.Hist.S. Professor of History, Royal Naval College, Greenwich. Published for The British Council by Longmans Green & Co. Ltd. London. 1946. 56pp., illus. 1s. net.

"The Ships and Seamen of Britain" is a new version of Professor Lewis' earlier essay, "British Ships and British Seamen", first published in 1940. Since that date, the ships and seamen of Britain have made history in a war that has tested their strength and proved their worth as never before. The story of how British seamen and their ships met this latest ordeal is told in the concluding chapters of this essay, which has in other portions been condensed and in part re-written from the earlier version.

Professor Michael Lewis, who is Professor of History in the Royal Naval College, Greenwich, presents the past and present of British seafaring as a historian, and shows how the tradition that has made Britain a race of seafarers has continued unbroken from the beginnings of the history of these islands to the present time.

Seafood Ships.

By A. C. Hardy, B.Sc., F.R.G.S., M.I.N.A., A.M.I.Mar.E. Crosby Lockwood & Son, Ltd. London. 1947. 248pp., profusely illus. 12s. 6d. net.

Mr. Hardy's publications cover in a very interesting way and in his own style, a wide range of maritime subjects, most of which are well known to those associated with shipping, marine engineering and naval architecture.

"Seafood Ships" is another fine example of his work; not only does it make excellent reading but it should prove of educational value to maritime minded readers. It deals solely and very fully with one of the least-known branches of shipping which in these times of world food shortage is a very important one.

The chapters of the book are exceptionally well illustrated in every respect and describe fully all the main types of fishing craft in service in various countries of the world, their methods of fishing for the different species of fish, the many types of gear and equipment which have to be used, and the processing, canning and refrigerating systems involved.

Various statistics as given of fish caught and their values, etc., are a clear indication of the magnitude of the fishing industry.

The book should be of particular interest to marine engineers and naval architects with regard to ship design, speeds, bunker capacities, horsepower installed for main propulsion, auxiliary use and general purposes, taking into account both steam and Diesel-engined vessels up-to-date. There is a great deal of other technical information which is very helpful and interesting.

The Author is to be complimented on the excellence of this timely publication, which illustrates most effectively these sturdy vessels, their machinery, and last but not least, those who man them, for once on the fishing grounds there is no return until the catch has been made.

The Escalator Method in Engineering Vibration Problems.

By Joseph Morris, Consultant, Structural and Mechanical Engineering Department, Royal Aircraft Establishment, Farnborough. With a foreword by Professor G. Temple, F.R.S. Chapman & Hall, Ltd. London. 1947. 270pp., 64 Figs. 21s. net.

Mathematics has been said to be the only real international language; unfortunately though international it is not universal, for though many are familiar with the x, y, z, of the language, few have more than an elementary knowledge of the rest of the alphabet. In common with many other mathematicians the author of this book forgets that many students of his work will be less practised in mathematical thought and methods than is he himself. As a result this volume will be of real value only to those with a first class training in mathematics and a considerable amount of practice in the application of such training to practical problems.

Joseph Morris is one of the world's leading experts in the mathematical solution of problems which involve the elastic deflection of structures, and in the "Escalator Method" of dealing with certain types of complex vibration problems he has put forward a method of solving these problems which is both simpler and more easily checked than the methods that had previously been in use. It is however not a method that can be used with safety except by those with sufficient mathematical experience to appreciate fully the principles involved, and is therefore not one that can be generally adopted in the design departments of engineering firms. On the other hand for research organisations who have to study such problems in much more academic detail, Morris's work should be of great value; it might for example be helpful in the vibration research of the British Shipbuilding Research Association, if his methods have not already been adopted by them.

The author, before coming to his main subject matter, gives in seven chapters a very thorough resumé of the known useful methods of dealing with the strength and stiffness of elastic structures. Methods of finding approximate vibration frequencies and the vibration problems of a rotating shaft are dealt with in the next two chapters. Following this, two chapters, some thirty pages in all, are devoted to explaining the principles of the "escalator" method of estimating vibration frequency; these chapters might well have been expanded to explain the principles of this device in somewhat less mathematical terms, as such explanation would be very helpful to the student.

Chapters 12 to 21 deal with various particular vibration problems, mostly relating to aircraft and their engines, though the methods used could be applied to similar problems in ships and marine engines. The last chapter on "Pendulum Dampers" deals in mathematical terms with the theory of this device, leaving the reader with very little idea of what form such devices take. As pendulum dampers have been very fully and much more clearly treated elsewhere, this chapter might well have been omitted.

Taken as a whole, the volume forms a most valuable addition to the available literature on vibration problems. Many authors who deal with this subject are either engineers with insufficient mathematical training to offer any real advance in methods of attack, or mathematicians unable to appreciate that their theory is only useful if it can have practical application. Mr. Morris has both mathematical skill and appreciation of practical problems, and as a result has been able to make a notable contribution towards the improvement of methods of calculation applicable to engineering problems.

Mechanical Vibrations.

(Third Edition). By J. P. Den Hartog, Professor of Mechanical Engineering, Massachusetts Institute of Technology. McGraw-Hill Publishing Co. Ltd. London. 1947. 478pp., 282 Figs. 30s.

This is a new edition of a book which needs no introduction to the majority of engineers who are concerned with vibration problems. The basic aim of the book, which is to deal with advanced problems of mechanical vibrations using the minimum of higher mathematics compatible with arriving at a complete understanding of the subject, has already given this book a wide popularity among practical engineers who may find some difficulty with the more usual type of mathematical approach to this type of problem. The examples, many of which are taken from the author's own experience in industry, add to its value.

The third edition has brought up to date certain sections on which wide advances have been made in recent years, notably wing flutter, torsional pendulum dampers, singing propellers, helicopter rotor vibrations and electronic instruments for vibration measurements.

Engineering Reconstruction.

Published by The Association of Scientific Workers, 15, Half Moon Street, Piccadilly, London, W.1. 1947. 90pp., 8 illus. 2s.

This book is the work of a number of members of the Association of Scientific Workers, drawn from the different fields which the book surveys. It owes its existence to a decision of the Engineering and Metallurgical Committee of the Association, which was anxious that scientists and technicians who are concerned in their daily work with the problems of industry, should make a contribution which might assist the nation in dealing with the immense task of reconstruction.

There is some variation in the relative emphasis that is placed upon technique, organisation or research in the different sections, in accordance with the conditions prevailing as seen by the various groups. The editors have endeavoured to correlate the views expressed in order to present, in the last chapter, a general picture of what is required if engineering reconstruction is to be achieved.

Workshop Engineering Calculations and Technical Science.

(Vol. 1). By J. Stoney, B.Sc. (Eng.), London. The English Universities Press, Ltd. London. 1946. 196pp., 151 Figs. 10s. 6d. net.

To quote the introduction, "this text-book has been written with the object of co-operating with the newer method of teaching engineering subjects". There does not, however, appear to be anything noticeably new in the method adopted, unless it be merely in a widening of the range of subjects dealt with in one text-book, with a corresponding reduction in depth. The object appears to be to provide a simple, interesting, and directly useful introduction to many things, suitable for one whose time for study is very limited, and who for some reason or other must begin with the very rudiments of arithmetic, learning first how to add a half to a quarter. For such a class of student the author has undoubtedly provided a very satisfactory first course.

Of the twenty chapters the first twelve give a general course in workshop mathematics—arithmetic, algebra, graphs, mensuration, trigonometry; the use of logarithms is not explained, although log tables are given at the end of the book. The remaining eight chapters deal with mechanics and heat—force, levers, transmission of motion, friction, energy and power, heat, temperature. Everywhere an effort is made to show the application of the processes learnt to the problems of workshop and laboratory; for example, the chapter on force touches, lightly indeed, on stress and strain, elasticity, strength of materials, factor of safety, testing machines, and hardness of metals—there is even a table showing the relationship between Brinell Hardness Number and tensile strength of steel.

There is a plentiful supply of examples for practice, with answers.

Preliminary Mathematics for Engineers.

(Third Edition). By W. S. Ibbetson, B.Sc., A.M.I.E.E., M.I.Mar.E. Chartered Electrical and Marine Engineer. E. & F. N. Spon, Ltd. London. 1947. 175pp., 40 Figs. 6s. 6d. net.

In a vain attempt to cover much ground in a short space of time, to make up for lack of previous instruction and to meet the requirements of various examining bodies, the subject of "Practical Mathematics" was devised and introduced. It was received in some quarters with great acclamation as an easy solution of the difficulties prevailing.

The author and many other teachers of the subject have always contended that this method of meeting the real difficulties has been a complete failure. Sooner or later the student fails to comprehend the more advanced requirements of the subject, and either gives up in disgust as he fails to understand or reluctantly returns to a study of the elementary principles.

In the present edition, an additional section dealing with the elements of trigonometry has been added. The time spent on a thorough mastery of the contents of this book will be time well spent.

Guide to the Literature of Mathematics and Physics Including Related Works on Engineering Science.

By Nathan Grier Parke III, Research Associate in Physics, Research Laboratory of Electronics, Massachusetts Institute of Technology. McGraw-Hill Book Company, Inc. New York and London. 1947. 205p. 25s.

This guide to the literature of mathematics and physics has been written to meet a long-standing need. Mathematics and physics are playing roles of increasing importance in engineering and in the other sciences. Thus there exists a large group of people who cannot maintain an independent awareness of the mathematical and physical reference literature but who can make effective use of a classified guide. This group includes scientists, engineers, librarians, and students.

In order to make this guide of maximum usefulness to engineers and applied scientists, the narrow limits of mathematics and physics have been exceeded and a considerable number of books on aeronautical, electrical, radio, and mechanical engineering have been included—sufficient, in fact, for most reference work.

The basis of selection is of practical interest. About half of the titles make up the author's professional library. The mathematical titles were augmented by a careful scrutiny of the reviews that appeared in the Bulletin of the American Mathematical Society, 1934-1945. The physics titles were augmented by a careful survey of the "Subject Catalog", Fine Hall, Princeton University. The engineering titles and those of general interest were less systematically compiled. The entire list has been compared with the reference collections at the Library of Congress, Johns Hopkins University, and the Massachusetts Institute of Technology. The comparison is favourable.

A bibliography of this scope has a special usefulness, which it is well to point out. The bounds of knowledge are so great that it is impossible to know in detail more than a small fraction of the information that could be used. Thus there is an increased emphasis on knowing where to find and how to assimilate information as it is needed. Browsing through a guide of this sort should build up a knowledge of what is available and where it is located.

Modern Electrical Engineering Mathematics.

By S. Austen Stigant, M.I.E.E., F.A.I.E.E., etc. Hutchinson's Scientific and Technical Publications. London. 1946. 372pp., 116 Figs. 31s. 6d. net.

The reviewer first became acquainted with the work of Stigant over 20 years ago when the present "J. and P. Transformer Book", of which he was co-author, was merely a few of the "J. and P. Pages". Since then we have noted the progressive evolution not only of mathematics, but of the work of Stigant who has made notable contributions to the electrical engineering branch. Any work of Stigant is worth reading.

The book covers general theory of the various plane vector operators, determinants, matrices, dyadics, those very useful techniques called tensors, symmetrical components, an introduction to the Heaviside operational calculus, dimensional analysis applied to electricity and certain transient phenomena.

The author exhibits a sincerity of interest in his subject, the work is well printed and excellent bibliographies are given. The dates of the references indicate that the work covered is up to date. Both author and publisher are to be congratulated on this comprehensive publication.

The concluding chapter deserves wide attention of those connected with electrical engineering education. In fact, the book would form a very useful basis of an advanced course in modern mathematics, but of more pressing need is the "closer liaison between engineers and mathematicians".

While the book is outside the scope of electricity as applied to marine engineering, the reviewer has enjoyed reading it, as it will form a most useful reference to the more specialised aspects of electrical engineering mathematics.

Efficiency Calculations.

By H. W. D. Cotteman. Published by Engineers' Coaching Service, 16-20 Young Street, Circular Quay, Sydney, Australia. 1947. 62pp. 7s. 6d.

The book contains numerous worked examples and questions (answers given) on the calculations with respect to the efficiency of steam and internal combustion engines, boilers, dynamos, electric motors and accumulators. Brief elementary descriptions of the various plants dealt with are given.

More care might have been taken with the wording in many cases. For instance on page 9 the definition for efficiency is given as "ratio of work got out to work put in"; the word energy would be more suitable than work. On page 13 "the steam in the form of heat energy . . . ", would be better expressed as the heat energy in the steam . . ., again, on page 33, with reference to the Indicated Thermal Efficiency of I.C. Engines, the statement "the ratio of the work out of the engine in B.T.U. value of H.P. to the work in, as measured by the C.V. of the fuel", would be better stated as the ratio of the indicated work per minute output to the heat supplied in the fuel per minute, both quantities to be expressed in the same kind of unit.

Several of the abbreviations used are incorrect, such as ft/lbs instead as ft. lb. and I.H.P./hr when i.h.p.hr. is intended.

In connection with properties of steam, a formula is used for obtaining latent heat and no indication given as to how the temperature of steam at any given pressure is to be obtained. Steam tables should be used for these quantities, but are not mentioned. In several cases results based on the latent heat formula are given to five figures, and in at least one case six figures.

The value of π used throughout is 3·1416, which appears to be unnecessary, 3·14 would be more suitable.

All the calculations are of a very elementary nature and the book is only suitable for young craftsmen.

Engineering Statistics.

By G. W. Stubbings, B.Sc., A.M.I.E.E. "Mechanical World" Monograph (38). Emmott & Co., Ltd., 31 King Street West, Manchester, 3. 1947. 24pp., 7 Figs. 2s. net.

As the applications of engineering extend in scope, and its operations increase in precision, so the range of the subjects with which the engineer may have to be acquainted becomes larger. Economics, business methods, and management have for some time been considered to be part of the liberal education of an engineer, and the latest subject to be included in this field is that of statistics, which plays so important a part in the modern control of production and which is likely to play an equally important part in the fixing of standards of quality and criteria for acceptance by purchasers. The purpose of this monograph is to deal with some of the conceptions of statistical theory in order to assist the engineer unacquainted with this branch of applied mathematics, to take up the study of its applications to modern engineering problems.

Fundamental Principles and Applications of Induction Heating.

By "Heat-Treater". Chapman & Hall, Ltd. London. 1947. 147pp., 104 Figs. 10s. 6d. net.

Until comparatively recently the only large-scale application of induction heating was in the melting of metals. In the past ten years, however, the method has found many industrial applications, including hardening of steel, brazing, soldering, forging, annealing, normalizing, stress-relieving, paint-drying, etc., etc. Much of the development work was done in America, but British firms are now able to supply equipment also. This small book describes the uses and possibilities of induction heating which has already shown itself to be of great value in many industries.

Purchased.

Lloyd's Register of Yachts, 1947.

Lloyd's Register of Shipping. £3 3s. 0d.

OBITUARY.

Mr. R. S. Kennedy.

It is with deepest regret that we record the death of Mr. R. S. Kennedy (Honorary Vice-President and Member 1234), who passed away at Oundle, Northants, on Wednesday, 2nd July, 1947.

Robert Sinclair Kennedy, who was born on the 6th April, 1874, was the son of John Kennedy, marine engineer. He was educated in Switzerland and at University College, London, where he was senior Gilchrist Scholar, and served his apprenticeship at the North Eastern Marine Engineering Co., Ltd., Wallsend-on-Tyne, at the Glenfield Co. of Kilmarnock and at the Gateshead Works of Clarke, Chapman & Co., Ltd. Subsequently he was employed for a short period as a draughtsman in the service of Rodger & Co. of Glasgow, followed by a period at sea as a marine engineer. In 1897 he was appointed assistant manager of The Glengall Ironworks, Ltd., of which Company he eventually became managing director. In 1910 Mr. Kennedy and his father were responsible for the formation of The British Arc Welding Co., Ltd. He was appointed managing director of the newly-formed Company, and in this capacity he pioneered the use of electric arc welding with the metallic electrode in this country. He relinquished this appointment in 1942 when he retired.

It was in 1897 that Mr. Kennedy became associated with the Institute, and he took an active and continuous interest in its affairs throughout the remainder of his life. In 1918 he was elected to the Council and he was re-elected in the same capacity for the 1921-2-3 and the 1925-6-7 terms of office. During the latter period he became Chairman for the 1926-27 Session. In 1928 Mr. Kennedy was elected a Vice-President, a capacity in which he served without interruption

until early in the present year when he was appointed an Honorary Vice-President.

Of the great amount of Committee work which Mr. Kennedy undertook, the most outstanding was the many years of exacting service which he rendered to the Membership Committee, of which he was Chairman from 1933 until 1945.

Mr. Kennedy, who was a Past President of the Caledonian Society of London, a member of the Scottish Corporation, and a member of the Institution of Civil Engineers, was keenly interested in church matters and for many years was a churchwarden at St. Peter's, Hampstead, and at St. Andrew's, Ferring.

In 1904 he married Annie Flora Ross, daughter of Alexander Ross, Past-President of the Institution of Civil Engineers. He is survived by his wife, two sons and one daughter, his other son having been killed on active service in 1942.

A man of modest and exceptionally charming personality, who really endeared himself to every one of his colleagues on the Council and to all the many members with whom he was personally acquainted, Mr. Kennedy leaves a wide circle of friends who deeply mourn his passing and who will look upon their association with him as amongst the happiest of memories.

The funeral took place at Kettering on Saturday, 5th July, the Council and Members of the Institute being represented at the ceremony by Mr. G. F. Silley.

MEMBERSHIP ELECTIONS

Date of Election 14th July, 1947.

Members.
Simon Archer, B.Sc.
Linnell Palk Barker, Lt.-Com'r(E), D.S.C., R.N.(ret.).
Hal Baldwin Bolus, Lt.-Com'r(E), R.C.N.
John Richard Burrows.
Leslie Horton Busby.
James William Dimond.
William John Duncan.
Harry Fenton.
Emmanuel Gauci, Lt.(E), R.N.R.
Harold Hamer.
Frank Hewitt.
William Stewart Horsburgh.
David Ross Innes.
Kenneth Macallister Macleod, D.S.C., M.A.
Norman Milne Mackay.
Michael Alwyn Munby.
William Ross.
Henry Hutchinson Taws.
George Villar, Eng. Capt., R.N.
Reginald Alexander Watson.
Herbert Cornelius Wilkins.
Harold Napier Williams.
Ivor Sydney Bond Wilson.
James Cowper.
Bernard Kirkby Hargreaves.
William Green Hibble, Lt.-Com'r(E), R.N.V.R.
Samy Aly El Rashidy.
Randhir Singh Rawal.
Robert Kenneth Roberts.
James Douglas Stewart.
John William Utting, Comm'd Eng'r, R.N.
Charles Alexander Wilson.
Richard Henry Withington.

Associate Members.
Joseph Winston Chapman.
Robert Michael Duggan.
Eric George Hickling.
Frederick John Rouse.

Associates.
Herbert James Aspin.
Percival Hamil Brook.
Archibald Cameron.
Ernest Frank Malcolm Cross, Sub. Lt.(E), R.N.

Students.
Edward James Humphreys.
Peter Richard McCleave.
Hayward Thornicroft Taylor.

Transfer from Associate Member to Member.
William Sephton.

Transfer from Associate to Member.
Gordon Thomas.

Transfer from Associate to Associate Member.
Thomas Dawson Mitchell.

Transfer from Graduate to Associate Member.
John Harry Vassie.

Transfer from Graduate to Associate.
Paxton South.

Transfer from Student to Associate.
Colin Victor Bryant.
George Walter Winter.

PERSONAL.

J. L. ADAM, C.B.E. (Member) has been elected President of the Institute of Welding.

JOHN B. ANDERSON (Member) has been appointed chief engineer of the Bank Line's s.s. "Tielbank".

C. BARTLETT, B.Sc. (Member), assistant to the chief ship surveyor, Lloyd's Register of Shipping, has been appointed deputy chief surveyor (administration).

E. A. BOOTH (Associate), who served in the Fleet Air Arm from 1939 to 1941, and as technical assistant in the Directorate of Mechanization from 1941 to 1945, followed by a period of employment in the Ministry of Supply and the Admiralty, has now been reinstated on the technical staff of Morris Motors, Ltd.

F. J. CARGILL (Member) has been released by the Ministry of Supply, Inspection Department, and has been appointed chief engineer of The Haddon Steamship Co., Ltd.'s s.s. "Empire Brutus".

W. J. FERGUSON, M.Eng. (Member), principal surveyor on the chief engineer surveyor's staff, Lloyd's Register of Shipping, has been appointed assistant chief engineer surveyor.

H. R. HOWELLS (Member), Lloyd's Register of Shipping's senior surveyor at Manchester, has been appointed principal surveyor for refrigeration on the chief engineer surveyor's staff.

R. J. JENKINS (Associate) has been appointed superintendent of the Port Elizabeth Ocean Terminal of Caltex (Africa) Ltd.

J. LEWIS LUCKENBACH (Vice-President, New York), President of the American Bureau of Shipping, has been elected President of the Board of Trustees of the Webb Institute of Naval Architecture, New York, in succession to Mr. Joseph W. Powell.