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The Diesel Engine for Passenger Vessels and Fast Cargo Liners.

BY J. CALDERWOOD, M.Sc.,

READ

Tuesday, January 8, 1929, *at* 6.30 *p.m.*

CHAIRMAN: MR. R. T. WILSON (Vice-Chairman of Council).

The CHAIRMAN: I have much pleasure in calling upon Mr. Calderwood to deliver his lecture. I am glad so many have taken the opportunity to attend this lecture, as I am sure, judging by previous papers read by Mr. Calderwood, that we shall have a most instructive evening.

UNTIL after 1920 the marine Diesel engine had not reached a stage in its development that made it suitable for passenger liners and for the faster classes of cargo vessel. Before that date the four-stroke single-acting engine held the favour of the shipowner; the two-stroke engine had, in the early days of marine Diesel work, proved a more difficult problem for the designer and thus lost headway, which took a long time to make up, particularly as the war period held up development on these lines. Towards 1920 it was generally realised that the trouble with two-stroke engines had been confined chiefly to the valve-scavenging type, and that the port-scavenging engine had proved thoroughly sound and reliable; as a result of this the latter started rapidly to gain ground. The four-stroke single-acting engine had not been suitable for high powers and its use had, therefore, been almost entirely confined to cargo vessels of comparatively low speed. With the more general adoption of the 2-cycle engine higher powers became available, and in 1924, after this type had had some years to prove its reliability in service, it was adopted for the first large oil-engined passenger liner, the *Aorangi* (Union S.S. Co.), built by Messrs. Fairfield Shipbuilding and Engineering Co., and fitted with Sulzer engines built under licence by that Company. About the same date shipowners began to realise that the advantages of the Diesel engine were even more marked for the fast cargo liner than for the slower classes of ship. As a result of this several orders were placed for this type of vessel, various types of machinery being adopted.

The author believes that he is correct in stating that the first Diesel-engined cargo vessel, with a speed of over 13 knots, was the *Limerick*, fitted with Sulzer engines built by Messrs. John Brown and Co. This ship was quickly followed by others of similar and higher speeds, some fitted with the same type of engine, others with Doxford engines.

The rapid advance of the 2-cycle engine resulted in the builders of 4-cycle engines turning to the double-acting type, in order to meet the competition of the former for fast vessels, while at a later date the 2-cycle double-acting engine was taken up by many builders, some of whom had previously been interested in the 4-cycle single-acting type.

The present paper deals principally with large ships designed for speeds of 14 knots or more. For such service the four-stroke single-acting engine, with direct drive is, in the author's opinion, quite unsuitable, and the choice of machinery must lie between 2-cycle single-acting engines and double-acting engines of either the two or the four-stroke type.

Other factors being equal, the choice of engine type for any ship must be largely governed by the space that can be allowed for the machinery, in order to allow the best arrangement of passenger accommodation or cargo holds, as the case may be. It is remarkable that this particular point of view often seems to escape notice when machinery is to be chosen for any particular ship. In a passenger vessel space above the water

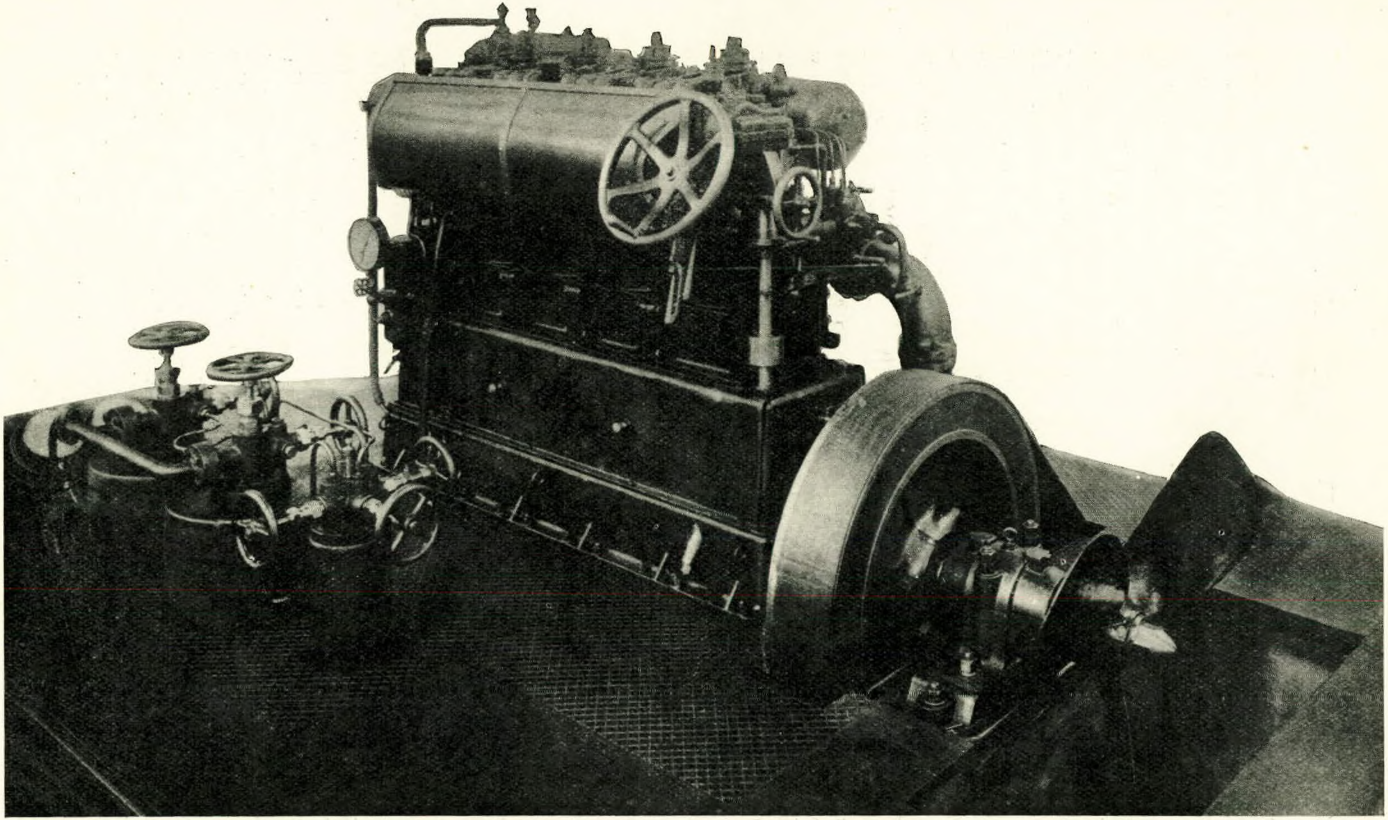


Fig. 1. The first reversible Sulzer Marine Diesel Engine of 100 B.H.P. on Exhibition at Milan, in 1906.

line is of the greatest value, and it is, therefore, essential that the full length of all decks in this part of the ship should, if possible, be available for accommodation. This sets a limit on the height of the engine. Length, on the other hand, is of minor importance. If direct drive be adopted, the revolution speed is limited by propeller design. For such conditions the single-acting two-stroke holds an overwhelming advantage over the double-acting engine of the 4-cycle type, and a very marked advantage over the double acting 2-cycle engine. If either of the latter is designed to meet the conditions, a very low piston speed must be chosen, which results in an engine which is heavier and more expensive than the two-stroke single-acting type. If, on the other hand, double-acting engines are designed with normal piston speeds, then at least one deck space, or possibly two in the case of the 4-cycle engine, is lost over the whole length of the engine-room. The loss of this valuable passenger space will more than balance any saving in weight and first cost that may be obtained by the use of double-acting engines, and it is very doubtful whether any such saving is actually obtained.

In the case of the cargo vessel, the whole of the space in the ship is of about equal value, so that the total cubic contents of the machinery space should be a minimum consistent with a reasonable and accessible lay-out for the machinery. For such conditions there is probably little to choose between the double and single-acting engine of the two-stroke type. The 4-cycle double-acting engine requires appreciably more space than either the single or double-acting 2-cycle type. Of the latter the double-acting engine has possibly a slight ádvantage as regards both space and weight.

Only the direct drive has been considered in the above remarks, but there is an increasing tendency to-day towards indirect drive either through gears or by electrical or hydraulic transmission. The main advantage claimed for the indirect drive is that it allows a much higher speed for the main engines, and consequently reduces the weight and cost of these, while at the same time making it possible to fit the engines into very limited headroom. The last of these claims is certainly justified, but the reduction in weight of the engines is largely counterbalanced by the weight of the transmission system, while the cost of the latter, in the author's experience, far more than balances any saving that may be obtained by using high-speed main engines. The gain in headroom makes it possible to fit double-acting engines with indirect drive in the space available in a passenger ship, but little advantage is gained in the case of the single-acting two-stroke type, as it is in almost all cases possible to fit engines of this type in the headroom available, whilst retaining a direct drive to the

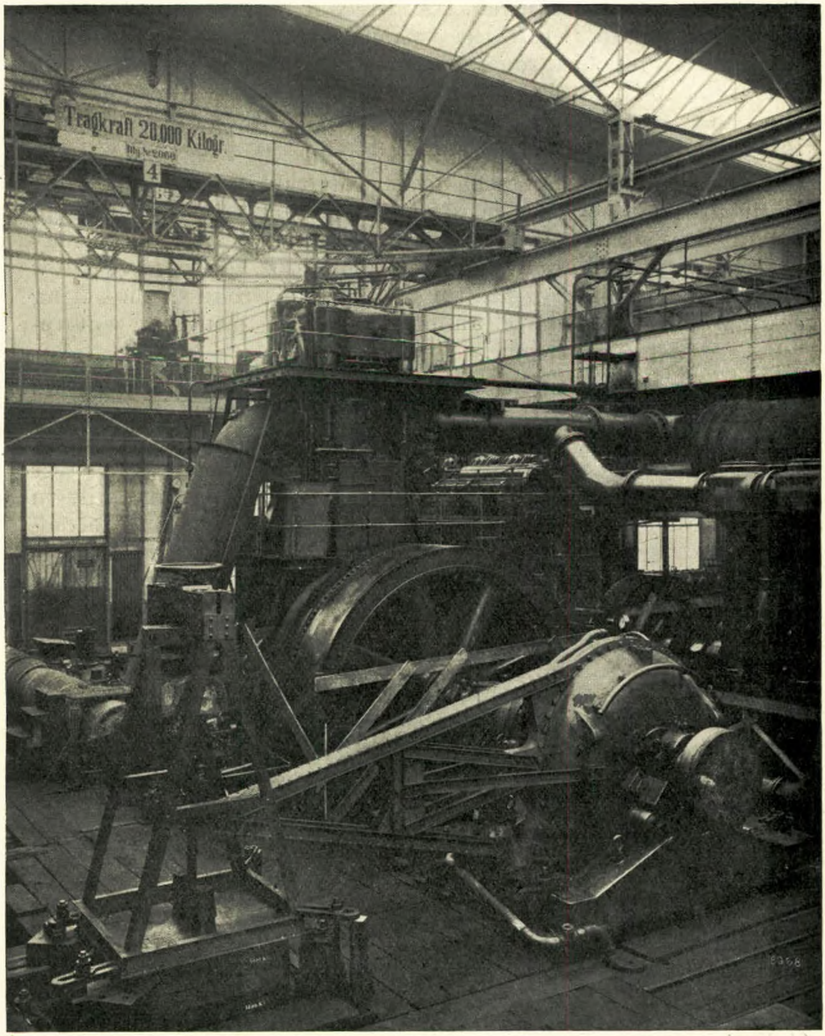


Fig. 2. Sulzer single-acting two-stroke, single-cylinder experimental Engine of 2,000 H.P.

propeller. It must be remembered that in the small high-speed vessels in which headroom is very limited, a comparatively high propeller speed is generally allowable, and this largely negatives the advantages of indirect drive. This is clearly shown in fig. 8, which shows rather an extreme case in which the headroom is only about 16 ft. and about 12,000 B.H.P. is required. A direct drive two-stroke engine can be used and, while the various alternative arrangements require even less headroom, no advantage is gained, as the space below the 16 ft. level is of little value as passenger accommodation. On the other hand, any of the indirect drives greatly increases the length of the engine-room.

The author does not wish to suggest that the indirect drive is unsuitable in every case; there are undoubtedly types of service for which either electric drive or geared drive may be the most suitable, but, speaking generally, there are very few vessels for which an installation with two-stroke single-acting engines with direct drive cannot be designed to suit the requirements as regards space.

The above remarks have dealt solely with the consideration of engine type from the point of view of the space available. The author has dealt with this question first and at some length, because it often appears to be overlooked when machinery is being chosen, and many passenger ships have been built in which valuable space which might have been used for accommodation has been lost due to the choice of unsuitable machinery.

No less important than space are such questions as first cost, running cost, and ease of overhaul and upkeep. Reliability need not be discussed, as any type of Diesel engine, built by reliable engineers, and which does not depart far from previous practice as regards size, design or rating, will be fully as reliable as any other type of marine machinery. Such failures as have occurred during recent years have invariably been due either to the too rapid adoption of a new untried design or else to a high increase in the rating of an engine as compared with previous engines of similar size.

In first cost there is to-day little to choose between the various types of engines; price is fixed by competition rather than by actual manufacturing costs, and builders of the heavier and more expensive types of engine cut their costs as far as possible by poor finish and relatively lighter scantlings for bedplate, columns, etc. Eventually, however, given a similar class of

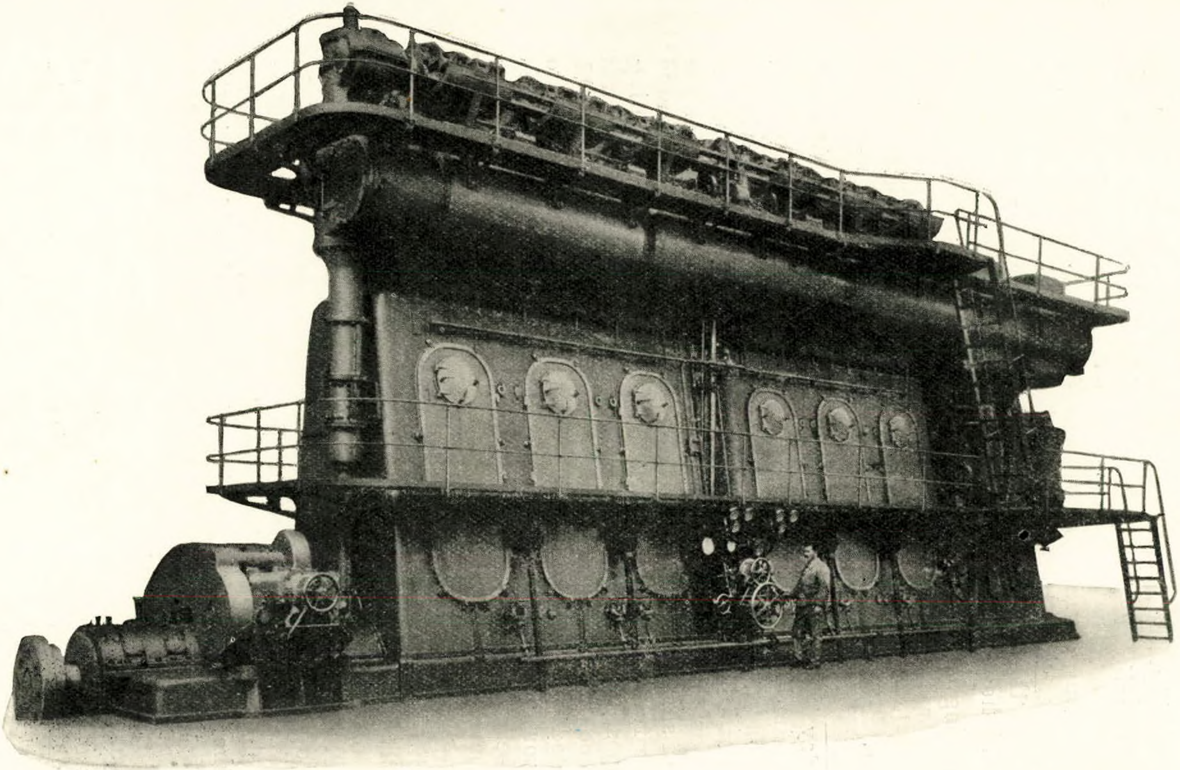


Fig. 3. Sulzer Main Engine of the M.S. Bintang (Netherland S.S. Co.) 3,600 B.H.P. One of the earliest large single screw-installations.

workmanship, the two-stroke engine, either of the single or double-acting type must prove considerably cheaper than the four-stroke. The difference in cost between single and double-acting engines is remarkably small, as although for a given power the latter is lighter than the former, a larger proportion of the weight is taken up by those parts whose cost per ton is highest.

Running costs, i.e., fuel, lubricating oil, stores and attendance at sea, are much the same for all types of single-acting engines, but no reliable data is yet available for double-acting engines. The Author has had values for the fuel co-efficient $\frac{D^{2/3} S^3}{\text{Tons/day}}$ from a number of ships with four-stroke and two stroke single-acting engines and also opposed piston engines. These have varied from 55,000 to about 78,000. The variation does not in any way appear to depend on engine type, but rather on the hull and propeller efficiency. Generally for the class of ships with which this paper deals, a fair average value for the fuel co-efficient is 65,000 for any type of single-acting or opposed piston engine. The author has no reliable figures obtained in service for double-acting engines, but it is to be expected that the consumption will be rather higher, due to the poor shape of the lower combustion chamber, although this may be off-set by the somewhat higher mechanical efficiency that may be expected.

Lubricating oil consumption does not vary much between the different types of engine. The 2-cycle type shows possibly a somewhat higher consumption than the 4-cycle, the difference being about 1 gallon per day per 1,000 B.H.P. This refers to single-acting engines. As in the case of fuel consumption, no reliable data is available for double-acting engines of either 2 or 4-cycle type, but such figures as have been published lead one to believe that the consumption of lubricant is considerably higher in the double-acting engine. Why this should be is difficult to explain, and the author is inclined to think that these reports are misleading, and to assume that consumption of lubricant is much the same in any type of engine, amounting usually to about 5 gallons per day per 1,000 B.H.P. for installations of fairly high power. This figure is obviously dependent on suitable oil being used for the conditions of service of any ship.

The question of cost of attendance and upkeep is chiefly dependent on the number of parts requiring regular attention

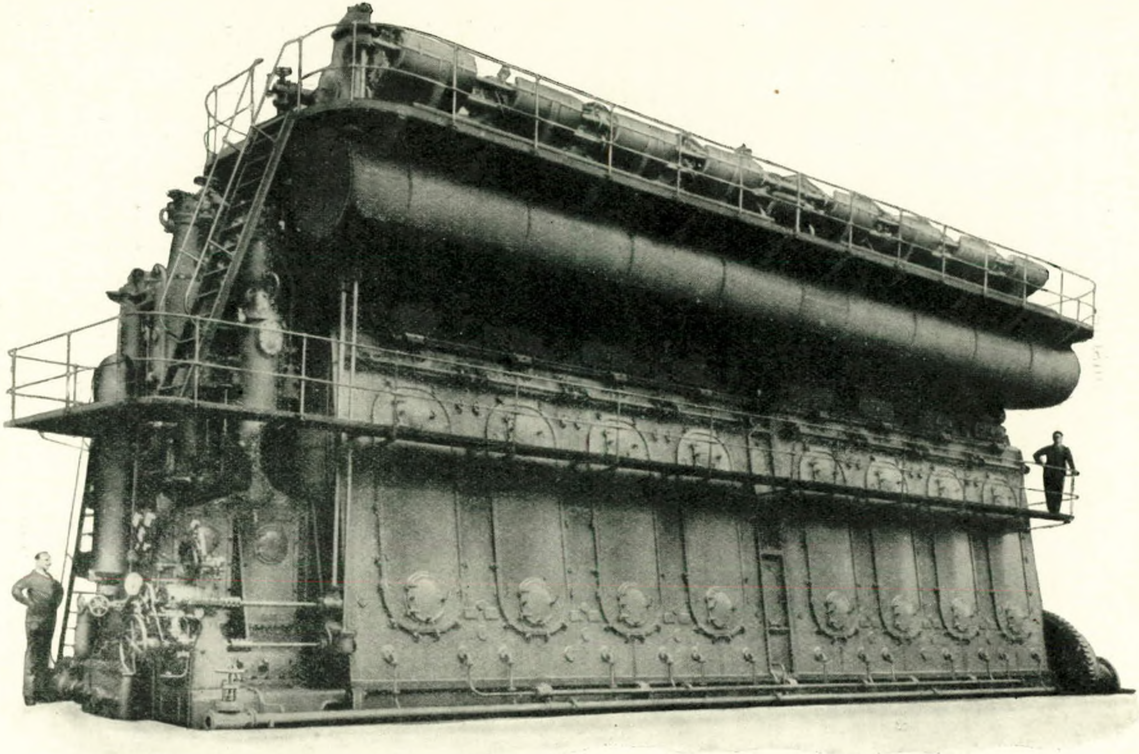


Fig. 4. Sulzer Main Engines of the M.S. "Peolau Roebiah" (Netherland S.S. Co.) 7,000 B.H.P. in service.
The highest power yet fitted in a single screw vessel.

and on the accessibility of such parts. The parts which require most frequent attention are undoubtedly the valves. The two-stroke single-acting engine has here a very marked advantage over either the two or four-stroke double-acting engine, both in the number of valves requiring attention and in their accessibility. Pistons also require periodic inspection. Here the two-stroke double-acting engine has some advantage over the single-acting engine in the number of pistons requiring attention, but this advantage is slight as compared with the disadvantage of its more numerous and less accessible valves. The author believes that almost any engineer who has had experience of various types of engine at sea will confirm that the two-stroke single-acting type gives much less work in overhauling than does any other type.

To summarise the above arguments: for the passenger liner the two-stroke single-acting engine has very marked advantages in all respects over any other type. For fast cargo liners the two-stroke double-acting engine has a slight advantage over the single-acting type in that it is lighter and requires less space; this is off-set by the probability of higher fuel consumption and upkeep costs, but on the whole there can be little to choose between these types except that the single-acting engine has the advantage of long experience behind it, whereas it can hardly be claimed that the double-acting engine is as yet fully developed.

The four-stroke single-acting engine, although it is undoubtedly a very reliable and successful type for lower powers, is quite unsuited to the class of vessel covered in this paper.

The double-acting four-stroke engine does not show to advantage in any respect for the types of vessel under consideration, and there seems little reason for its existence except as a stop-gap in the programme of those builders who had no experience of two-stroke engines and had to put some type of engine in the market quickly to fill the demand for higher powers, until they had time to experiment with the two-stroke type.

In the above remarks the opposed piston engine is classed with the single-acting two-stroke, as these two types have generally the same advantages over others. The opposed piston engine can, however, hardly be a type with any great future, as it is essentially a very expensive engine to manufacture. The only successful engine of that type has been able to compete with other engines because it has the advantage, as regards first cost, of the only solid injection system that has

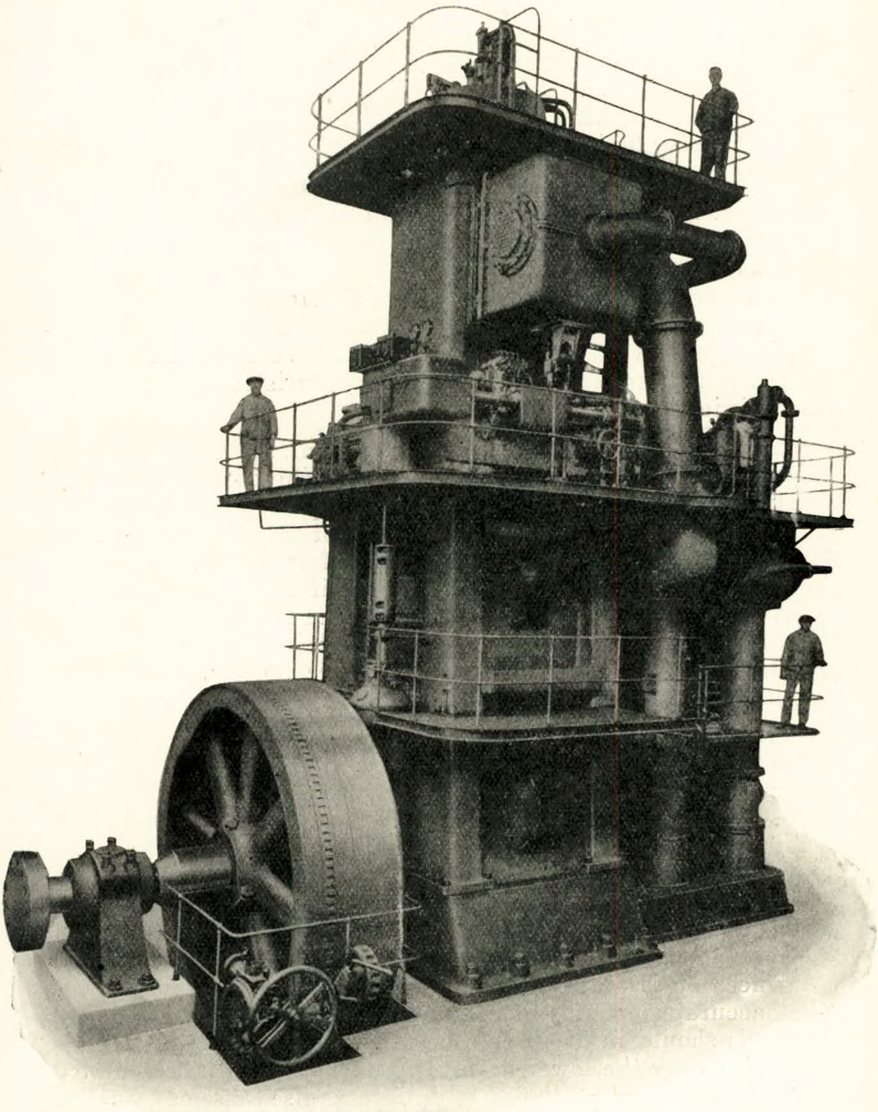


Fig. 5. 2,000 B.H.P. Sulzer single-cylinder, two-stroke double-acting Engine.

yet proved itself comparatively satisfactory for a large marine engine over a reasonably long period in service. Other reliable systems of direct injection are being developed and, as these are proved in service and more widely used, the opposed piston engine will lose this advantage and must soon be forced out of the market by its high price compared with other types.

There is at present a strong tendency towards the adoption of direct injection, but the author does not think that it has yet shown itself to be so reliable and adaptable to varying running conditions and quality of fuel as to be completely satisfactory for large marine engines and, in spite of the attractive saving in first cost, it is not likely to be generally adopted until experience has shown that some of the more recent developments make it as reliable and consistent in service as is air injection.

A question which is of great interest at the moment is the effect that exhaust gas turbo-super-charging may have on the relative position of the 2 and 4-cycle type of engine. In the author's opinion the published results of tests on that system lead one to believe that the claims put forward for the system are considerably exaggerated, but even if this view should not prove correct, the system cannot influence the relative position of the 2 and 4-cycle engine as if the claims put forward are found to be actually justified by service results, the system would be equally easily applied to either type of engine.

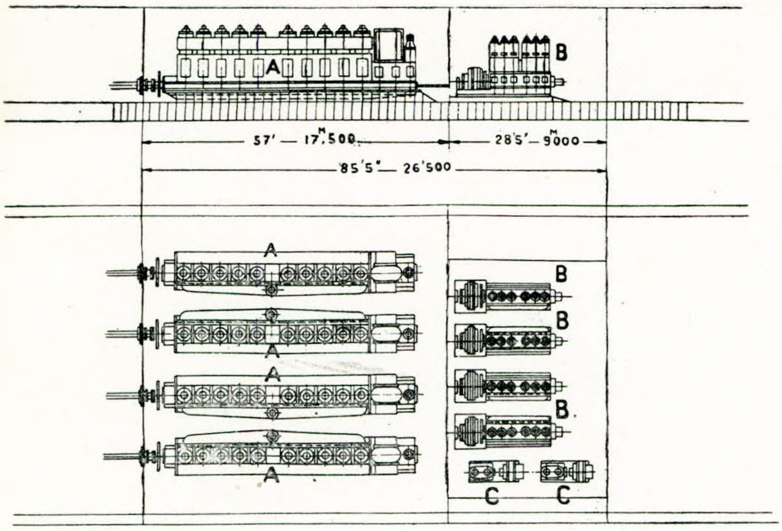
Freedom from vibration and noise are considerations of first importance in passenger liners, and while ship vibration is not of such vital importance in cargo vessels, it should, none the less, be given careful consideration. Torsional vibration of the shafting has been dealt with so thoroughly in recent years in papers published in many languages that there is no excuse for any engine builder who experiences trouble from this cause, or for any shipowner who does not insist on having the problem looked into before he accepts a machinery installation. All that need be said about this side of the subject of vibration is that accurate methods of calculation are available, and these methods should in every case be used. Approximate methods by which only the lower natural frequencies can be calculated should be avoided, as they may lead to a false sense of security. The greatest danger from a torsional vibration lies in the fact that it may in some cases reach a dangerous magnitude without any marked external evidence of its existence, in which case the first sign of vibration will be the breakage of a shaft or a slack crankweb. The only certain way to avoid serious torsional vibration is by calculating the speeds at which it causes dangerous stresses and avoiding these speeds in service.

From the passengers' view-point a ship vibration arising from unbalanced forces is much more unpleasant than is a torsional vibration of the shafting. The calculation of the natural frequencies of vibration of a ship is a complex problem, and although many papers have been published on this subject, no one has yet put forward methods which would enable all of the more important modes of vibration to be calculated within a reasonable length of time. In practice the modes of vibration which most frequently give trouble are vertical vibrations of the 2nd and 3rd degree. The 1st degree vibration may also give trouble if the engine framing is badly designed, so that stresses arising from 1st order forces which the frame should be capable of carrying are transmitted to the hull. This question is dealt with later in the paper. First order unbalanced forces and couples in the main engine should be of negligible magnitude, and these are the only ones likely to synchronise with the 1st degree vertical vibration of the hull. Further, a vibration of such low frequency is not likely to be very noticeable or unpleasant unless it be of considerable magnitude. Of much greater importance are the 2nd and 3rd degree frequencies mentioned above. These may synchronise with either 1st or 2nd order unbalanced forces in auxiliary machinery, with 2nd order forces from the main engine, or with the varying force on the hull caused by the propeller blades passing the stern post. All except the last of these causes of vibration can be eliminated by balancing the machinery concerned. The propeller can only be altered by changing the number of blades. In a paper read last year (N.E.C.Inst. E and S., Jan., 1928) the author gave an approximate empirical method of estimating the 2nd and 3rd degree vertical natural frequencies of the hull, which should be sufficiently accurate to determine the number of propeller blades most suited to any particular case. Taking as an example of the application of that method a passenger ship 550 ft. long with main machinery running at 95 r.p.m., the 2nd degree natural frequency of the hull will be from 210 to 240 per min., and 3rd degree frequency 350-400. A 4-bladed propeller would cause considerable forces of a frequency 380 per min., which would cause a serious ship vibration because of its synchronism with the 3rd degree frequency. A three-bladed propeller would, on the other hand, give impulses of frequency 285 per min., which would be well clear of either of the natural frequencies mentioned above and would not cause any marked vibration.

The author does not wish to suggest that by this simple method all vibration troubles can be eliminated, but it at least affords a means of avoiding one of the commonest causes of trouble. Complete and accurate methods of calculating the various natural frequencies of a ship structure are badly needed, and it seems probable that, with the ever-increasing knowledge of this subject, such information must shortly become available.

It was mentioned above that the best method of avoiding vibration caused by main and auxiliary engines was by having these properly balanced, but that is perhaps an incomplete statement. One should add that the engine framing should be so designed that none of the internal forces of the engine can be transmitted through the seating or in any other way to the hull of the ship.

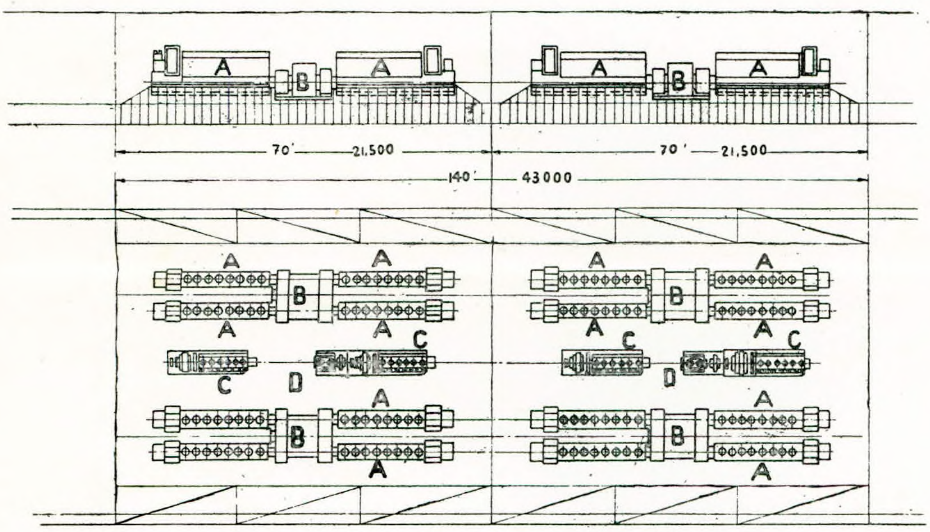
The ordinary balancing diagram for a multi-cylinder engine is based on the primary assumption that the engine framing has infinite rigidity, or that it is attached to a rigid foundation. A land engine is mounted on a heavy concrete base, which may be assumed to be infinitely rigid, and the engine framing need not have the same rigidity that is essential in a marine engine which is mounted on a much more flexible foundation. The A type frame to carry the transverse loads at each cylinder, combined with through bolts to carry the vertical stresses to the bedplate, and from there to the foundation, has proved satisfactory on land engines, where torsonial stress and longitudinal bending stress must in part be transmitted to the foundation, which is essentially stiffer than the engine framing can possibly be made. In a marine engine the position of affairs is reversed. The foundation cannot possibly be made stiff enough to carry the bending and twisting stresses without marked distortion and consequent vibration. This is a point which many designers seem to have failed to appreciate, with the result that many engines, which on paper are perfectly balanced, can, nevertheless, transmit forces to the seating which cause unpleasant ship vibration or, alternatively, a transverse vibration of the engine on its seating. In the latter case the whole engine twists, the after-end having a heavy transverse vibration, while the forward end has little or no motion. The vibration of the ship's hull is due to the



Two Stroke Single Acting Direct Drive.

4 ENGINES EACH 3000 B.H.P. AT 300 R.P.M.

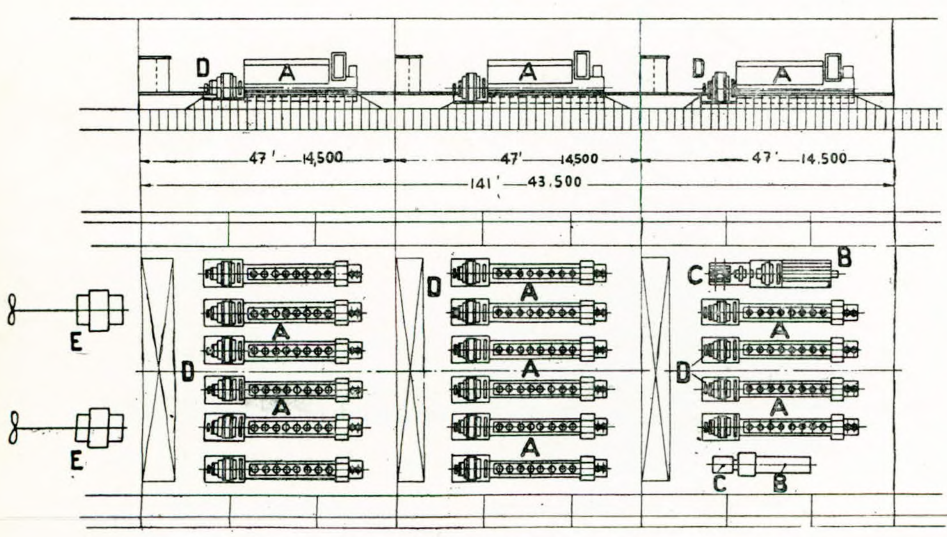
A. – Main Engines	440	Tons
B. – Auxiliary Generator Sets	105	"
C. – Auxiliary Compressors	5·4	"
Total	550·4	Tons



Two Stroke Single Acting. Geared Drive.

16 ENGINES EACH 800 B.H.P. AT 400 R.P.M.

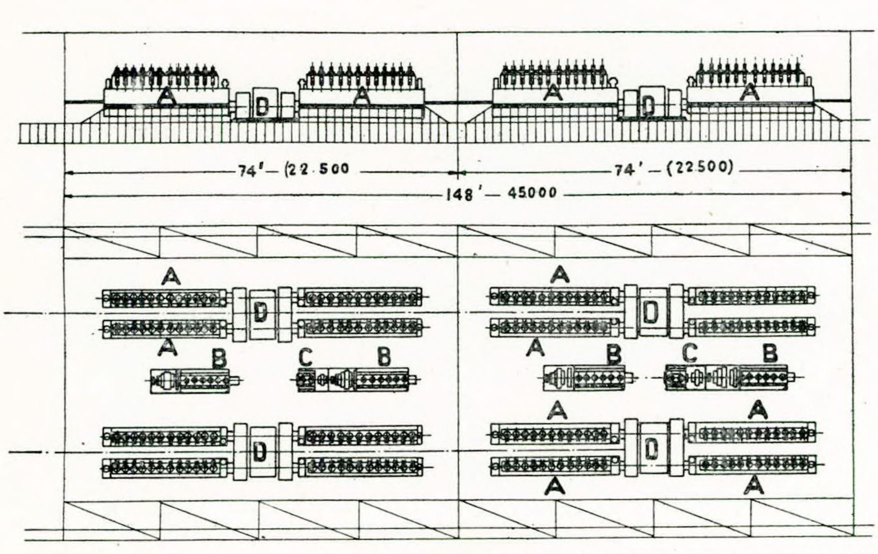
A. – Main Engines.	432·0	Tons
B. – Reducing Gear.	120·0	"
C. – Auxiliary Generator Sets.	63·6	"
D. – Auxiliary Compressors.	3·4	"
Total	619·0	Tons



Two Stroke Single Acting. Electric Drive.

16 ENGINES EACH 850 B.H.P. AT 375 R.P.M.

A. – Main Engines.	430·0	Tons
B. – Auxiliary Generator Sets.	52·6	"
C. – Auxiliary Compressors.	3·4	"
D. – Main Generators.	204·0	"
E. – Main Motors.	210·0	"
Total	900·0	Tons

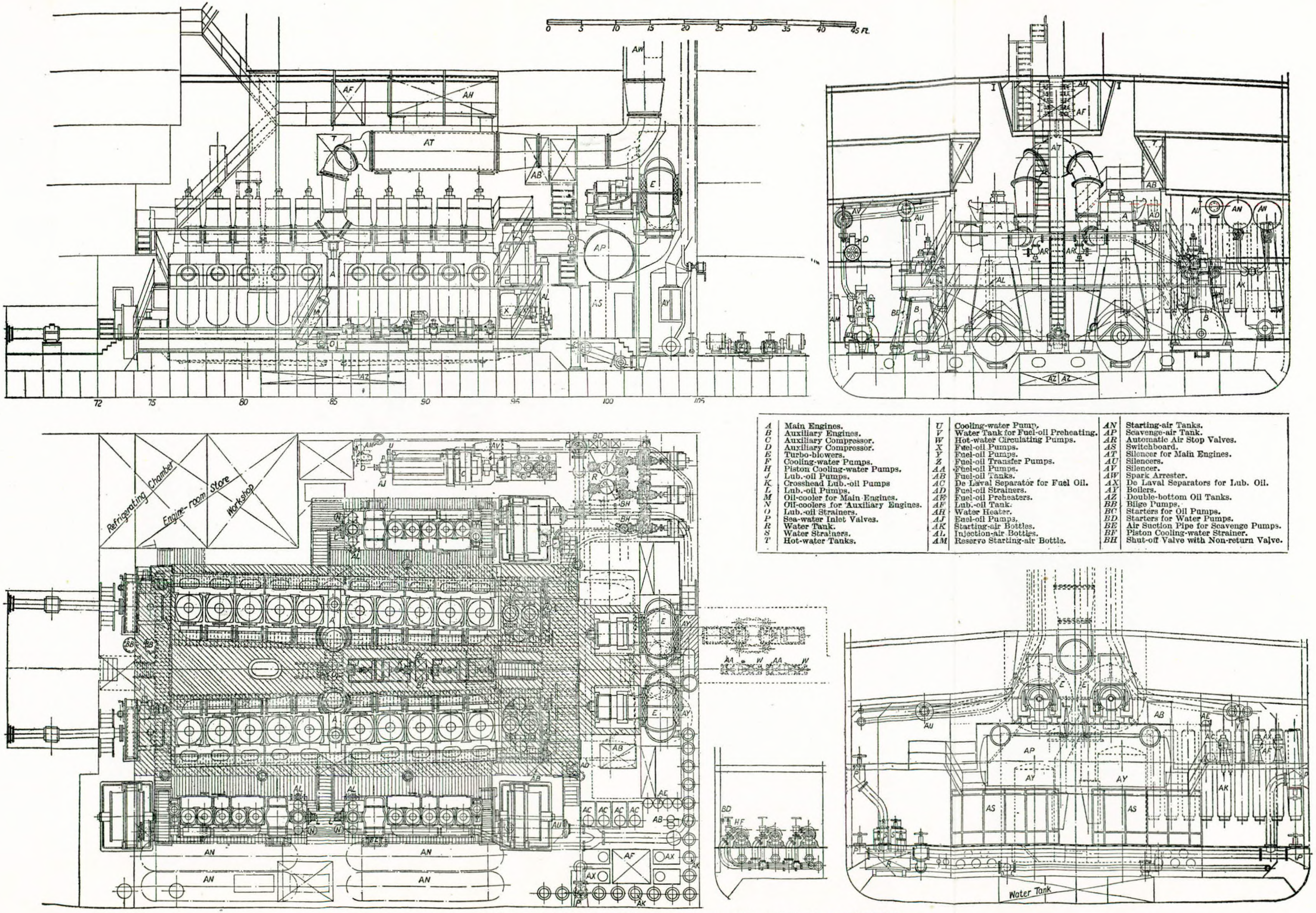


Four Stroke Trunk Guide. Geared Drive.

16 ENGINES EACH 800 B.H.P. AT 500 R.P.M.

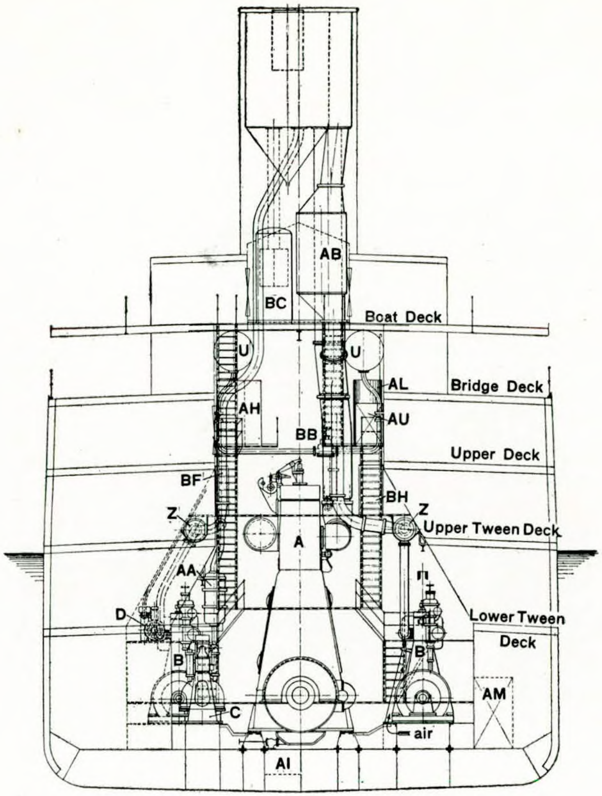
A. – Main Engines.	265·0	Tons
B. – Auxiliary Generator Sets.	63·6	"
C. – Auxiliary Compressors.	3·4	"
D. – Reducing Gear.	112·0	"
Total	444·0	Tons

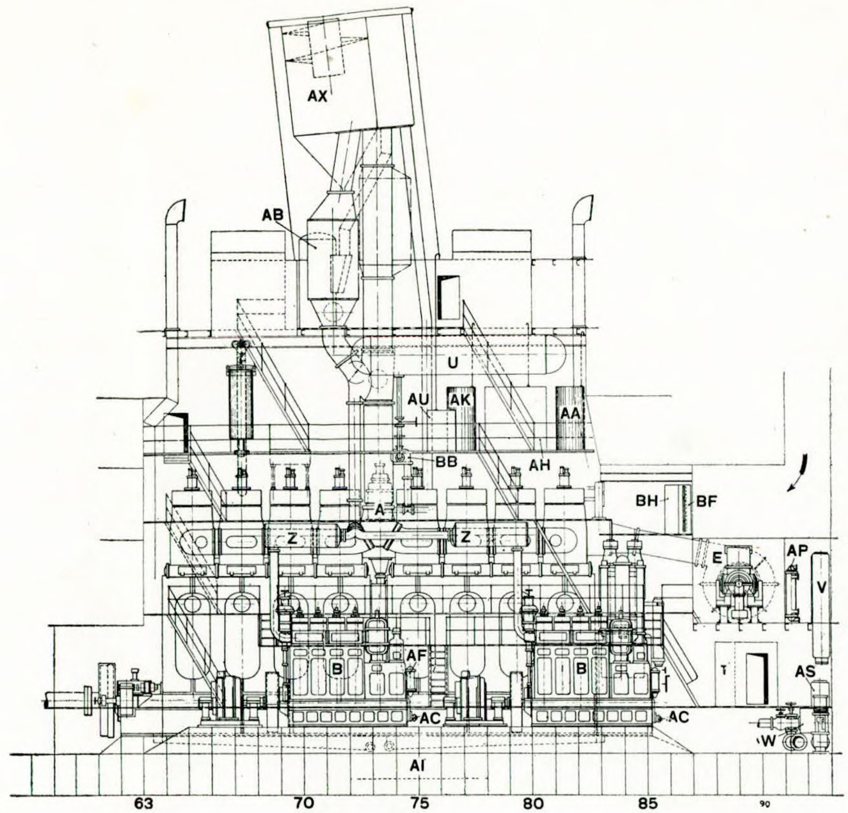
Fig. 8. Comparison of machinery space and weight for direct and indirect drive in a small fast Passenger Vessel requiring 12,000 B.H.P.



A	Main Engines.	*U*	Cooling-water Pump.	*AN*	Starting-air Tanks.
B	Auxiliary Engines.	*V*	Water Tank for Fuel-oil Preheating.	*AP*	Scavenge-air Tank.
C	Auxiliary Compressor.	*W*	Hot-water Circulating Pumps.	*AR*	Automatic Air Stop Valves.
D	Auxiliary Compressor.	*X*	Fuel-oil Pumps.	*AS*	Switchboard.
E	Turbo-blowers.	*Y*	Fuel-oil Pumps.	*AT*	Silencer for Main Engines.
F	Cooling-water Pumps.	*Z*	Fuel-oil Transfer Pumps.	*AU*	Silencers.
H	Piston Cooling-water Pumps.	*AA*	Fuel-oil Pumps.	*AV*	Silencer.
J	Lub.-oil Pumps.	*AB*	Fuel-oil Tanks.	*AW*	Spark Arrester.
K	Crosshead Lub.-oil Pumps	*AC*	De Laval Separator for Fuel Oil.	*AX*	De Laval Separators for Lub. Oil.
L	Lub.-oil Pumps.	*AD*	Fuel-oil Strainers.	*AY*	Boilers.
M	Oil-cooler for Main Engines.	*AE*	Fuel-oil Preheaters.	*AZ*	Double-bottom Oil Tanks.
N	Oil-coolers for Auxiliary Engines.	*AF*	Lub.-oil Tank.	*BB*	Bilge Pumps.
O	Lub.-oil Strainers.	*AH*	Water Heater.	*BC*	Starters for Oil Pumps.
P	Sea-water Inlet Valves.	*AJ*	Fuel-oil Pumps.	*BD*	Starters for Water Pumps.
R	Water Tank.	*AK*	Starting-air Bottles.	*BE*	Air Suction Pipe for Scavenge Pumps.
S	Water Strainers.	*AL*	Injection-air Bottles.	*BF*	Piston Cooling-water Strainer.
T	Hot-water Tanks.	*AM*	Reserve Starting-air Bottle.	*BH*	Shut-off Valve with Non-return Valve.

Fig. 9. Machinery arrangement of twin screw Passenger Liner, "Christiaan Huygens."





A	MAIN ENGINE TYPE 8 ST 62	Q	FUEL OIL CIRCULATING PUMP	AE	LUB OIL COOLER FOR MAIN ENGINE	AU	WARM WATER TANK
B	AUX ENGINES TYPE 4 S S 34	R	FEED PUMPS	AF	LUB OIL COOLER OF AUX ENGINES	AV	PISTON COOLING WATER DRAIN TANK
C	AUX ENGINE 4 RKH 30 WITH COMPRESSOR 4 C...	S	TRANSFORMATOR	AH	LUB OIL SERVICE TANK 7 m³	AW	WATER TANK
D	AUX COMPRESSOR M.C 6	T	SWITCH BOARD	AI	DOUBLE BOTTOM OIL TANK	AX	CENTRIFUGAL SPARK COLLECTOR
E	TURBO BLOWER	U	STARTING AIR TANKS 2 × 11000 Ltr × 30 atm	AK	CYL. OIL TANK	AY	MANOEUVRING GEAR OF MAIN ENGINE
F	COOLING WATER PUMPS 400 m³ × 3 atm EACH	V	STARTING AIR BOTTLES 16 × 800 Ltr × 70 at	AL	FUEL OIL SERVICE TANKS	AZ	BILGE PUMP FITTED ON MAIN ENGINE
H	LUB. OIL PUMPS 85 m³ × 3 atm EACH	W	RESERVE STARTING AIR BOTTLE 245 Ltr	AM	TANK FOR SEPARATED FUEL OIL 7 m³	BA	COCOS-OIL PUMP
I	CROSSHEAD LUB. OIL PUMPS 8 m³ × 8 atm. EACH	X	INJECTION AIR BOTTLES OF ENGINES	AN	FUEL OIL SEPARATORS	BB	AUTOMATIC STARTING AIR STOP VALVE
K	BILGE PUMPS	Y	EXTRA INJECTION AIR BOTTLE 2 × 800 Ltr	AO	LUB. OIL SEPARATOR	BC	BOILER
L	FRESH WATER PUMP	Z	SILENCERS OF 5 S S 34 ENGINES	AP	FUEL OIL PREHEATER	BD	TROUGH FOR CLEARING PURPOSES FOR INSETS OF SEPARATORS
M	BALLAST PUMP	AA	SILENCER FOR 4 RKH 30	AQ	LUB. OIL PREHEATER	BE	RESERVE OIL PUMPS 4 T/h for AUXILIARIES
N	SANITARY PUMP	AB	EXHAUST HEATED BOILER	AR	FUEL OIL STRAINER	BF	MEASURING TANK FOR CYL. OIL
O	FUEL OIL TRANSFER PUMPS	AC	LUB OIL PUMPS OF AUX ENGINES	AS	WATER STRAINERS	BH	OIL TANK FOR AUX ENGINES
P	FUEL OIL SERVICE PUMPS	AD	LUB OIL STRAINER OF MAIN ENGINE	AT	SEA WATER INLET VALVES		

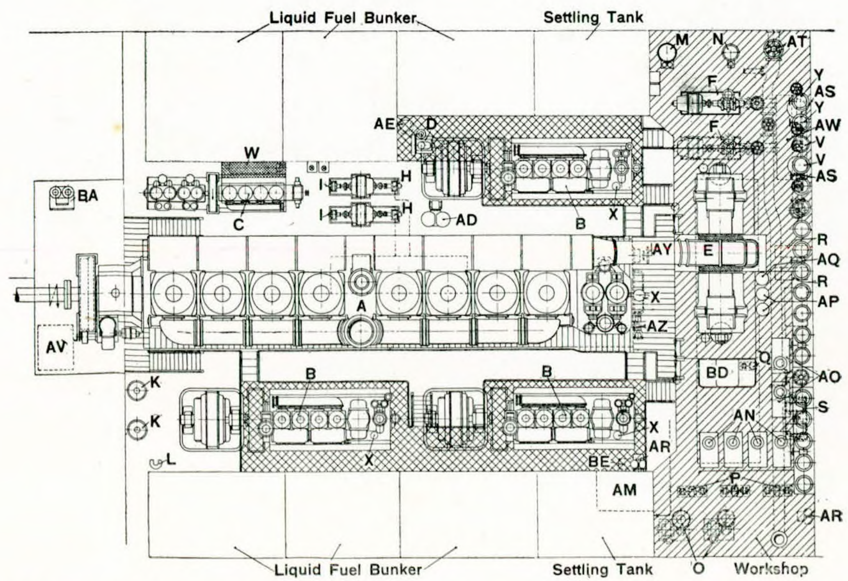


Fig. 10. Machinery Installation of the M.S. "Peolau Roebiah" (Netherland S.S. Co.) 7,000 B.H.P.

engine having little longitudinal beam stiffness, so that bending stresses are transmitted to the ship's structure. The transverse vibration at the after-end is caused by insufficient torsional stiffness in the engine framing, which allows the engine to twist, so that the whole of the variable torque has to be carried at the after-end of the seating, a duty which it is quite unable to meet. Both of these troubles frequently result from the marine engine designer following the A frame and through bolt practice of stationary engines. This type of construction is quite unsuited to a marine engine, unless the bedplate itself is stiff enough to carry all the internal forces without appreciable distortion, or, alternatively, there is a very heavy cross-bracing between the A frames. Neither of these constructions is economic in material, or altogether satisfactory in results. The nearest approach practically possible to the ideal framing for a marine engine is that in which bedplate and columns form a compact and very stiff box girder, which gives the maximum possible stiffness both in bending and torsion. This method of construction was clearly shown in fig. 5 of the paper read by Mr. Le Mesurier before this Institution in 1922. Marine engines in which this type of construction is adopted have been completely free from vibration, as the primary assumption of a rigid engine, required for balancing, is fully justified and, therefore, if a multi-cylinder engine of this type is well balanced, little or no forces that could cause vibration can be transmitted to the hull of the ship from the engines.

Not the least important part of the machinery for large and fast vessels is the auxiliary installation. In the class of vessel now under consideration the power required for the various auxiliary services is frequently 15% to 20% of the main engine power, and in all vessels the reliability of this machinery is as important, in some cases even more vital than that of the main machinery itself. The cost of upkeep of the auxiliary engines is also a considerable item in total running cost as they must of necessity be subdivided into comparatively small units; the total number of parts requiring attention is therefore considerable and the time required to keep these in good running order is comparable to that required on the main engines themselves. It is then essential that the greatest care and thought should be bestowed on the auxiliary engines and on the arrangement, size and number of units in order to facilitate overhaul and upkeep work.

The author dealt at some length with the various types of engine available for auxiliary service in a paper read last year before the North East Coast Institution of Engineers and Shipbuilders.* To reiterate briefly the general merits of various types; for the smaller sets the two-stroke cross-head type engine, fitted with the precombustion chamber type of airless injection, has undoubted advantages due to its simplicity and robust and compact design. For larger units there is little to choose between the four-cycle trunk guide type and the two-stroke cross-head type fitted with air injection. Direct injection has certain advantages as regards engine balance and simplicity, but as has already been mentioned, it has not yet proved in service its suitability for widely varying conditions as regards load and fuel quality and until such proof is available it does not seem advisable to adopt this system unless on services where a fairly consistent quality of fuel can always be relied on.

Generally for the size of auxiliary unit required for the faster classes of ship the four-stroke auxiliary has some advantage as regards first cost and fuel consumption, while the two-stroke engine has the advantage of somewhat greater simplicity and consequently lower upkeep and is also rather more economical in lubricant. Either type is equally reliable provided that they are of the very best design and material and built by engineers with extensive experience of marine Diesel engines.

The choice of size and number of units is of course dependent on the particular requirements in any case and it is quite impossible to generalise but suitable arrangements for some services are shown in the illustration accompanying this paper.

The first consideration in auxiliary layout is that the size and number of the generators should be so chosen that for any required load such units as are running should be as nearly as possible on full load. In port the load should be carried by one less than the total number of units so that overhauling may be carried out during normal working hours without interfering with the power required for cargo handling. In many cases there are auxiliaries of comparatively large power which are not working continuously, such as the auxiliary compressor. If these are electrically driven, it is essential to choose generators larger than would otherwise be necessary. In such cases a direct Diesel drive for these units is usually

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* N.E.C. Inst. E. & S. "Diesel Engine Drive for Generators and other Marine Auxiliary Machinery on Board Ship."

the best arrangement and it is generally found advantageous to drive from the engine of this set a small generator which can be used for lighting at night in port or at other times when the power required is less than the output of one of the main generators. Another example of a unit that might with advantage be direct driven is the refrigerator plant on vessels carrying frozen or chilled products. In such ships the auxiliary load in port and on outward voyages is much lower than when homeward bound. If electrically driven refrigerating machines are adopted, a considerable proportion of the generator plant is necessary only because of these. It is obviously uneconomical both in first and running costs to convey the power by means of electricity where the units are of suitable size for direct drive. Direct drive for machinery of this type has recently been adopted for the first time and there seems to be no reason to fear that difficulties will be experienced. Everyone must look with the greatest interest for the results obtained after a period of running in service, as the success of the system must result in its adoption by many other owners running ships in similar services.

The auxiliary services for the main engine: *i.e.*, cooling and lubrication, require the most careful attention. Of the pumps themselves, little more need be said than that they should be very ample for their duties. The systems for both services should be as simple as possible and for this reason the author favours salt water cooling for both pistons and cylinders. Fresh water cooling for pistons has been adopted in many cases due to fear of contamination of the lubricating oil with salt water, but with reliable cooling systems such as are available on many types of engine, no such leakage can occur. In cases where vessels are running into shallow rivers, fresh water cooling is often suggested because of the amount of sediment liable to be carried by river water into the cooling spaces. Even in such cases there are very strong arguments in favour of salt water cooling. The probability of dirt settling out in the pistons is slight, whereas the coolers often form an excellent dirt separator and as they become choked their efficiency is quickly reduced, resulting in excessive fresh water temperatures which may make a reduction of engine load essential. The coolers of a fresh water system require frequent cleaning and consequently increase running costs, and the weight of fresh water to be carried reduces to some extent the cargo carrying capacity of the ship. There seems to be no compensating advantages to balance these drawbacks.

The lubricating system most frequently adopted consists of a large drain tank in which the bulk of the oil is carried; from this tank the pumps supply oil direct to all bearings. This system has the disadvantage that the drain tank, which must be cleaned occasionally, is in the double bottom and therefore not remarkable for its accessibility. The bearings are entirely dependent on the oil pumps, the supply of oil stopping at once should these fail. A more satisfactory system is to provide a small sump from which the oil is pumped to a gravity tank which supplies all bearings except those requiring a higher pressure than can be obtained by gravity. This system has the advantage of a storage tank which is reasonably accessible for cleaning and if the lubricating oil pump fails it provides a supply of oil for a few minutes during which there is time to start a standby.

Generally it may be said that in the design of the auxiliary installation, first consideration must be given to simplicity, accessibility and reliability. Complications intended to meet conditions that are never likely to arise in service should be avoided, as they reduce the reliability during normal running.

In conclusion, it may be well to review briefly the present position and future possibilities of the large Diesel engine. The two-stroke single-acting type, which as shown in the early part of the paper is particularly suited for the passenger liner, has now reached a stage where about 1,000 horse-power per cylinder can be developed without going to cylinder sizes appreciably larger than those that have been tested over long periods in service. It is possible to build a quadruple screw vessel with twelve cylinder engines which can develop about 50,000 B.H.P. in continuous service, and such an installation could in no way be considered as experimental. Such a power is sufficient for any except the largest vessels on the North Atlantic service. Higher powers with direct drive must be a matter of gradual development. The adoption of cylinder sizes much larger than had previously been tried has on many past occasions greatly damaged the reputation of the Diesel engine as a whole and it is to be hoped that no further wild ventures will be attempted as they are the most serious pitfall in the path of progress. Vessels of the largest and fastest class could be fitted with Diesel engines to-day if indirect drive were adopted, and while there could be little or no risk in such an

A. COMBINED DIESEL ENGINE & AMMONIA COMPRESSOR SETS, 78 TONS REFRIGERATION CAPACITY EACH SET, ABSORBING 127 S.H.P.
B. LIQUID RECEIVERS
C. ELECTRICALLY DRIVEN AMMONIA COMPRESSOR FOR PROVISION ROOMS
D. MAIN CONDENSERS
E. ACCUMULATING BOTTLES
F. OIL SEPARATORS
G. BRINE THAWING TANK
H. CONDENSER (PROVISION MACHINE)
J. STARTING AIR BOTTLES
K. FUEL VESSELS

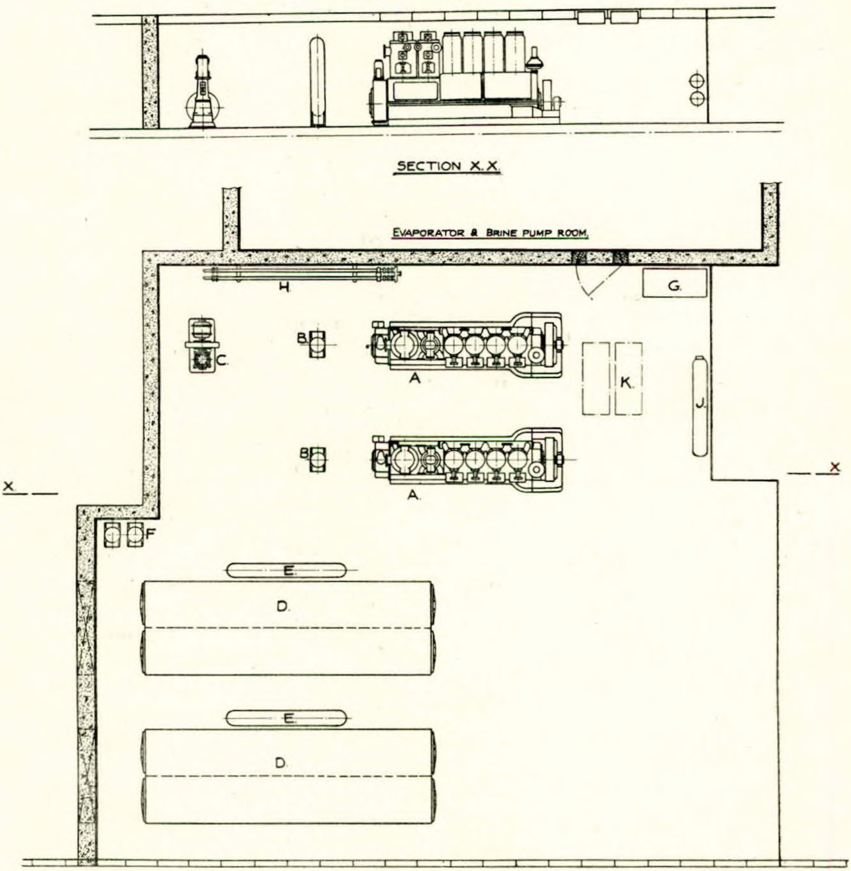


FIG N°11 DIESEL DRIVEN REFRIGERATOR PLANT

FOR

CHILLED & FROZEN MEAT VESSEL

WITH

HOLD CAPACITY 600,000 CU. FT.

SCALE IN FEET

installation, it is improbable that any shipowner would invest in so expensive a plant without experience of a similar installation of comparatively large size. Before there is any general tendency towards the adoption of the Diesel engine for Atlantic greyhounds, it is probable that it will have developed to such an extent as to make direct drive feasible.

For the cargo liner the power required for the speeds called for to-day can be provided by single or twin-screw single-acting two-cycle engines. There is still a tendency towards higher speeds but the development of the Diesel engine is more than keeping abreast of this demand for higher power, and the single screw arrangement is being more widely adopted even for the fastest cargo liners.

While the direct drive seems to be the best arrangement for most ships, there are undoubtedly particular services and classes of vessel where electric or other indirect drive would be preferable were it not for its high first cost. This problem is being met by the development of high speed engines of fairly large power which will no doubt be widely adopted in future in these special cases. The Diesel engine during the last few years has shown itself to be much the most economical means of propulsion on all services where speeds of from 14 to 20 knots are required, and while the turbine still holds the field for the fastest vessels, the Diesel engine is making such rapid progress that before long it will be available for any ship that is likely to be built during the next few decades.

DISCUSSION.

Mr. W. A. Christianson: I should like at the outset to thank the author for his interesting paper and the trouble he has taken in preparing it. It is indicative of the continued and general interest in the Diesel engine, and one more proof that this type of engine has come to stay in marine service.

The author has referred to two-cycle, solid injection, crosshead type engines for auxiliary service, and I am in agreement with him that this is a good proposition for such service.

Referring to the driving of refrigerator plants by independent engines, though this appears an attractive scheme at first sight, and has been adopted in a recently completed motor vessel, I do not think it will be generally adopted. The more general motor driven compressor, enabling all the auxiliary engines to be concentrated in common engine generator sets, seems to me to offer the best all-round arrangement, as well as lowest weight and cost.

The author is perhaps not too kind to the double-acting engine, and, in reference to his statement that this engine is not yet fully developed, he must have overlooked the several double-acting engines now in service. In particular, I can refer him to the Worthington double-acting engine, which is an established and successful one. The 2,500 S.H.P. 4-cylinder 95 r.p.m. engines on the single-screw vessels *Tampa* and *Unicoi* have now been in operation for over two years, and, apart from minor troubles at the beginning (from which no single or double-acting engines have been free) these engines have been an unqualified success. These vessels are in regular service, making trans-oceanic voyages to all parts of the world. Two further similar engines are now in hand for propulsion, and another for the generation of electric power on land.

Whilst I have not figures of running costs of these engines by me, the information available shows that these will not be greater than for single-acting engines of corresponding power.

The author states that the Büchi supercharging system will benefit the two-cycle engines as much as it does the four-cycle engine. I think, however, it must be admitted that the system mainly benefits the four-cycle engine, though not necessarily to place this in a position of superiority over the two-cycle engine.

I agree with the author on the subject of box frame design and engine balance.

Referring to Fig. 6, and particularly the comparison of the two-cycle single and double-acting engines, it will be noted that, although naturally requiring more headroom, the double-acting engine requires less length. The diagram, however, shows the double-acting engine as requiring much greater length for its auxiliaries than the single-acting engine, but there is no reason why this should be. Perhaps the author will explain.

I am pleased to note the author's final remarks about the future of the Diesel engine, and endorse his views.

Mr. A. C. Yeates: This paper constitutes an important and valuable addition to the literature on this subject, especially in showing the importance of seeking the most suitable type of machinery with regard to the space available.

The author mentions that in a passenger vessel the space above the water line is of great value and it is therefore essential that the full length of all decks in this part of the ship should be available for accommodation. This applies equally well to decks below the water line necessary for accommodation other than for passengers. If the machinery occupies a large portion of this latter deck space, then it simply means that this necessary accommodation encroaches on the valuable deck space above the water line and thereby reduces the earning capacity of the ship.

One of the outstanding features of these large motor liners is the size and number of the auxiliary Diesel engines, especially where these have to perform part of the work of the main engines by driving the air compressors and in some cases the scavenging blowers.

Referring to Fig. 6 it will be seen that the auxiliary machinery not only occupies space on the tank tops, but also extends through both G and F decks for the full width of the ship in all cases. Now, owing to the importance of this deck space, surely the obvious solution of the problem would be to instal horizontal auxiliary engines. Taking the first example, Figs. A_1 and A_2 show a suggested arrangement for three horizontal auxiliary Diesel engines, each of 425 K.W. capacity, from this it will be seen that the whole of the plant can be accommodated under " G " deck, thereby leaving the space on that deck and " F " deck available for other purposes and increasing the space for accommodation by approximately 46,000 cubic feet.

Figs. B_1 and B_2 show a similar arrangement for the second example, with three engines driving compressors and four generating sets of 330 K.W. each. The saving in this case amounts to over 70,000 cubic feet.

This economy in space, however, is not the only point in favour of the horizontal engine, which, if the designer takes full advantage of its inherent features, it can be made the most completely accessible engine there is, without introducing any special features, such as divided pistons or liners, etc., and in addition to this, it is from 20 to 25% lighter than a similar vertical engine without any sacrifice of strength or rigidity, largely due to the fact that there is no crank chamber between the cylinders and bed.

The firm with which I am connected have been building large horizontal multi-cylinder engines for many years, and it is the users of these engines who have shown how their accessibility has reduced up-keep and maintenance charges, a most important consideration where marine auxiliary engines are concerned. The reasons for this are three-fold: (1) the fact that all the gear, main bearings, camshaft, valve gear, fuel pumps and valves are visible and within reach from one floor level, and, therefore easily watched and examined during operation; (2) The ease with which pistons and bearings can be removed and examined—for instance a 17in. or 20in. piston can be removed, cleaned and replaced in about one hour by two men and this operation can be performed without having to break a single joint; (3) Low lubricating oil consumption owing to the ease with which the oil draining from the cylinder can be isolated from the main system.

There is, however, another problem which requires more attention than it has received in the past, particularly with regard to large cargo liners. With the usual arrangement of placing all the auxiliary engines low down in the ship, there is always the danger of the main source of supply being interrupted in the event of stranding or collision, with possible flooding of the engine room. This risk of interruption is a serious matter and may be disastrous. With the horizontal engine, however, this serious difficulty can be overcome by installing a large portion of the generating plant on a deck well above the water line, as these engines can be accommodated 'tween decks and therefore without any great loss of valuable space.

This applies equally well to refrigerating plant in large meat and fruit carrying ships, and it has been adopted in the case of some oil engine driven refrigerator plants, the sets being installed on the upper deck and so arranged that in the event of the engine room being flooded they can continue to operate and preserve the cargo, which could not otherwise be done if the main source of supply were low down in the ship.

Mr. G. R. Hutchinson: I think we are all agreed that Mr. Calderwood has given us a really good paper. His power of advocacy is unique; in fact, one might suggest that Messrs. Sulzer Bros should at once arrange a twenty-five years agreement with him! His case for the two-stroke single-acting engine is very well put, but I am not sure that we all agree with him. We must remember that the double-acting two-

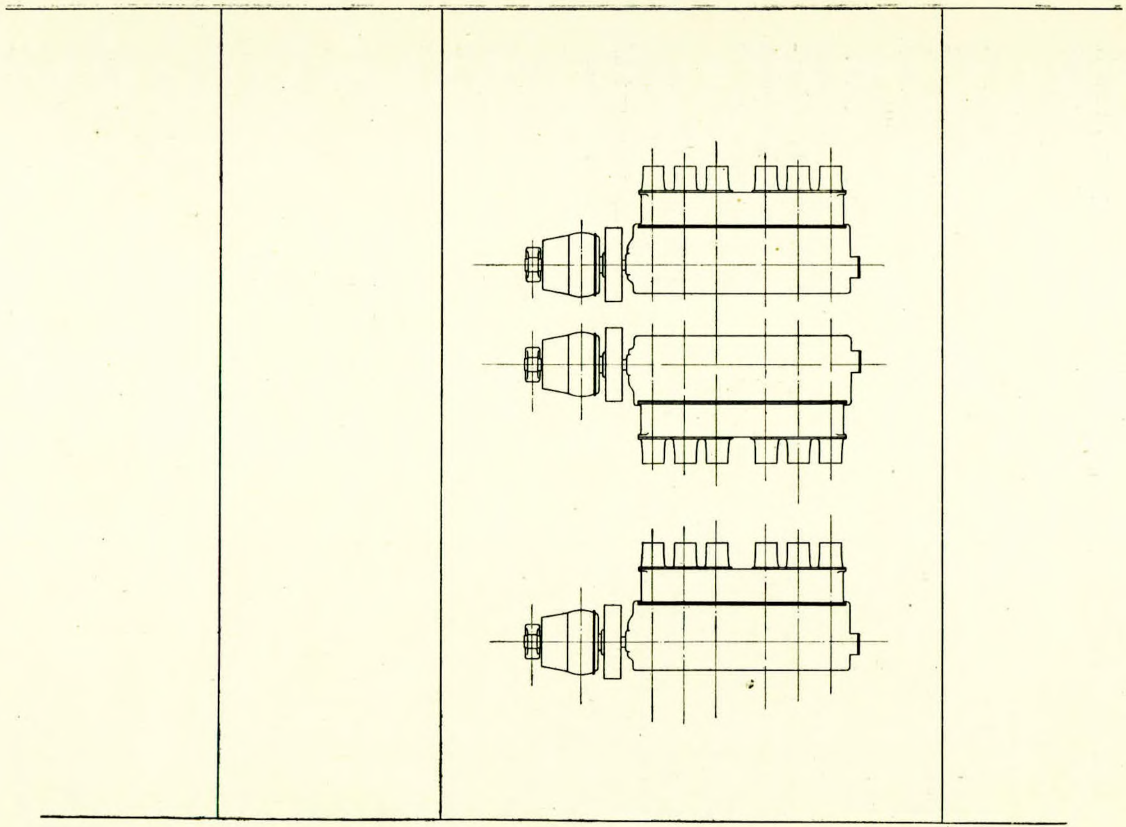


FIG. A1

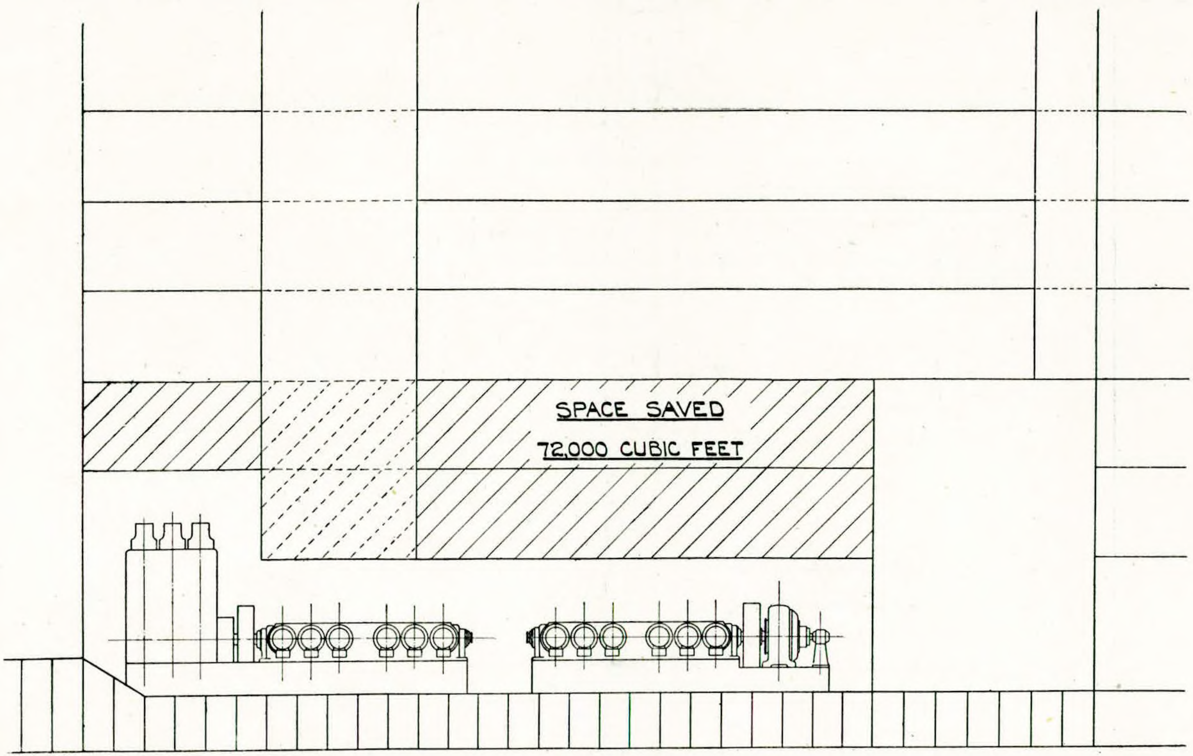


FIG. A_2

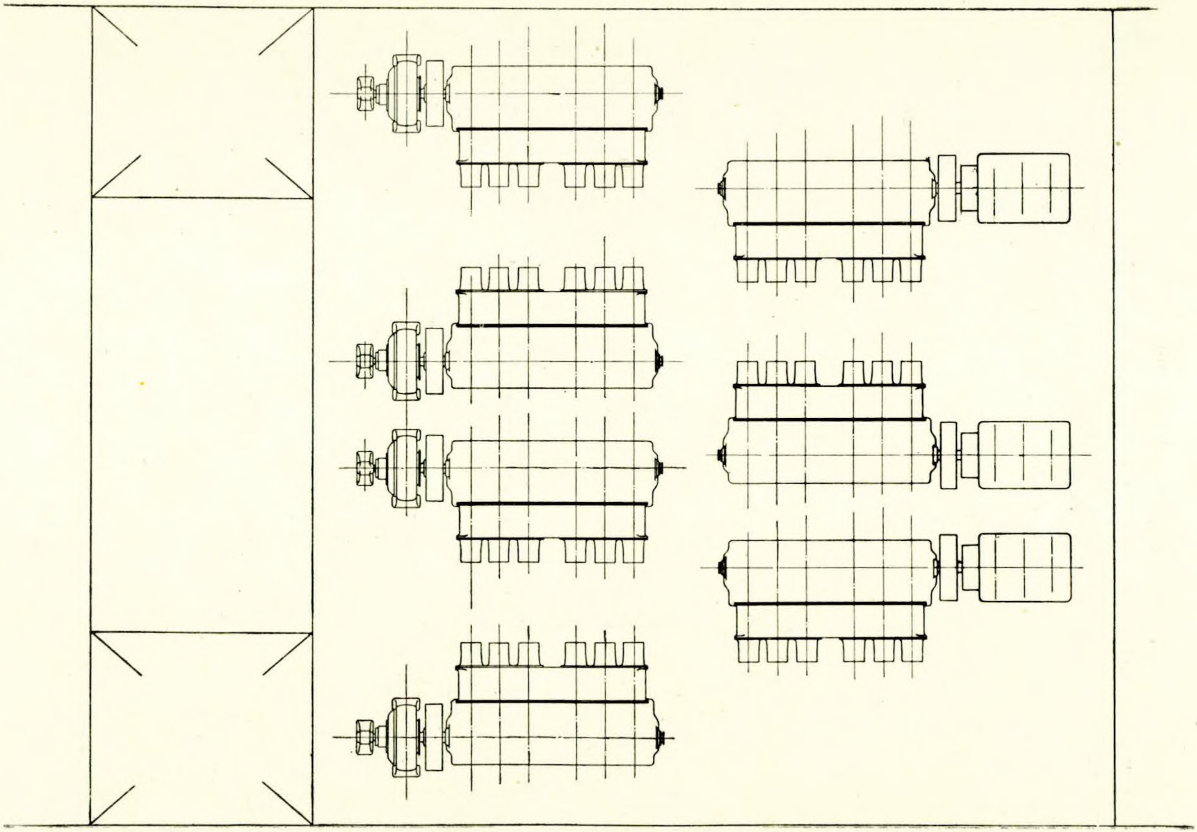


FIG. B_1

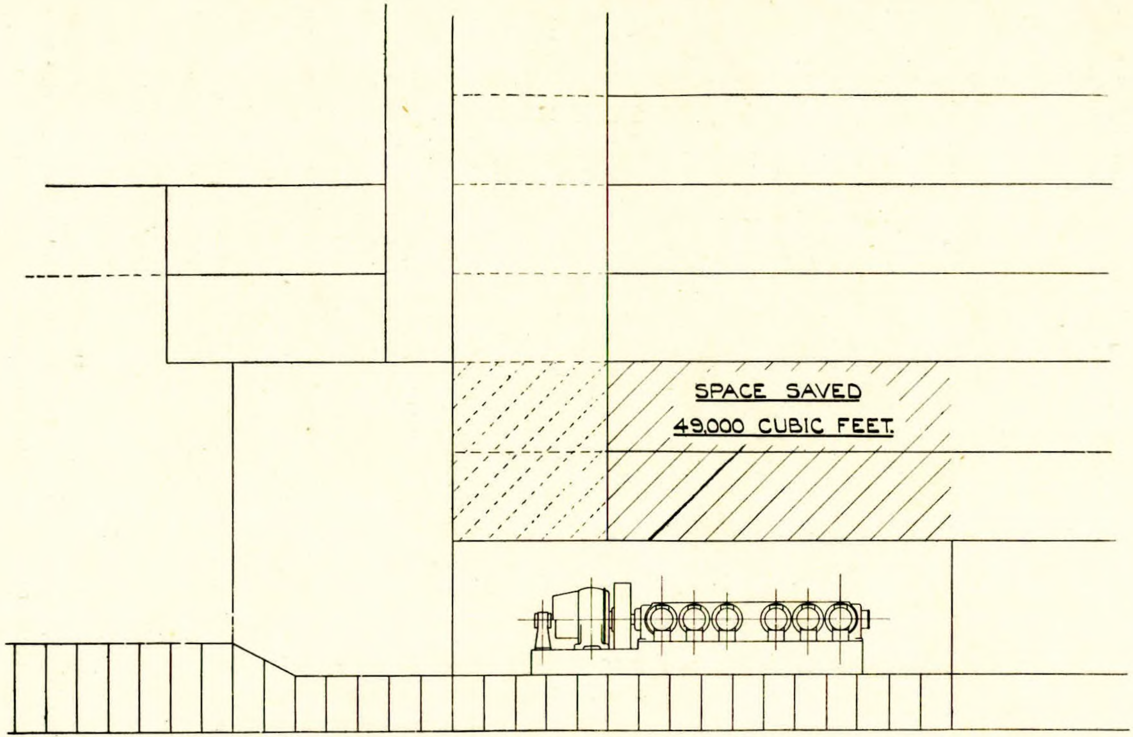


FIG. B_2

stroke engine is now very much in its infancy, and at the present time makers of this type of engine are going slowly. In other words, the rating is on the low side, and much of the disparity between the two types, single and double-acting, will be wiped out when more experience is gained with two-stroke double-acting engines. When double-acting two-stroke cycle engines are built to run at higher mean pressures than those now obtained, the cost will be much lower than that of the equivalent single-acting engine.

The author's figures of fuel coefficients are, I think, very fair. The figures are, generally speaking, about right, but when he refers to double-acting two-stroke cycle machinery, I am not sure that he is right. The first double-acting A.E.G. engine has shown remarkably good results, a specific consumption of ·36 lb. per B.H.P. per hour having been obtained. Whether this high performance will be maintained remains to be seen. On the question of lubricating oil consumption, I think the author is right. There have been some erroneous statements made on the subject and I think that some of the high lubricating oil consumption figures published have been for engines fitted with oil-cooled pistons, an important consideration which is sometimes overlooked when discussing this question. On the subject of piston cooling, I am interested to see that the author recommends salt water cooling. Salt water cooling is all right in theory and sometimes in practice, but when you lead salt water up the interior of the piston rod and circulate it round a fairly hot two-stroke double-acting engine piston, I think you will have trouble due to scale deposits, and corrosion. The author has found in his experience, he tells me, that scale settles out on verticle surfaces, and I should think that the use of fresh or distilled water is a safer plan to adopt in double-acting engines.

Concerning ease of overhaul, the author says that the double-acting engine has advantage over the single-acting type in that the number of cylinders is less. That is a theoretical advantage for there are engines and engines! In some designs you can get a piston out fairly easily, in others the job is difficult and in some it is a painfully protracted and thoroughly demoralising undertaking. I know of an American two-stroke cycle single-acting engine, for example, where the removal of a piston requires a day's hard work.

The author is very pungent in his criticism of the two-stroke cycle opposed-piston engine. I think we shall be having a contribution to the discussion from Mr. Keller written on asbestos! The success of the Doxford opposed-piston engine is well known. Probably Doxford engines carry a higher normal rating than any other two-stroke engine, and I think some of the success of this design is due to the intrinsic excellence of the scavenging principle, and combustion arrangement, as is borne out by the high m.e.p. referred to above, as well as to the elimination of the air compressor.

I subscribe very heartily to the author's remarks about airless injection. I think it is a very difficult problem and certainly one has to go slowly with its adoption on marine engines. I am pleased to see that the makers of the M.A.N. engine have not advocated airless injection for their marine type. On land, where one has a constant supply of the same grade of fuel oil, it is quite satisfactory, but at this stage of development it is generally more prudent to utilise air injection. Time will, however, alter this.

I think the author has been rather unkind in his remarks about the Büchi system. I do not agree with him when he says that what applies to the four-stroke engine applies also to the two-stroke type. One cannot get enough power out of the exhaust gases to dispense with the engine-driven scavenging pump on a two-stroke engine. The Büchi system is certainly enabling the four-stroke cycle engine to prolong the "battle of the cycles" but it remains to be seen whether turbo-charged engines will stand up to continuous sea service over a long period of years. I have seen one Büchi installation running with 138% overload, but one can hardly envisage such conditions being even approached at sea. No doubt the Büchi system will be applied to two-stroke engines, with the assistance of an engine driven or motor driven scavenging pump or blower, and it would be interesting to hear Mr. Büchi's views on this interesting possibility.

We all, no doubt, read the author's remarks on vibration with great respect, because we know that he is an acknowledged authority on the subject. I was very much interested in what he said on engine framing. There is no doubt that the framing of the Sulzer engine is very good, because of its excellent torsional rigidity and its ease of erection in the shop. The author says that the A-frame type of construction is quite unsuited to the marine engine and then qualifies this statement by adding "unless the bedplate itself is stiff enough to carry all the internal forces without appreciable distortion, or alternatively, there is a very heavy cross-bracing between the A-frames. That is the designer's job and should always be done in practice, while usually the framing and cylinder jackets are relieved of tensile stresses by long through bolts. Does the author consider that the through bolts do what they are supposed to do over long periods of service? It is a questionable point, and in Germany there have been exhaustive investigations as to the efficacy of these bolts, with surprising conclusions. I should like to hear what the author has to say on this point, and on the relative advantages of the different types of framing, particularly as his own statements seem to show the "A" frame system, which he condemns, to be all right.

Mr. Calderwood's remarks on auxiliary engines are very interesting. I should "plump" for the two-stroke engine every time because the biggest factor in auxiliary engine maintenance is valve grinding. If one can safely do away with the air compressors and with engine valves one has an ideal marine auxiliary engine. I know Messrs. Sulzers make such an engine which is very successful, and I think we should all like to have the author's figures of fuel and lubricating oil consumption, etc., for such a simple auxiliary engine.

The statements about a simple lubrication system are interesting, but Mr. Calderwood rather goes against himself when he advocates gravity tank system for giving a supply of oil which is adequate for all the bearings of an engine except those requiring higher pressures. These bearings, presumably, are the crosshead pins of a single-acting two-stroke engine.

I should like, in conclusion, to add my meed of praise to those of other speakers. The paper is brief and to the point; the author says what he means and we all respect him very much for it, even if we don't agree with him in every way.

Mr. A. F. Evans (Contribution by Correspondence): This paper is obviously written by a master hand. There is much that one must agree with, and many home truths have been brought to the fore, for instance, the advantage of the box girder construction so as to form one complete girder instead of a number of steeples mounted on a shallow bed plate.

However, instead of praising this paper, I will endeavour to criticise it from aspects that are far more clear to the idle observer than to those in the forefront of the battle.

Why does he assume that deprecating attitude so generally found in connection with airless injection. When properly carried our airless injection will be found to be more flexible and give a greater indicated horse-power than blast air, but it looks as though quite a different branch of engineering will establish this fact.

On the question of gearing, as the majority of oil engines would like to run just twice as fast as the propeller desires, why not put the Burn gear into use by incorporating it in the design of the engine. If arranged in this manner it costs very little, and takes up an inappreciable amount of room, and as it is quite robust and has a mechanical efficiency of 98%, why not try it?

I regret to find that Mr. Calderwood is an advocate of the pre-combustion chamber, that inefficient palliative for incorrect pumping, for this advocacy must be because of the production of engines having a brake mean effective pressure of 40 lbs., and that brings us to the results which were obtained when the pre-ignition chambers were introduced some years ago.

Further, Mr. Calderwood speaks of the possibilities of large engines for passenger liners that will not take up quite the amount of space as is occupied at present.

I am collecting data from entirely different sources than steam or marine Diesel practice. I am able to visualise an engine giving 16,000 h.p. and 125 propeller revolutions that will be 24ft. high, 13ft. wide and 64ft. long, and this engine moreover will be enclosed and balanced and will not weigh more than 100 lbs. per H.P. instead of the usual 300.

Mr. J. L. Chaloner: The remarks I am going to make will be very general, because of the general character of the paper. A comparison of different makes of Diesel machinery is usually unsatisfactory. A compiler of the required material, if he be connected with the manufacture of any particular make, knows the advantages of his own side but is handicapped by not knowing the advantages of the other side.

The following will serve as a typical example:—

In Fig. 8, four lay-outs quoted of what should be taken as representative examples of Diesel machinery. Indeed, the twin-screw 10-cylinder two-stroke engine installation with direct drive is a typical equipment, but example four showing a four-stroke installation comprising 196 power cylinders and 32 compressor cylinders is not a fair alternative. The author comes before an intelligent body of engineers and asks them to accept such a cumbersome lay-out as the only equivalent four-stroke proposal to his 40-cylinder two-stroke equipment. Engineers aim at the simplest job, and in looking through some of my records I find a four-stroke arrangement meeting the author's ideal case in every way. The appended table shows comparative particulars for both four-stroke and two-stroke lay-outs, the four-stroke equipment comprising four 12-cylinder trunk type Diesel engines with direct drive.

	2-Stroke.	4-Stroke.
Output per Engine ..	3,000 S.H.P.	3,000 S.H.P.
Speed	300 r.p.m.	300 r.p.m.
Piston Speed	1,100 ft p.min.	1,045 ft.p.min.
Overall length of Engine	47′6″	43′3″
Maximum Engine Height from Tank Top ..	14′3″	11′3″
Available Head Room ..	1′9″	4′9″
Weight in Tons including identical Auxiliaries ...	551	511

Why did he not choose this example? Surely the persistency of advocating two-stroke irrespective of what is possible points to a somewhat unfortunate prejudice. I am afraid this atmosphere persists right through the paper.

Mr. Hutchinson visualises the character of Mr. Keller's reply. I should like to hear Mr. Büchi's comments on the suggestion of his engine being a " stop-gap."

Whilst for passenger vessels the author sees the only solution in the single-acting two-stroke engine, he concedes with much dignity a certain advantage to the double-acting engine when applied to cargo vessels. The encouragement to shipowners to run their cargo vessels faster is due to increased economy. This in turn is more pronounced in the case of motor vessels. Increased overall economy becomes a function of the reliability. Mr. Calderwood advocating the advantage of the two-stroke for cargo vessels, makes an indirect implication that he is satisfied with the reliability of the double-acting type. Perhaps too much stress is laid on the many advantages alleged to accrue from a slightly lower engine room height. I am afraid I can only consider such an argument of merely temporary importance.

Anyhow, it is questionable whether in the case of the author having at his disposal a double-acting two-stroke engine ready for the market he would say " Don't buy it yet until we have tried it out to the fullest extent." I suggest that the author would back up his recommendation for a two-stroke double-acting type with the whole of Messrs. Sulzer's previous Diesel engine experience in general.

The author stresses the question of experimental work and the lack of experience at sea of the double-acting type. But what period does he actually consider as adequate? Is it three years or three months? Progress to-day is very rapid, and when manufacturers are in a position to put an engine on the market it can be taken generally that the experimental stage has been passed by a safe margin.

I would like to say a few words about first costs. The author writes as follows:—

"In first cost there is to-day little to choose between the various types of engines; price is fixed by competition rather than by actual manufacturing costs, and builders of the heavier and more expensive types of engine cut their costs as far as possible by poor finish and relatively lighter scantlings for bedplate, columns, etc."

I want to know how long has this been going on! Surely shipowners might accept such light scantlings for one engine, but not for a second time. The remark moreover implies that either the marine superintendents do not know their job, or some of the manufacturers are sure to go out of business very quickly. I think the author will be wise to take out this paragraph from his paper.

A brief remark about airless injection may be appropriate. There have been difficulties which to a certain extent have been alleviated by the improvement in the supply of fuel oils. Let us go back, say, fifteen years, when we were faced with the necessity of burning heavy Mexican grade if we looked for low priced fuel. It was my conviction in those days that airless injection was better for dealing with such heavy fuels. I maintain that opinion to-day. On the other hand the grade of fuel has been materially improved, and we are in a position to obtain to-day a very good grade under the name of heavy fuel oils.

The two systems of airless injection are the open nozzle and the spring-loaded type respectively. The spring-loaded type is more sensitive to adjustment and more flexible with regard to range of fuels. The open nozzle type is less sensitive to adjustment and slightly less flexible with regard to range of fuels. In due course a common system embodying all advantages will no doubt be developed.

The two-stroke double-acting is already a simple type of construction. The simplification of the fuel injection system will complete the effort towards the highest form of simplicity and maximum degree of standardisation. It will become possible to reduce the diameter of the cylinder for the double-acting type so that eventually we shall reach a degree of standardisation identical to that which was accomplished with the steam engine.

I wish to add my thanks to the author for the paper, which by its very nature of being provocative has stimulated a good discussion.

Engr.-Lieut.-Comdr. A. J. Elderton, S.R, R.N. (By correspondence): In the author's opinion the four-stroke single-acting engine with direct drive is quite unsuitable for large ships designed for 14 knots or more. I question if the Diesel engine at all, is suitable for vessels of this type. When we have to consider large powers, the objections are more or less the same with reciprocating engines, either of the oil or steam types: viz., the large number of parts which require upkeep; for this reason the turbine displaced the reciprocating steam engine and on this basis alone would appear more suitable than the Diesel engine. To my mind the only justification for the installation of a high powered Diesel engine in any vessel is the advantage which is to be obtained by its low fuel consumption and consequently greater steaming radius. Modern high pressure steam turbo installations are approaching the Diesel engine in this respect.

The author states that in a passenger vessel the space above the engine room is of the greatest value, and if possible should be available for accommodation; personally, I think the machinery space should be kept clear to the topmost deck for reason of health and comfort of the engine room personnel.

I do not agree with the author that builders of the heavier and more expensive types of engines cut their costs as far as possible by poor finish and relatively lighter scantlings for bedplate, columns, etc.; any neglect in proper design would soon react on the engine sales.

I question if the fuel consumption of a two-stroke engine is as good as that of the four-stroke; scavenging is not so good with the two-stroke, more trouble is often experienced with smoky exhaust. It must be remembered too that trouble with the exhaust valves of a four-stroke engine have their counterpart in the two-stroke engine, in that trouble is sometimes experienced with the exhaust ports.

In the matter of exhaust gas turbo supercharging, I think the two-stroke engine must be at a disadvantage when compared with the four-stroke because the four-stroke engine can be scavenged when the piston is at the top of its stroke with a small volume to be swept through, while the scavenging of the two-stroke engine takes place when the piston is at its bottom centre through ports which have the tendency to congest or short circuit each other; for this reason the four-stroke engine offers advantage of turbo supercharging and high power per cylinder which the two-stroke engine does not seem to be able to share.

In the matter of auxiliary machinery, I should like to ask the author if the two-stroke crosshead type engine, fitted with pre-combustion chamber type of airless injection is a cold starting engine, because if not it does not seem to offer the best practice. To-day there are several makes of small cold starting engines which are started only by the heat of compression. It might be recalled that Brons of Holland took out British patents in 1904 for a cold starting oil engine in which he originated the pre-combustion chamber system of cold starting ignition.

In the matter of piston and jacket cooling, salt water has the disadvantage that with temporary overheating of the cooling water which at times is liable to happen, scale may be formed which would hinder the heat transfer from the surfaces to be cooled. It must be remembered too, though rarely admitted, that steam is often fed to the jackets to warm up the cylinders so as to provide an easy start.

The author's remarks with regard to solid injection appear to me to be somewhat biased. Whilst the principle of solid injection may not be as flexible with reference to the quality of the fuel to be burned, as the blast injection system, it must be remembered that poor fuel causes additional cylinder upkeep costs. I think the saving in first cost and maintenance with the solid injection system is of more importance than the doubtful economy obtained with a system of injection whose only claim is its flexibility. The cooling effect of blast air must result in heat losses and add to the difficulty of starting.

The remarks made by the author that the four-stroke double-acting engine is a stopgap in the programme of those builders who are experimenting with the two-stroke engine equally applies to the maker whose engines are used to illustrate the paper, viz., that the two-stroke single-acting engine is a stop-gap whilst they are developing the double-acting two-stroke, and as this type of engine is still in the experimental stage, I do not consider that a definite case has been made out for any particular type.

Mr. H. V. Stead, M.Sc. (By correspondence): Mr. Calderwood's first remarks serve to bring home to us how recent are the majority of marine oil engine developments. We are all apt to forget this and as a consequence expect too much and overstate the claims of the Diesel engine for ship propulsion. The initiative of the author's firm, however, and of the Union Steamship Co. in building the *Aorangi* is worthy of a place in history.

The cold water Mr. Calderwood throws on the double-acting two-stroke engine is, however, not justified. Developments with the double-acting engine are taking place rapidly at the present time; on the score of height for example, the M.A.N. have recently made considerable improvements. Moreover, if the tendency is towards indirect drive for large vessels (as so many people think), the question of height will become of much less importance so that this factor will disappear as a consideration in the relative merits of the single and double-acting type.

The author's statement that there are very few vessels for which a suitable single-acting two-stroke could not be designed is not startling as no doubt a similar claim would be made by every other engine builder. The trouble comes in reconciling what the builder considers suitable with what the owner wants.

When we can completely satisfy the latter, the millennium will have come.

When the author comes to the case or otherwise of overhauling he seems apt to forget that as soon as an engine has been on the market for a year or two, special provisions can be made such as platforms and small trollies, etc., to facilitate handling. If attention is paid to this point there is little to choose between the single and double-acting two-stroke types.

The author has hit the nail on the head in his explanation of the existence of that monstrosity the double-acting four-stroke engine. Even now this type is nearing its end and those owners now installing such motors will in a year or two find themselves with a lot of junk on their hands.

In considering balancing and vibration questions one fact is so often lost sight of. Although an engine may be balanced in itself there are free forces between individual cylinders. As the author points out, a weak bedplate and framing may allow these forces to emerge from the engine and produce vibrations in the ship.

Later on, the author refers to the question of fresh water for piston cooling, and is rather of the opinion that it is unnecessary to use fresh water for that purpose. Fear of contamination of the lubricating oil by sea water is not, however, the reason why fresh water has been chosen in so many instances; the more important reason is the greater wear on the telescope pipes if sea water is used.

Near the end of his paper Mr. Calderwood is rather despondent as to the possibility of the high-powered Diesel liner, and seems to pin his faith to the direct drive.

The problem of manœuvring very large direct drive engines should not be lost sight of, however, as troubles and accidents nearly always occur whilst manœuvring.

Mr. W. Hamilton Martin (By correspondence): It is good to see Mr. Calderwood giving so much attention in his paper to balancing.

We all realise how important this question is in turbine and Diesel-engined vessels and deserving of the closest care of engine designers. Professor W. E. Dalby, F.R.S., of the City and Guilds Engineering College, London, recently demonstrated with a beautiful little working model at the Institution of Mechanical Engineers in the Thomas Hawksley Memorial Lecture he delivered entitled, "The possible effects of Vibration of Machinery on a Ship's Hull," how highly important it was to eliminate all pulsating forces from machinery in vessels. When in his model the engine speed synchronised with the hull's vibration period, the deflection caused by a given small unbalanced weight was *increased fiftyfold*.

Dr. B. P. Haigh, M.B.E., D.Sc., of the Royal Naval College, Greenwich, in a recent article in "The Engineer" on "The Static Balancing of Rotors," showed how a small unbalanced force is liable to be greatly magnified where an unbalanced couple is not.

For any ordinary ship the wave length is very great (commonly over 200 ft. in a large liner) from which it will be realised that a very great unbalanced couple is required to produce the same vibration as a small unbalanced force.

Again, Sir Westcott Abell, K.B.E., M.Eng. (Professor of Naval Architecture of Armstrong College, Newcastle-on-Tyne) likewise pointed out lately at a lecture he gave before the Liverpool Engineering Society that it was chiefly the unbalanced forces causing the two node vertical vibration in a hull against which the closest guard should be taken. When the estimation of vibration frequency of a vessel as yet cannot be sufficiently closely made and this again largely depends on the vessel's loaded or unloaded condition, the only satisfactory method at present to avoid possible excessive vibration is to tackle its cause; that is, to balance accurately all parts of engines and propellers which are apt to produce such unbalanced forces.

The present interest shown by such eminent authorities in this matter will emphasise its importance which would seem to deserve close consideration from all those who own or construct vessels.

I would add my appreciation to Mr. Calderwood for the very interesting lecture he has given us.

Mr. K. O. Keller (By correspondence): Having perused Mr. Calderwood's paper read before the Institute meeting on the 8th January last, I firstly observed that whilst the paper deals with a general reference to all internal combustion engines, it specially refers throughout to the Sulzer type, and incidentally mentions the Doxford opposed piston type. I propose, therefore, to refer to the various statements relating thereto, as I feel that the author has been somewhat misguided on various points.

He refers to large ships, 14 knots and upwards, and gives his opinion that four-stroke single-acting for direct drive is quite unsuitable, and that the choice lies between the two-cycle single-acting and the double-acting two or four-cycle engines, thus eliminating the Doxford opposed piston type from all consideration.

I wonder if the author has ever compared the engines and lay-out of the *Aorangi* and that of the *Bermuda?* It is rather easy to be misled on the question of height, as at the first sight the Doxford appears higher, but this is actually compensated for by the fact that in dismantling for inspection the upper piston is housed within the frame of the upper crosshead guide, and the actual height of the lift is only 12 to 14 inches. To demonstrate, I give a sketch (Fig. C) of the *Aorangi*—Sulzer, and *Bermuda*—Doxford, showing the position of lifting gear and piston, which in *Bermuda* allows space for a travelling electric crane under the deck, and I think this should go far to bring the opposed piston type into consideration for high speed and space, both vessels having the same height of engine room.

The author next refers to costs, and again I feel he has been misled by lack of information as in the reference he automatically includes the Doxford opposed piston type, which is certainly not of the light fraternity, and I am sure if he examined the workmanship and design, he would not accuse it as lacking in finish or being of light scantlings in bedplate, etc.

Perhaps the author is comparing costs of British production with Messrs. Sulzer's costs in Winterthur, of engines built there and shipped to British yards. If so, then due consideration must be given to the difference in national conditions in Switzerland and in Great Britain, where Switzerland has no doubt very great advantages in costs, and has the "open door" for free import into Great Britain for their production of this class of motor.

Dealing further with "space" in direct drive, he shows 32,000 B.H.P. in Figure 7 (which I take the liberty of reproducing) with 48 cylinders, and a total space longitudinally 53·5 metres = 175 feet, and I attach a comparison print (Fig. D) of same power and similar heights which produces the power by the Doxford opposed piston engine in 24 cylinders, and the total space including the auxiliaries for equal power in 134 ft. longitudinally.

Running costs. We supplement the author's figure by records of lubricating oil in our hands, in some cases taken from Press reports.

Doxford opposed piston engine, four twin screws vary from 3·4 to 4·7 gallons per 1,000 B.H.P. for engines only, and two twin screw Sulzer 7·5 to 9 gallons per 1,000 B.H.P. for engines only.

Mr. P. Jackson, B.Sc. (By correspondence): There was such a demand on the part of your members to express their appre-

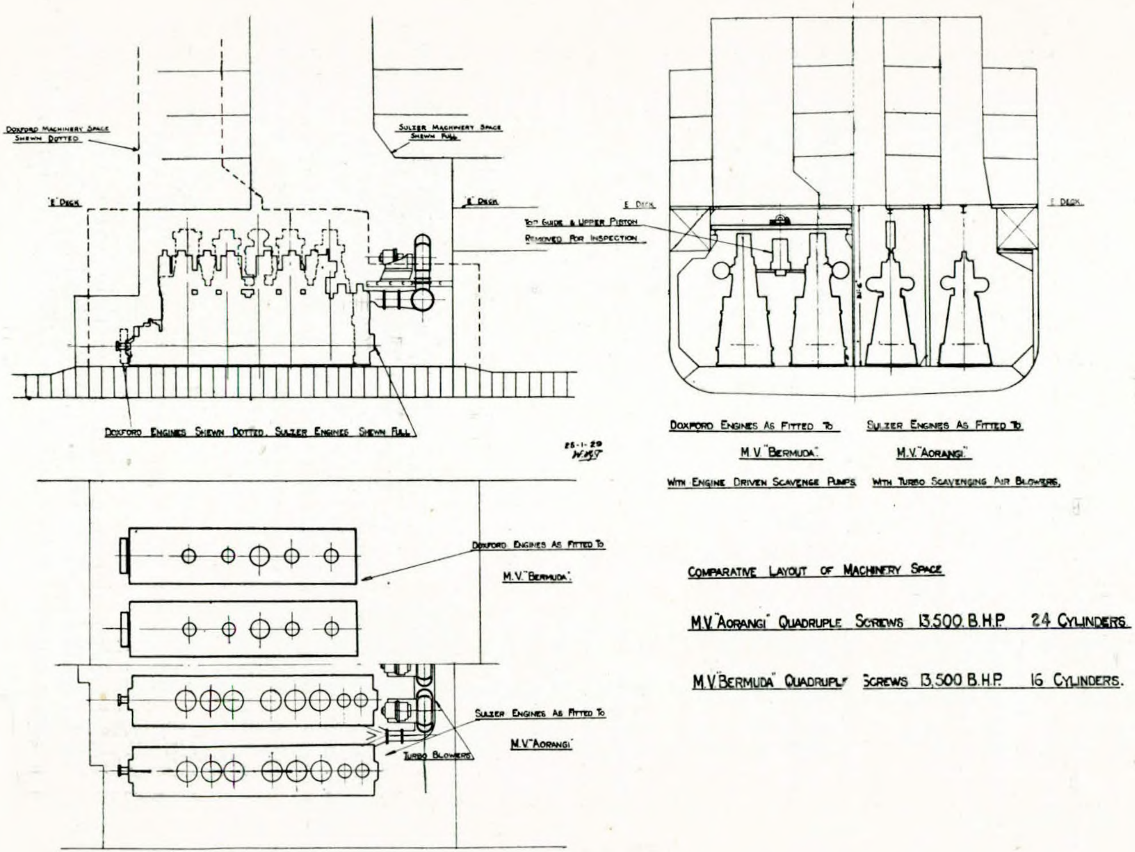
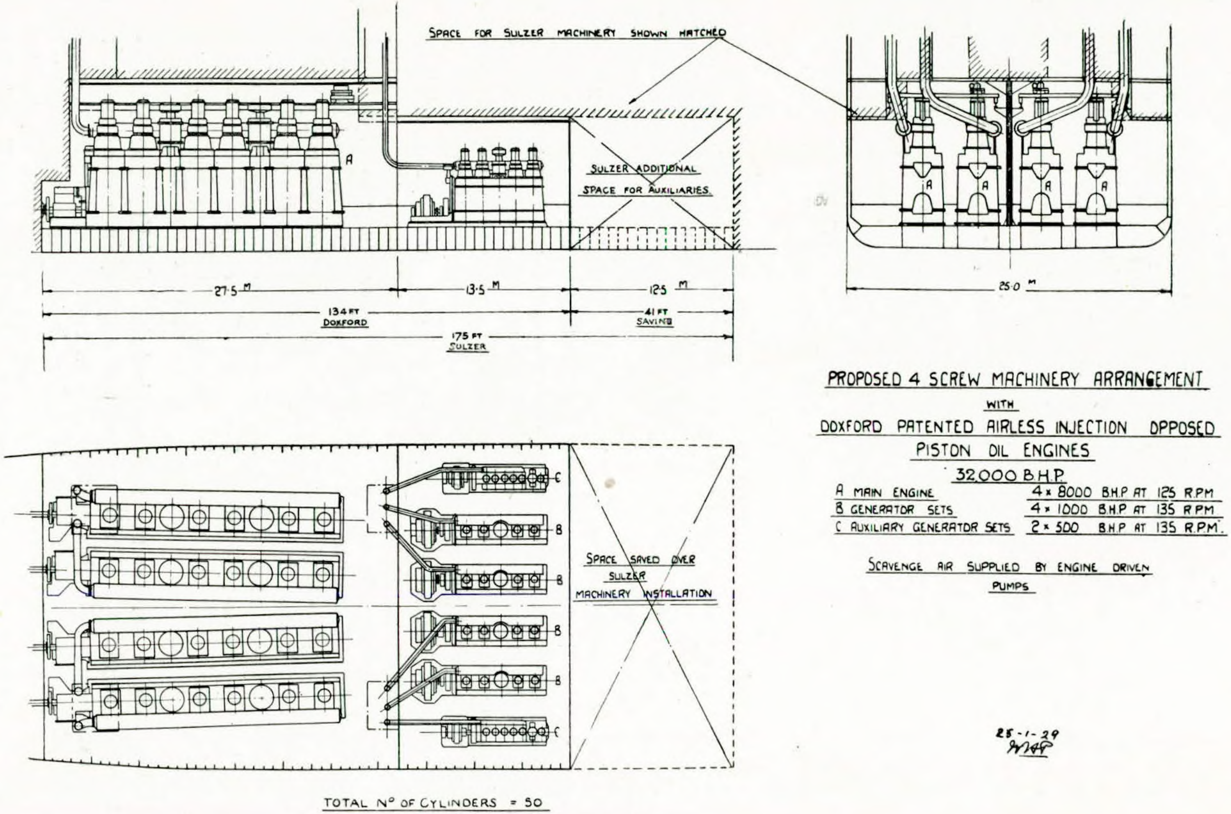

Doxford Machinery Space Shewn Dotted
Sulzer Machinery Space Shewn Full
'E' Deck
'E' Deck
E Deck
E Deck
Top Guide & Upper Piston Removed for Inspection
Doxford Engines Shewn Dotted. Sulzer Engines Shewn Full
25-1-29
Doxford Engines As Fitted To M.V. "Bermuda".
Sulzer Engines As Fitted To M.V. "Aorangi".
Turbo Blowers
Doxford Engines As Fitted To
M.V. "Bermuda".
Sulzer Engines As Fitted To
M.V. "Aorangi".
With Engine Driven Scavenge Pumps
With Turbo Scavenging Air Blowers.
Comparative Layout of Machinery Space
M.V. "Aorangi" Quadruple Screws 13,500 B.H.P. 24 Cylinders.
M.V. "Bermuda" Quadruple Screws 13,500 B.H.P. 16 Cylinders.

FIG. C.



SPACE FOR SULZER MACHINERY SHOWN HATCHED
A
SULZER ADDITIONAL SPACE FOR AUXILIARIES
27·5 M
13·5 M
12·5 M
134 FT DOXFORD
41 FT SAVING
175 FT SULZER
25·0 M
C
B
B
B
B
C
SPACE SAVED OVER SULZER MACHINERY INSTALLATION
PROPOSED 4 SCREW MACHINERY ARRANGEMENT
WITH
DOXFORD PATENTED AIRLESS INJECTION OPPOSED PISTON OIL ENGINES
32,000 B.H.P.
A MAIN ENGINE 4 × 8000 B.H.P. AT 125 R.P.M.
B GENERATOR SETS 4 × 1000 B.H.P. AT 135 R.P.M.
C AUXILIARY GENERATOR SETS 2 × 500 B.H.P. AT 135 R.P.M.
SCAVENGE AIR SUPPLIED BY ENGINE DRIVEN PUMPS
25-1-29
TOTAL N° OF CYLINDERS = 50

Fig. D.

ciation of Mr. Calderwood's paper, and also to state where their views were in opposition, that as a visitor I did not find an opportunity of making a few remarks on one of the sections of the paper in which I think the author has unduly stressed the advantages of his own product, viz., on the question of troublesome vibration.

Vibration is of two kinds:—

1. Transmitted vibration which is caused by unbalanced forces in a ship's machinery producing deflection in elastic supports, and according to its magnitude the energy of these deflections dissipates itself throughout the ship as vibration.

2. Synchronous or critical vibration which may be caused even by a small force or pulsation having a periodicity agreeing with the natural frequency of vibration of any part of the ship.

With regard to the first type, if we have a perfectly balanced engine of infinite rigidity, then there can be no transmitted vibration. Few engines are perfectly balanced and it is a case of "Hobson's choice." Mr. Calderwood's favourite engine is not, however, among the best.

The best balanced engine is undoubtedly the latest Doxford opposed piston engine in four cylinders, as fitted in the successful passenger vessel, *Bermuda,* the primary forces are balanced in the individual lines and in four cylinders, the secondary forces and couples are also in balance. The only out of balance is the scavenge pump when of the reciprocating type.

Similarly, both six and eight-cylinder four-cycle engines have balance of primary and secondary forces and couples. With the two-cycle engine in six cylinders there is always an out of balance couple due to the secondary forces and in the four and eight-cylinder engines due to both primary and secondary forces. In a large engine the magnitude of these couples is large and will cause vibration to be transmitted in the flexible structure of a ship. These couples are inherent to the crankshaft arrangement, and can only be balanced at great cost.

The above arguments assume infinite rigidity for all the types of engines. While an engine may be in almost perfect balance as a whole this may be due to two equal couples opposing each other. Such a state exists in varying degree in all engines. It is least in the Doxford opposed piston engine in four cylinders where two secondary couples from each pair of lines are neutralised at the centre. In the six and eight-cylinder four-cycle engines both primary and secondary couples from each half of the engine, and in the six-cylinder two-cycle engine the primary couples from each half are neutralised at the centre. In general the primary forces per line have half the frequency but some four to five times the magnitude of the secondary forces. Forces of a higher order are so small as to cause no trouble from transmitted vibration. Therefore the relative couples which the framing of the above engines have to absorb without perceptible deflection are in magnitude approximately as shown in the following table assuming equal engine powers and speeds.

	Engine type.	Relative couple.	Cause.
1.	Doxford opposed piston 4-cylinder.	1	Secondary couples.
2.	Six-cylinder four-cycle engine	3·3	Primary ,,
		·75	Secondary ,,
3.	Eight-cylinder four-cycle	1·68	Primary ,,
	engine.	1·35	Secondary ,,
4.	Six-cylinder two-cycle engine	2·2	Primary ,,

Given a substantial top and bottom beam, some distance apart, running the full length of the engine, almost any type of framing will be rigid under these couples, but the construction may be relatively weak in the better placed types. The old A frame engines do not exist for marine work, but I consider the normal column, cross-tie construction with the cylinders braced together at the top to satisfy the demands of these couples equally with the enclosed crankcase construction, and the former possesses advantages of weight and accessibility.

With regard to synchronous vibration of the structure, as Mr. Calderwood says every effort should be made to calculate natural periods of vibration and to keep engine forces and impulses clear of them. In my own opinion much supposed synchronous vibration would disappear, if the vibration transmitted by the seatings, the platform connections, the air suction and exhaust connections, and impulses, of the main and auxiliary engines, were less. The effect produced by a transmitted vibration varies directly as the square of its amplitude and directly as the frequency.

I have never heard of a case where internal deflection of the engine structure (apart from deflection of an A frame) was caused by the unequal torque. The crankshaft transmits this unequal torque and how much stronger is the weakest framing.

If, however, the engine seating be weak or unconnected by stiffeners to the ship's structure, then, whatever the engine construction there could be rocking and transmission of vibration by the unequal engine torque.

I trust you will forgive my dealing with this one aspect of the paper at such length. I should like to have waged war on Mr. Calderwood's remarks on the doubtful benefit of the Büchi system of exhaust gas supercharging, for four-cycle engines, on his hopes of equal benefit on two-cycle engines, and on his choice of layouts for comparison in Fig. 8, but I fear your space will not permit.

I join with other speakers in my praise of the paper; it can be used as a source of reference on its subject provided one realises that the author has advocated only his own type of engine.

The CHAIRMAN: As I foreshadowed in my introduction, we have had a most interesting and instructive evening, and I should like you to express your appreciation by according a hearty vote of thanks to Mr. Calderwood for his paper.

Votes of thanks to the author, also to the Chairman, on the motion of Mr. W. McLaren, were carried unanimously.

The Author's reply: While reading my paper I expressed the hope that a good discussion would result; that hope has, I think, been more than justified, and I must thank those who have taken the trouble to read and criticise my paper.

Mr. Christianson criticises the direct driven refrigerator plant on the score that it is lying idle for a considerable part of its life, but surely the same disadvantage arises whatever form of drive be adopted for this plant, as it must be able to operate at its maximum load when the electrical load for other auxiliary purposes is also a maximum. If the refrigerator compressor is electrically driven, then the generator plant in the ship must be increased in size by the full amount of the power required for this unit. The amount of machinery lying idle on outward voyages is, therefore, greater than when direct drive is adopted for the refrigerator.

The same objection can be raised to the suggestion of fitting a dynamo driven from the same engine as the refrigerator compressor, as the other generating plant would still have to be ample to deal with the maximum load, and the dynamo driven by the refrigerator engine would never be required.

With reference to Mr. Christianson's remarks on the Worthington double-acting engine, I think he rather confirms my own objections to the type in general, for he states that it will not cost more than any other type. Surely before it can meet competition in face of the disadvantages of greater headroom and poorer accessibility, it must be developed to a stage where it costs much less than the single-acting type.

With reference to the auxiliary machinery space in Fig. 6, the double-acting two-cycle engine requires a larger space for auxiliaries, as the compressors have been shown separately driven in order to reduce the main engine room to a minimum and thus allow the maximum possible space on the higher decks, this giving the most advantageous arrangement for that type of engine. The single-acting engine arrangement on the other hand was taken from an actual installation and this type would show to even better advantage as regards space available above deck E, if the compressors were separately driven. The total length below Deck E would then be slightly greater than for the double-acting engine, but this space is of relatively minor importance in the ships under consideration.

Mr. Christianson refers to the Büchi system, and while speaking about that I may answer Mr. Hutchinson's remarks on the same subject. The trend of the remarks in both cases was that the Büchi system or other similar system of supercharging offers greater advantages for a four-stroke than a two-stroke engine. I quite agree that with a two-stroke engine you would have to have scavenging pumps, but you have to have them now, so that you would be no worse off in that respect, and you would still be able to increase your power in the same proportion as you could in a four-cycle engine, of course always assuming that the claims put forward by Mr. Büchi are justified. These claims are that this increased power is obtained without any increase in heat stresses, and that is where I disagree either with Mr. Büchi's or any other system of supercharging as it is being applied at present. One cannot by altering the method of supercharging alter the thermodynamics of the system, and experience of supercharging has been available for many years. Certainly the supercharger has been driven by an independent unit, so that some efficiency has been lost, but as far as the supercharging itself is concerned it is an undoubted fact that those manufacturers with a number of years' experience of the system in both two and four-stroke engines are of the opinion that it does increase the heat stresses. After all, maximum temperature in itself is not a measure of heat stresses. The heat flow through the cylinder wall depends on the temperature and pressure in the cylinder, and whilst the maximum temperature with Büchi supercharging may not be higher than without supercharging, it is maintained for a longer time and the heat flow through the cylinder walls must be increased. I think if you analyse the results published in Dr. Stodola's paper you will find that the heat stress in the Büchi supercharged engine is much more than in the ordinary four-stroke engine at normal rating. So long as this is the case, supercharging can only be adopted if one is willing to take the risk of greater heat stress. Supercharging must also increase the mechanical stresses and must result in increased upkeep cost.

Mr. Yeates' remarks deal chiefly with the horizontal engine, and this is undoubtedly an extremely interesting departure in marine work and one which will be watched with interest by all marine engineers. I cannot, however, understand Mr. Yeates' claim that horizontal engines for an installation such as that shown in Fig. 6 could be arranged in the same floor space as the vertical engines. If horizontal engines of the same power and revolution speed as the vertical engines shown in Fig. 6 are taken for comparison, the floor space occupied is about 50% more than that shown in Mr. Yeates' illustration; this makes it necessary to arrange the horizontal type on two decks, and there is then no saving in the height of the auxiliary machinery space. The arrangement of horizontal auxiliaries at two deck levels, while it has no very serious disadvantages, is not, I think, one which will find great favour with superintendent engineers. The most serious disadvantage, however, of the horizontal type of engine is that in most twin-screw installations with auxiliaries in the main engine room it would be difficult, if not impossible, to find floor space for that type of auxiliary. The claim that horizontal engines are lighter and cheaper than vertical engines is one on which I cannot express an opinion, as I have no experience in the manufacture of the former type. It seems, however, rather difficult to find any logical reason for believing that there should be any great difference between the two types.

I quite agree that it is an advantage to have some power arranged on an upper deck, but this can be done with vertical engines of suitable design, as is shown in the illustration (Fig. 11) of a refrigerator plant driven direct by a vertical Diesel engine and arranged in the normal 'tween deck space. I would point out that many passenger ships are already fitted with a source of power arranged on an upper deck and the engines used have been generally, if not universally, of the vertical type.

Mr. Hutchinson points out that the double-acting two-stroke engine is as yet in its infancy and that it will in time be greatly improved and its cost reduced. This is an opinion with which we must agree. The scope for reduction of cost is not, however, very great and even when based on the same rating as regards m.i.p. and piston speed, it is questionable whether the cost will be sufficiently below that of the single-acting type to justify the general adoption of double-acting machinery. This, however, is a question on which one must keep an open mind but for the present and for some considerable time ahead I think there is no doubt that the single-acting type has very marked advantages.

The remarkably low test bed consumption of the A.E.G. engine seems to be due rather to the use of solid injection than to the double-acting principle, and as seems to be the case with other solid injection engines it is probable that average service consumption will be appreciably higher than the test bed figures.

I quite agree with Mr. Hutchinson that for a double-acting engine some difficulty with corrosion and scaling in the steel piston rod might be experienced if salt water cooling were adopted. This, however, is a question of experiment in practice with various materials and arrangements. It would probably be safer in the preliminary stages of development to adopt fresh water cooling of the pistons of double-acting engines, but the cooling gear would have to be so arranged as to eliminate the possibility of oil finding its way into the fresh water system.

With reference to Mr. Hutchinson's remarks regarding the Doxford engine, I would refer him to my reply to Mr. Keller.

I am afraid that to answer fully Mr. Hutchinson's question regarding the relative advantages of different types of framing, would involve the writing of another paper, as so many types have been tried. I can, however, deal briefly with the principle alternative to the type of frame that I suggested as ideal. The A frame construction with through bolts and other similar types of construction seem for a marine engine to be utterly illogical. If the through bolts are fitted, it can only be because the framing is insufficiently strong to carry the stresses arising from the cylinder pressures, and if it has not the strength for this purpose it cannot be stiff enough to carry without serious deflection the stresses caused by pairs of opposite couples, due to the inertia forces of moving parts. This lack of stiffness in the framing can only be compensated for by a bedplate of such heavy scantlings that it would make the weight and cost of the engine prohibitive; alternatively heavy and rigid cross bracing between the columns would be essential, and one would then have the equivalent of the ideal frame that I suggested, but carried out in an expensive and, therefore, inefficient manner. I think that it will be found that serious vibration of a low frequency (corresponding to the main engine revolution speed) only occurs with engines having framing with the characteristics described above.

With reference to the fuel consumption of the airless injection two-stroke auxiliary engine, this varies widely with the type of injection system that is adopted. The type of engine to which Mr. Hutchinson refers is fitted with the precombustion chamber system of injection, and while this system has rather a higher consumption on the test bed than is obtained with direct injection, it has the great advantage of flexibility as regards quality of fuel and ability to run at widely varying loads without carbonisation of the fuel sprayer. The actual consumption varies with the size of engine from about 0·43 lbs. per B.H.P. hour for large engines up to 0·5 lbs. per B.H.P. hour for the smallest sizes. Mr. Hutchinson refers to the high pressure crosshead lubrication on a two-cycle single-acting engine, but I would point out that it is possible to run with low pressures, although the life of the bearing might be reduced by doing so. In case of emergency, however, the low pressure oil from the gravity tank will be sufficient to keep the crosshead bearing running satisfactorily until a lubricating oil pump can again be started.

Mr. Evans seems to be under the impression that I am an opponent of the direct injection system, but I think that if he reads my remarks carefully he will appreciate that I am rather an advocate of the eventual adoption of that system. It has in fact already reached a stage in development where it may safely be adopted on land, but the difficulties have not yet been entirely overcome, and I think that for marine work it should only be adopted after it has been further developed so that there is no danger of trouble arising from its use under any circumstances.

Mr. Evans' remarks about the Burn gear are interesting and if it can be applied at a reasonable cost it would be well worth trying.

With reference to the pre-combustion chamber, Mr. Evans may be interested to learn that this system is frequently adopted on engines with mean effective pressures up to the same as those adopted with air injection, *i.e.*, 75-80 lbs per sq. in. The pre-combustion chamber has the great advantage of ability to burn a much wider range of fuel than is possible with direct injection. I quite agree, however, that when direct injection has been developed to a stage which makes it as flexible as the pre-combustion chamber system the latter will be superseded.

It is a pity that Mr. Evans has not told us more about the the engine mentioned in the last paragraph, as it sounds very interesting. I would, however, point out that it would be quite possible to build a Diesel engine to meet his dimensions and weight if special methods of construction and materials were adopted.

I quite agree with Mr. Chaloner that it is extremely difficult to draw up a true and complete comparison of types as so many possible arrangements are available, but he is rather unfair in taking Fig. 8 to be a comparison between the two and four-cycle types as it was clearly described in the paper as a comparison between various arrangements of indirect drive. Example 4 was taken as showing the lightest possible installation with the types of engine whose design I had available. Mr. Chaloner next compares example 1 of Fig. 8 with a four-cycle engine which I presume is a submarine engine, as no four-stroke engine of a commercial design could be fitted in a space such as is given in his table. The two-stroke single-acting engine which I show in Fig. 8 is designed on ordinary commercial lines and built of materials used for commercial engines. A four-stroke engine designed on similar lines to fit into the same head room has an overall length of over 60 feet and weighs about 750 tons. On the other hand, a two-stroke submarine type engine would be much smaller and lighter than the four-stroke submarine type shown in Mr. Chaloner's table.

In replying to Mr. Christianson I have alreaady answered Mr. Chaloner's comments on the double-acting two-stroke type, and Mr. Hutchinson in his remarks also answered many of these arguments put forward by the advocates of the double-acting type.

Mr. Chaloner disagrees with my remarks as regards first cost. I can only suggest that he should visit a ship fitted with the type of two-stroke engine that he advocates and then one fitted with any type of engine which should normally be much more expensive. If he does this I think he will alter his opinion to agree with mine. While speaking on this question, it is interesting to note that during the past year the B.H.P. of four-cycle engines on order has decreased and that of two-cycle engines has shown a very large increase.

Mr. Chaloner seems in general to agree with my remarks as to the need for further development in direct injection before it is generally adopted for marine work.

Commander Elderton questions the advisability of using Diesel engines of any type in fast vessels, principally because he considers that upkeep costs in reciprocating machinery is more than for turbine machinery. I quite agree that if engines alone are considered this may be the case, but has he forgotten that the turbine must have boilers and condensers which are responsible for a large proportion of the total upkeep costs. Actual figures that I have had for the relative repair costs of different types of machinery running in the same fleet show that there is little to choose between turbine and reciprocating steam engines; though the balance is perhaps rather in favour of the former. The Diesel engine is, however, some 20% to 30% less expensive than either type of machinery. The attempts to improve the efficiency of the turbine by means of higher pressures and temperatures can only result in an increase in upkeep cost, and the best efficiency that can be hoped for will still give a fuel consumption some 50% higher than that regularly obtained to-day in the Diesel engine, and it must not be forgotten that improvements in the latter are by no means impossible.

I quite agree with Commander Elderton that it would be ideal for the engine room staff if the whole space above the engines could be left clear, but I don't know where he will find a shipowner who will give up this paying space. Engineers must design machinery to meet the requirements of their clients, and the most that they can hope in a passenger vessel is to have a small casing carried through to the upper deck. After all, the shipowner can hardly be blamed for wanting to use the most valuable space in his vessel, and one wonders where some fast turbine driven boats would carry their passengers if the whole of the space above the machinery, which to be logical must include the boilers, were left open up to the top deck.

If Mr. Elderton doubts that in the more expensive types of engines, costs are cut in the way I suggested, I would refer him to my reply to Mr. Chaloner, and also to the relative number of four and two-stroke engines on order at various dates since 1925 as shown in the following table:—

	B.H.P. on order at various dates.			
	June, 1925.	July, 1926.	July. 1927.	July, 1928.
Two-stroke	173,000	355,000	574,000	640,000
Four-stroke	520,000	402,000	584,000	570,000

As will be seen, the four-stroke type has apparently reached a maximum and appears to be losing ground, while the two-stroke has gained steadily and is now well ahead of the rival system.

It is suggested that scavenging of a two-stroke is poor, resulting in high consumption and smoky exhaust. This has certainly not been my experience. In general service results that I have available show no difference between two and four-stroke types, and I have never come across a case of either type of engine with smoky exhaust except when something has been essentially wrong with the valve settings, a trouble equally liable to occur with either type. Actually a two-stroke engine with a properly designed scavenging system is better scavenged than is a four-stroke, for in the latter the clearance space must be left full of exhaust gases. This excellent scavenge is proved by the high mean indicated pressures than can be carried in two-stroke engines with correctly designed scavenge systems.

To turn to turbo-supercharging, if the scavenging of a two-stroke engine without supercharging can be perfect, there is no reason why it should not be equally perfect with supercharging and the same advantage will then be gained in a two-stroke as in a four-stroke engine. However, as already explained, I am not in favour of any form of supercharging unless it is used only for carrying an overload for short periods.

The pre-combustion chamber injection system cannot strictly be considered as a cold starting system as, although a cold start is possible, it is always advisable to use a tinder plug to ensure an easy start. This is due to the intense cooling of the small water-cooled pre-combustion chamber. The advantage of the system more than counterbalances the slight disadvantage of using tinder plugs when starting. If the area of the holes in the division plate between cylinder and pre-combustion chamber were much greater, as I believe they are in the Brons engine, engines of this type would start readily from cold, but the system would then have little or no advantage over direct injection.

Commander Elderton refers to the scale formed with salt water cooling if overheating occurs, but such scale is much less likely to cause damage than is a deposit due to the oil that always finds its way into a fresh water system. Commander Elderton's experience of boilers will no doubt confirm this, as trouble is rarely caused by scale deposited from salt water, but a very little oil may cause a collapse of the furnace crowns. Reference is made to steam heating of the jackets, but I can assure Commander Elderton that at any rate with Sulzer engines such heating is quite unnecessary.

I would refer Commander Elderton to my reply to other speakers on the question of direct injection.

Commander Elderton considers the two-stroke single-acting engine to be like the four-stroke double-acting—a stop gap—but a gap must have two sides and as most builders of successful two-stroke engines have relied solely on that type since they entered the field of marine work it cannot be considered in the same light as an engine which has been thrown quickly on the market by four-stroke engine builders in order to meet the demand for higher powers until they have had time to gain for themselves experience of the two-cycle type.

Commander Elderton appears to agree with me that the two-stroke double-acting engine is still in the experimental stage. One cannot therefore make a definite case for the single-acting type that will hold for all time, but neither can one make out such a case for anything else in the field of engineering, for if one could, there would be no possibility of progress. My paper does not deal with engines that may be developed in five or ten years' time, but with machinery that is available to-day, and among such machinery I do consider that the two-cycle single-acting engine is undoubtedly the best type for marine work. No engine builder can, however, consider his present product as final, and the double-acting engine must be the subject of further research in case it should eventually be possible to develop it to a state where it shows a real advantage over the single-acting type.

I quite agree with Mr. Stead that if indirect drive were generally adopted the disadvantage as regards headroom of the double-acting type need no longer be considered, but I am afraid that until there is an enormous reduction in the cost of the indirect drive there is little chance of its being generally adopted. Even with indirect drive, one of the most serious disadvantages of present-day designs of double-acting engines, *i.e.*, inaccessibility, would not only remain but would probably be accentuated.

With reference to the owners' requirements as regards space, my claim was that the two-stroke single-acting engine more nearly fulfilled these than any other type.

I cannot agree with Mr. Stead that present designs of double-acting two-stroke engines can be as easily overhauled as can single-acting engines, but there is no doubt that with further development of the former, it will closely approach the latter in this respect; such improvement is, however, a matter of time.

I am glad to see Mr. Stead agrees so forcibly with my opinions of the double-acting four-stroke type.

I quite agree with Mr. Stead that with some designs of piston cooling gear, salt water is liable to cause serious wear of the tubes, but I can assure him that this difficulty is easily overcome by suitable design.

Mr. Stead seems to think that I am pessimistic about high powered liners, but I certainly did not wish to convey that impression. I do, however, feel that too rapid an advance should not be attempted, as with increasing size new problems are more likely to be solved by steady progress than by spectacular experiments.

Mr. Hamilton Martin's remarks call for little reply as they are supplementary to my paper rather than critical. I am glad, however, to note that he stresses the comparatively small effect of unbalanced couples as compared to the serious results due to unbalanced forces. He also refers to the experiments of Professor Dalby. I would point out that some rather misleading conclusions may be drawn from such experiments as the models were not true free free vibrating systems, and were not therefore truly comparable to a ship's hull. As a result of this difference, the conclusion was drawn that an unbalanced force at a node would not cause vibration, whereas in actual ships or other free free systems, unbalanced forces at the natural node do cause serious vibration.

It is rather a pity that Mr. Keller did not read my paper more carefully before criticising it. There is an old saying about making the cap fit, but when Mr. Keller tries to fit on several caps that are not there at all it makes me suspect that he has very good reason for expecting the criticism which he answers in his remarks.

Mr. Keller first accuses me of eliminating the Doxford type from all consideration, whereas on page 11 (galley proof page 3, paragraph 4) I state definitely that it is classed with the two-stroke single-acting type, *i.e.*, the type for which I have throughout the paper shown preference.

Mr. Keller next speaks about headroom, but surely in classing his engine with the single-acting two-stroke, I automatically agree that the headroom occupied by either type is about the same. His diagrams show that both types in almost every dimension require the same space. In the *Aorangi—Bermuda* comparison, length and headroom are very similar for the two types of engine, the Doxford being slightly longer over the cylinders only because it has direct driven scavenge pumps. The same remark applies to the 32,000 B.H.P. proposal; in that case if the Sulzer engine were fitted with direct driven scavenge pumps, to make the proposal truly comparable, the main and auxiliary engine rooms would be identical for either type of engine.

On the question of costs again, Mr. Keller attacks a statement that I did not make or imply. I explained on page 11 (galley proof page 3, paragraph 4) that the Doxford engine though essentially expensive, had been able to meet competition due to the saving in cost obtained by the use of the only comparatively successful solid injection system yet put into service on a marine engine. Mr. Keller admits that his engine should be included with the expensive types and expects me to accuse it of workmanship of inferior quality; he could hardly have expected such criticism unless in his own mind he thought that there was some reason for it.

I cannot understand Mr. Keller's reference to the country of manufacture. I was in my paper only referring to the relative costs of various types built under similar conditions. I feel sure that he will agree that comparing engines of all types built in this country, the two-stroke single-acting engine is much cheaper than any other type if quality of workmanship be the same.

I think everyone admires the remarkable success of the Doxford engine, which is the outcome of perserverance with a design which no one else has been able to make run satisfactorily. But like many of the fancy designs of steam engine that were at one time built, it must eventually be forced out of the market by simpler and more practical types.

Mr. Keller's figures for oil consumption are interesting, but it would not be difficult to find figures that showed the exact reverse, *i.e.*, Sulzer engines with about four gallons for 1,000 B.H.P. and Doxford with about eight gallons per 1,000 B.H.P. The figure of five gallons per 1,000 B.H.P. per day which I mentioned is a fair average under good conditions, and with suitable lubricant.

Mr. Jackson speaks of two kinds of vibration, but surely this is an error. Any alternating force will produce vibration and the amplitude will depend on the ratio between the frequency of the force and the natural frequency of the system to which it is applied, and on the amplitude of the force. I think under his first heading Mr. Jackson is classifying forces of sufficient amplitude to cause appreciable vibration even when far out of synchronism with the natural frequency. No engine that had such unbalanced forces could remain in the market for long.

Mr. Jackson refers to the latest Doxford type as the "best balanced engine," but I can assure him that no Sulzer engine with unbalanced forces as high as those caused by the scavenge pump in the Doxford engine would be fitted into a passenger liner. Throughout his remarks, he seems to have forgotten that the working cylinders are not the whole engine and that scavenge pumps and compressor must also be taken into account. Six and eight-cylinder four-cycle engines have, as he says, perfect balance of primary and secondary forces, and couples, if no compressor is fitted, but if a single compressor is fitted there are considerable unbalanced forces of both first and second order; if two compressors are fitted unbalanced first order couples and second order forces result. In a two-cycle engine unbalanced couples from the working cylinders can be compensated by opposite couples in the compressor and scavenge pump or if separately driven scavenge pumps are provided, two compressors can be arranged to give the necessary couples. In this way the two-cycle engine can be almost perfectly balanced. The four-cycle engine can only attain better balance if it is fitted with direct injection or if sufficient compressor cylinders are fitted to balance perfectly among themselves. Similarly, the Doxford engine can only attain better balancing then the two-cycle single-piston engine if its scavenge pump be independently driven, an arrangement which is not always suitable; or alternatively, if several scavenge pumps are arranged on the engine to balance each other.

I think, however, that the most frequent cause of vibration arising from the main engines is pairs of opposite couples causing deflection of the framing. I have never heard of such vibration occurring in ships having engines with deep girder construction of the framing and bedplate, but have heard of many cases where the engine has consisted of the all too common bedplate with a cylinder beam mounted on columns without longitudinal cross-bracing. The stiffness of such a frame does not weight for weight approach that of the deep girder construction, for it has only the stiffness of two separate beams each about 4ft. deep, while the enclosed crankcase is a single beam which in large engines may be about 16ft. deep. For the same weight, the stiffness of the latter is obviously about eight times greater than that of the former.

With reference to twisting vibration of the framing, I have seen diagrams taken on an engine of the two-beam construction which showed a transverse vibration of about $\frac{1}{8}$in. at the after-end of the engine, while the forward end was steady,I have never heard of any trace of such vibration on an engine with really stiff framing. This twisting vibration must not be confused with the rocking of the whole engine—that may be caused by badly designed seating.

I am very gratified by the lively discussion that has resulted from my paper, and I am very pleased to note that while every one of the speakers has disagreed with some of my contentions they have at the same time agreed with other arguments, and on the whole, I think they have confirmed the arguments that I have put forward—that at any rate for the present, the two-stroke single-acting type of engine is the most suitable for marine work.

Finally, I wish to thank those who heard my paper for the very kind way in which it was received, and in particular I wish to express my appreciation to those who spoke at the meeting or have since sent in written contributions to the discussion.

Notes.

[To the Editor of the "Journal of Commerce."]

POWDERED FUEL. EQUAL DISTRIBUTION OF FUEL.—Sir,—I have been very much interested in the many articles appearing in your paper with regard to powdered fuel, and especially one giving the views of Engineer Captain W. Onyon, R.N. (Ret.), M.V.O., which appeared in your issue of January, 10th, 1929.

I agree with Captain Onyon as to the possibilities of powdered fuel in our Merchant Navy. I cannot concur with his remarks with regard to carrying powdered fuel in bulk in the bunkers of a ship; if the latter are made air-tight, and the powdered fuel is dried on shore before injection into the bunkers, no more air, which is the source of moisture, will find its way to the bunkers. Coal when dry is fluid. It is quite true that this material tends to pack under the vibratory conditions present on board ship, but if the dust is re-aerated or "fluffed," to use the technical term, with funnel gas so that the interstices between the particles are filled with gas, the dust again becomes fluid and will flow through the pipes. As he remarks, there is no danger of spontaneous combustion provided certain safeguards are observed, and the fuel is no more dangerous than oil, which has been used for many years.

I would further like to point out that the unit pulveriser does not deliver pulverised dry fuel, and that this is the type referred to by Captain Onyon; also the unit pulveriser is limited to a flexibility of $3\frac{1}{2}$ to 1, due to the amount of air required to lift and separate coal at the full output of the machine. There is a further difficulty with regard to the distribution of coal direct from the unit pulveriser, and this has not been solved so far on any sea-going vessel. I am happy to be able to state that a distributor has now appeared which is capable of distributing fuel equally between the various furnaces on board ship, and this may be seen working at the experimental station of Messrs. "B and L" Powdered Fuel Limited at Stratford. Even this invention, however, does not overcome the objections with regard to flexibility, which, in my opinion, should not be less than 6 to 1. In addition, there is no reserve of ground fuel ready to maintain continual combustion in the boiler should the pulveriser fail through electrical or mechanical defects.

It is interesting to note that the eminent American inventor, Mr. Peabody, after a large experience of fitting the unit pulveriser directly connected to marine boilers, now advocates the fitting of a ready use bin and meter feeder between the pulveriser and the furnaces.—Yours, etc.,

"B & L" Powdered Fuel Ltd.

James C. Brand,

Eng.-Capt. R.A.N. (Ret), Managing Director.

York Mansion, Petty France, S.W.1.

Jan. 12th, 1929.

The following letter indicates the view which will doubtless coincide with that of the majority of our members. It seemed to be peculiar that the evaporator was seldom used in many steamers, and by quoting this it was expected that some members would express opinions from their own experience:—

In the Transactions of the Institute, January, 1929, I read with much interest the article "High pressure boiler feed," by Engr.-Capt. W. Onyon, R.N. On page 970 the statement is made: "I regret to say without the slightest hesitation that in many ships these evaporators have been seldom used in the past."

Graduates and Students reading the above statement may form a very poor estimate of the abilities of their predecessors, as the statement is in direct contradiction to all my seafaring experience. In *all ships* in which I have sailed the evaporator was faithfully used, and after (say) the third day at sea the evaporator was in operation almost as frequently as the sanitary pump.

I have sailed with all classes of marine boilers, tight, or leaky, and have only seen "salt feed" used in a case of grave emergency, when the evaporating plant running for 24 hours per day was unable to cope with the leakage.

In all my sea-service the daily use of the evaporator was ruled by the condition of the boilers, and the following typical cases may be of interest:—

Ship No. 1. Boilers eight years old. Evaporator on six hours per day.

Ship No. 2. Boilers sixteen years old. Very leaky. Evaporator on from 18 to 24 hours per day.

Ship No. 3. Boilers one year old. Evaporator on four hours per day.

Ship No. 4. Boilers eighteen years old. Evaporator on four hours per day.

All these vessels were on fairly long voyages, and in Ship No. 3 on two occasions we were seventy-five days between our loading and discharging ports, averaging ten knots per hour.

In the very exceptional cases quoted by Capt. Onyon, in my opinion the engineer officers could not have been properly exercised, and certainly could not have been members of the Institute of Marine Engineers.

Yours faithfully,

P. H. Hunter, Eng.-Lieut.-Comdr., R.N.R. (Member).

Then and Now.—It is stated in "The Engineer and Iron Trades Advertiser" of November 13th, that the great bell of Rouen Cathedral whose history goes back eight centuries is now rung by electricity. A strange mixture of old and new. The hand apparatus which the new electrical installation supersedes was set up 550 years ago; it was a creaking contrivance of wheels and ropes, and a man had to climb five flights of winding stairs to ring it for 15 minutes every night, with straining muscles and bent back. Now it is rung by touching a switch.

From "The Metal Industry" of November 30th:—

Aluminium Welding (By Fred. Grove-Palmer, A.I.C.).—The rapid increase in the commercial uses of aluminium for many industrial purposes during the past ten years, has led to considerable improvements in the technique of welding.

For a long time the employment of aluminium was hung up because of the difficulty experienced in working it. Soldering was never satisfactory or lasting; pressure welding is practically impossible, save for rods of small diameter and electric welding has its limitations.

With oxy-acetylene welding, however, has come the success so long striven after, and now all is plain sailing. But it must not be imagined that any amateur can weld aluminium, nor that an experienced welder of iron and steel can switch his blowpipe over to aluminium and immediately produce good results. This is not the case because autogenous welding of aluminium is a skilled craft with its own technicalities that can only be acquired by practice, plus common-sense. In the hands of the expert, aluminium can be welded easily and rapidly, and there are not many inherent difficulties to be met, as witness the fact that in some works with a large output of small repetition pieces, the welding is done by women.

Different Technique for Sheet and Castings.—Welding gives excellent results, but, as Matte has very justly remarked, it will not stand comparison with even poor riveting, if it is done by unskilled labourers.

The methods employed for manufacturing parts of plant and machinery require some modification to fit them for repairing breaks in pieces of alloy, for castings are more brittle than sheet, for instance, and with the increased thickness there is greater liability of cracking due to expansion and contraction during the working. In the case of sheet the welder is faced with the added risk of burning through the thinner metal unless he exercises great care in the manipulation of the blowpipe.

Welding, baldly stated, consists of applying the intensely hot pencil flame of mixed oxygen and acetylene to the abutting edges of the pieces of metal; these melt, and when the thick coating of oxide that covers even well scraped surfaces has been removed by means of a flux, the molten metal coalesces and a weld is formed. The flame is confined to a very small part of the metal at a time and the surface tensions prevents the falling away of the liquid aluminium which solidifies as the blowpipe passes on in the rapid hands of the welder. The metal in the seam is now in the condition of a casting and has different characteristics from the main sheet. If the whole is a casting, however, there is but little change.

Annealed Zones.—Returning to the welded sheets, down each side of the seam lies a zone of annealed metal which, again, differs from both the hard rolled sheet and the cast seam. These zones are the weakest parts of the job; any lack of strength in the seam itself is counterbalanced by a purposeful increase in the thickness of the metal while the welding is in progress.

Alternatively, the joint may be hammered out to its original thickness and the increase of strength obtained by this cold-working. But whatever may be done, the annealed zones remain and their breaking strain is only five to six tons per square inch compared with nine tons for cold-worked hard aluminium.

When dealing with alloys of aluminium the position is different. Welding does not give rise to annealed zones of low tensile strength; in fact, their strength may be increased. The best plan in this case is to hammer over the seam in order to ensure compactness of structure and as near homogeneity as possible.

After that the whole thing is annealed. This will, at any rate, help to remove internal stresses set up by the intense local heating, which may be a source of considerable weakness to the machine when submitted to the shock of working conditions even though it may not be sufficient to cause distortion and cracking.

A repair treated in the manner suggested should not be weaker at the weld than elsewhere, and even when the casting is made from the very useful " silicon alloy " the rapidity of the melting and solidifying should, as Painton puts it, prevent any tendency on the part of the mixture to revert to its normal structure.

A weld in hard-rolled sheet of the alloy containing four per cent. of copper may be regarded as consisting of three separate metals:—

1. Cast metal having a tensile strength of about eight tons per sq. in.

2. The flanking annealed regions of say 11 tons per sq. in.

3. The remaining parts, untouched, with a strength of 20 tons.

Annealing will, in all probability, bring the breaking strain of the whole within the region of 20 tons, but as the cast metal at the join will not be normally so strong as the rest, when practicable it is thickened up in order to maintain equality.

The weld should be hammered or rolled, as the case may indicate, before annealing so as to bring it into proper condition.

Care Required for Duralumin.—In welding duralumin sheets, annealing has been recorded by Painton as bringing the strength up to 25 tons per sq. in. This alloy consists of four per cent. copper, $\frac{1}{2}$ per cent. magnesium and $\frac{1}{2}$ per cent. manganese, and its normal strength when tempered is the figure just mentioned. Tempering is a matter calling for extreme care. The metal must be heated cautiously to between 480 and 500° C., quenched in water, and then aged for four days. If the temperature is below 475° the metal will not be hardened, and if it rises above 500°, brittleness and blistering will result; the melting point of the alloy is 545°, consequently it will be realised that the handling of duralumin needs caution and precision, the more especially because its great strength leads to its being used in very thin sheets.

Incautious welding might result in the partial oxidisation of the magnesium, present to the extent of only one half of one per cent.; this will be the cause of a great alteration in the metal's reaction to the heat treatment.

In the welding of aluminium and its alloys the normal form of plant is employed. An oxygen cylinder under pressure of 120 atmospheres and an acetylene cylinder under 12 atmospheres, are needed. Sometimes a low pressure generator working with calcium carbide and water is used for the source of the acetylene. The cylinders are more easily portable, the gas is always pure and there is no fluctuation in the flame, besides which the whole apparatus is very much simplified, and in addition there are no troubles with the law over the storage of carbide. A generator must be kept in an outhouse, needing pipes to bring the gas in, and the whole thing requires constant attention and cleaning. Practical experience has shown that this is a very real drawback, as the plant was continually going wrong at the most inconvenient times. Our man in charge used to say that merely whispering the words "Rush Order" outside the door was sufficient to throw the plant out of gear for hours.

Importance of Pure Gas.—On the other hand, the cost of cylinder gas is several times higher than that of generator gas, which, in large scale work, may prove of considerable interest, but for thin work there is no doubt that we can obtain far better results when using cylinders. A generating plant is equipped with a cleaning and purifying system for the removal of sulphur compounds and lime powder, this must be kept constantly cleaned out, for if these impurities are deposited on the weld they will be found to be very deleterious to the strength. Impure gas very quickly notifies its presence at the blow-pipe as the flame becomes opaque and yellowish instead of the normal clear blue. A piece of white blotting paper dipped in a ten per cent. solution of sugar of lead (obtainable from the laboratory), and held in the unlit gas will instantly show by its blackening the presence of the sulphur impurities.

It is essential to have an efficient hydraulic safety valve between the burner and the generator. The pressure of oxygen at the blowpipe may be up to 30lb. per sq. in., and there is some danger of a blowback, which might lead to an explosion. Though the safety-valve may be nothing more than a simple water-seal fitment, it requires attention; the workers may be careless and forget to clear out rust, dirt, etc.

Different intensities of heat are obtained by varying the size of the nozzles of the blowpipe. In the low pressure system the gases are mixed by injection; the stream of oxygen rushes out drawing acetylene as a surrounding blanket; they mingle in the expansion chamber and are then burnt.

The sizes of the blowpipes are designed to give certain power, and this cannot be varied, although the intensity of the flame can by changing the nozzle. Orifices should be gently cleaned with soft wires to prevent any chance enlargement, which would throw the supply of gases out of balance. In any case the oxygen injection should not be touched. If a blowpipe is designed to supply equal parts of both gases it would not be economical to alter it.

The theoretical mixture is $2\frac{1}{2}$ vols. of oxygen to one of acetylene, but as in practice the greater part of the oxygen is derived from the air, equal parts are sufficient for high pressure work and from 1·3 to 1·5 part of oxygen to one of acetylene when a generator is used. Unless the pressure of oxygen is kept at the figure advised by the makers of the blowpipe, oxygen will be wasted. Suitable apparatus should be chosen in the light of experience, guided by the size of the jobs to be handled.

Gas Consumption.—Economy in gases is effected by preheating the work. For an unheated weld, sheets of 3/16ths aluminium or steel both require 400 litres of mixed gas per hour, but sheets $\frac{3}{8}$ths. thick take 1,400 litres for aluminium and 930 for steel. Although the melting point is lower (aluminium: 658° C. and steel anything over 1,320° C.), the heat conductivity is very much greater and is a more pronounced factor in thicker plate.

The adjustment of the flame calls for some little practice in getting the supply of gases equal without excess of either. The correct flame shows two very distinct portions: at the nozzle is a white luminous cone surrounded by a non-luminous blue part in which there are two zones. If acetylene is getting in too freely the white cone is shrouded by a faint whitish mantle whose size varies with the excess. If the pressure of oxygen is right and both taps are wide open, acetylene is always in excess; the appropriate valve is gently tapped (often with the blowpipe itself, being handy) until it is sufficiently closed to give the correct current. Should it be closed too far, the white cone grows smaller and the blue coating changes to violet and is less transparent. Excess of either gas is bad from the point of view of economy, though this may not interest the welder so much as its effect upon his work. Too much oxygen causes more oxide to form in the weld, giving a bad joint; too much acetylene causes bubbles in the melted metal, leading to oxidation. Of the two evils it is generally held that the first is the greater, and some experienced men prefer to run a small excess of acetylene in order to make certain that there is not too much oxygen. It is, of course, far better to have the adjustment correct.

The pressure in the generator is regulated by the acetylene tap, and when the oxygen pressure has been properly set, it should remain constant varying the other only. It is found that soon after starting up there is too much oxygen coming through, this arises from the expansion by heat of the acetylene. This point must be remembered and a slight adjustment made.

The skin of oxide on the surface of aluminium is the bugbear of the welder, it prevents the coalescence of the molten edges and must therefore be removed. This can be done by puddling with an iron or aluminium rod, stirring the melt as the weld proceeds. This is applicable only to fairly thick welds, the progress is slow and when finished the seam must be filed or ground level.

Composition of Flux.—It is far better to use a flux of some kind which consists usually of chemical salts that will melt earlier than the aluminium and will dissolve the oxide. It must be of such a constitution that when melted it is just sufficiently liquid to run over the metal as a film without flowing into the weld in a mass, and it must dissolve the oxide quickly in the case of the rapid working essential for thin plate. Heavy work, not so likely to burn through may have a slightly different flux. The following typical formulation is quoted from Painton:—

	Per cent.
Potassium chloride	45
Sodium chloride	30
Lithium chloride	15
Potassium fluoride	7
Potassium bisulphate	3

It is a matter for individual discretion as to whether the flux is bought ready made or compounded at home. It is not very easy to make it properly because the mixing must be very complete. The salts cannot be melted together as some of them would volatilise and there would be chemical reactions which would absolutely spoil the mixture.

The mixed powders take up moisture from the air and should be stored in damp-proof tins, for like the salt of old, if it gets damp it loses its "savour," owing to the action of the bisulphate.

The chemical action of the flux may be explained by the fact that under the influence of heat hydrochloric and hydrofluoric acids are set free and these dissolve the oxide coating.

Flux, if kept dry, may be stored indefinitely, and as it is expensive, economy in use is indicated.

When used with a welding rod for thickening the seam, the flux is better applied as a varnish to the rod. This is done by heating the end of the rod and dipping it into the tin, when a tuft adheres to it; this is carefully melted along until it coats about six inches of rod, which should be enough for the work. In welding, the flux melts just before the rod and, running ahead of the flame, prepares the metal.

From "Fairplay" of December 6th:—

Safeguarding, For and Against.—The so-called De-rating Bill is at the moment casting a temporary eclipse, so far as the general public is concerned, over the question of safeguarding—indeed, all that the Prime Minister had to say a week ago at Glasgow on that latter subject was that "as we know it, as we deal with it, it is a process that involves strict scrutiny on lines well understood in the country, and subject to the watchful control of Parliament at any stage." It still, however, looms large in the Press, and has given occasion to some interesting articles and correspondence in which the advocates and opponents of the policy show such an amazing knowledge of economics, theoretical and practical, that the mere layman is lost in amazement when it is brought home to him that a problem which, so obviously to each school of thought has only one side to it, can be convincingly solved by diametrically opposite processes. Therefore I will content myself to-day, not with trying to tackle the question as a whole, but with considering one or two minor issues which have arisen out of the views recently expressed on the subject.

* * *

Firstly, I will take an admirable letter from Sir John Latta which appeared in the "Daily Telegraph" on 17th November. The conclusion which he comes to is that the only sure way of reaching permanent success in this country and of absorbing our unemployed is to meet the prices of our competitors who, by working longer hours and accepting lower wages, are capturing trade from consumers in India, China, Japan, etc., who have hitherto taken their supplies from us; and that "the imposition of duties on foreign imports cannot possibly assist our manufacturers in recovering such trade." That is a direct issue, and therefore I do not comment on it. Also for the moment I will content myself with only calling attention to the ingenious suggestion—not recommendation—that, as regards the coal and iron trades, and the vital importance of resuscitating them, "it might be worth considering whether tariff reformers could not immediately test their principle without running the risk of disturbing our integral fiscal system," and that "instead of a tariff wall against the foreigner, a little wire netting round offending British purchasers from abroad might suffice." The question he propounds is, "When large importations of iron and steel are contemplated, could not the purchaser, before committing himself, be asked to afford the Government an opportunity of deciding whether the difference in price could not at their instance be abridged?" Sir John Latta surmising that in the process the Government would be guided by the additional employment that would accrue to the coal and iron trades here, and that "it might transpire that the margin at issue is not more than the dole—the country's running sore."

Empire Free Trade.—It is not on the above suggestion that his critics fall foul of Sir John Latta; and as far as I am aware they are silent regarding his opinion that:—

" If we could attain Free Trade without our Empire—which, unfortunately, the Dominions will not listen to—we would then have a self-supporting entity similar to the Free Trade that exists within the borders of the United States of America. Under such conditions there would be material to justify Protection, when, like America, we might progress in spite of it; but anything short of Free Trade within the Empire would simply represent an effort to make bricks without straw."

Where Sir John Latta has struck sparks from one of his critics, Mr. P. I. Hannon, M.P., is in respect of the assertion that:—

" When America was under Free Trade and we were protected, American shipping made great progress while ours languished. With the position reversed, it has been shown that American ships, owing to high internal charges, cannot economically compete in open world transportation. Germany also discovered that her shipbuilders could not compete with Free Trade countries, so was forced to remove all import duties on shipbuilding materials—unanswerable evidence that tariffs do increase prices."

U.S. Ships and World Competition.—As was only natural, Mr. Hannon pounced on the assertion that it is " owing to high internal charges " that American ships cannot economically compete in open world competition; and he may be correct in emphasising the point that presumably " Sir John Latta attributes what he calls the ' reversed position ' to the fact that the United States levy an import duty on iron and steel and Great Britain does not." And he is undoubtedly right in pointing out that shipping is now not dependent upon wood, but upon iron and steel; and he also may be partially justified in arguing that " the difference in the development of shipping is to be discovered in the fact that Great Britain found it essential to develop her shipbuilding because she was dependent upon it for her existence; whereas the important factor in the developent of the United States was internal, and showed itself in the vast railway organisations." When, however, he proceeds to argue, in effect, that the enormous growth of the American railway system proves that its vast network was hampered neither in construction nor upkeep by any import duty upon iron or steel or internal charges, Mr. Hannon, so it seems to me, doth protest too much. He appears, indeed, to overlook the possible fact that, if there had been no such duties, the cost to that extent would have been correspondingly lessened, and that it was only owing to the superabundant prosperity of the United States that it was not felt. Moreover, even if his reasoning is tighter than it may seem to some to be, he will certainly not win over the economic waverers to his side by adducing as an additional argument in his favour that "in spite of duties the gross tonnage of American vessels in 1923 was over 18,000,000 and approximated to that of the United Kingdom"; that "it may be noted also that the foreign commerce of the United States is largely carried in American bottoms"; and by crowning it all with the astonishing statement that "one other factor which seems to me to be overlooked is the fact that British shipping is highly protected by large Government subsidies both for mail services and for right of hire in case of necessity." Frankly, it does not take a very tall man to overlook "facts" of that sort; indeed, an intellectual pigmy would have no difficulty in doing so, assuming that the adage still holds good that "Truth will out."

THE GERMAN STEEL LESSON.—If Mr. Hannon vitiated some otherwise good arguments by trying to over-prove his case—and incidentally in doing so he drew a devastating reply from Sir John Latta—he need not be unduly despondent, for he is in good company. Mr. F. H. Lambert, of Penarth, for example, falls into a very similar error in the course of an otherwise admirable article contained in the recent safeguarding supplement issued by the "Daily Telegraph," and in which my contemporary published the views of yet more leaders of industry. It is not for me to quarrel with Mr. Lambert's conclusion that no Government should exercise its power to impose burdens on the public for the benefit of any specially selected industry; that taxation is always, under any circumstances, an evil; and that the cardinal principle, that taxation should not only be imposed for revenue purposes and not with the object of benefiting private interests, should be jealously guarded. Nor is any fault to be found with the argument—it was also, as has been shown, adduced by Sir John Latta—that several years before the war the German Government, in order to enable German shipbuilders to compete with our own, were compelled to abolish protective duties on iron and steel required for shipbuilding; the result being that:—

"The German shipbuilders did not import steel from abroad, as might have been anticipated, but having the power given them of buying freely from abroad, they were able to buy from the German manufacturer all the steel they required for shipbuilding at the world's price, *i.e.*, the British lowest Free Trade price, instead of at the higher price which, owing to the tariff, they had hitherto been compelled to pay."

A Fundamental Fallacy.—To that deduction no one can logically object, however much the reasoning may appear to some to fall short of reality. Mr. Lambert, however, is not content to let facts do their own stubborn will; he calls phantasy also to his aid, and with direful results, as the following quite superfluous statement shows. According to his reading of history:—

"During the first half of last century, when this country was Protectionist and the United States Free Trade, the United States shipping progressively increased; but when, during the second half of the century, the positions were reversed, our shipping increased under Free Trade until, at the outbreak of war, we owned nearly as many seagoing ships as the rest of the world put together, whereas the United States shipping had gradually decreased. The intention of a tariff is to restrict the exchange of goods between countries, and must, therefore, be detrimental to shipping."

The last assertion contained in the above extract will certainly not be admitted by the Safeguarders; but the rather obvious fallacy contained in it is granite when compared with the quite remarkable error with which Mr. Hannon supports his primary assertion. As Sir John Latta very reasonably pointed out in his communication to the "Daily Telegraph":—

"There is one important fundamental fallacy which seldom receives the consideration it deserves. It is the capital which Protectionists make out of Cobden's confessed belief that the world would immediately follow his free import policy. The fact that it did not do so was what disclosed the unbounded benefits of a system which even he, its creator, did not comprehend. Had his prognostication been right, we would never have attained the commanding position in world markets that immediately followed. We would have been limited in our operation to the potentialities reposing within these islands. Grasping the opportunity, however, we extend our tentacles far beyond those limits; we laid the foundation of our matchless re-export trade, which the combined tariff operations of the world have never been able to uproot."

Incidence of Iron and Steam.—When Cobden was preaching his doctrine we were stirring as it were to an industrial renaissance. The Free Trade slogan doubtless stimulated the movement, and to what extent it would have progressed without that incentive no one can say; though it can be safely assumed that even had it never been cried we should still have been irresistibly impelled towards the conquest of the markets of the world. But it was not the practical application of the principle of Free Trade or its theoretical adoption, but the advent of iron and steam which enabled us to take the lead from America, in that, owing to the introduction of those two factors into the situation, she at a stroke lost the advantage over us which she held in the timber which provided her, so to say at the door, with the material for shipbuilding, which we lacked. With iron—coal being in juxtaposition—and steam we came into our own; and we grasped our opportunitity to such good effect that our name speedily ranked so high as the suppliers of the best iron and steel ships and the most reliable machinery that we held it even up to the outbreak of the war. It was not Free Trade which gave us supremacy on the sea, nor Protection which robbed the United States of the chance of winning. Rather, as Mr. Hannon puts it in the letter above: "The difference in the development of shipping is to be discovered in the fact that Great Britain found it essential to develop her shipping because she was dependent upon it for her existence; whereas the important factor in the development of the United States was internal, and showed itself in its vast railway organisation."

From "Fairplay" of December 6th:—

Shipowners and Their Staffs.—It is stated that Messrs. David MacBrayne, the Glasgow shipowners, have allocated £30,000 from their profits as a gift to their staff in recognition of their loyal service, the cheques varying from £15 to £500. During the shipping boom, when a number of Companies sold out the whole of their vessels and wound up with a big capital profit, several cases were reported where the managers were extremely generous to their old staffs. For example, one Liverpool firm gave to everyone in its employ sufficient War Loan to bring in the same income as they were receiving; in another case an owner, who was retiring, gave his manager enough money to purchase a steamer for himself; in many instances sums representing several years' salaries were forthcoming—and in others the clerks were dismissed with three months' pay. The late Sir R. P. Houston gave his staff nothing when, having sold his fleet at a huge profit, he retired from business, but, when he was approached shortly before his death with a view to his doing something for those who had unfortunately been dismissed, he replied that he would see to the matter in his will; and he left them £50,000. Though, of course, strictly speaking, when the heads of a firm retire, sell their business satisfactorily, and the staff is kept on by the new owners, they are under no obligation to pay their old employees anything, it is a matter for satisfaction to find that there are employers who still take such a personal interest in the welfare of their staffs as to deny themselves something in order that those who have served them well in the past may still share their good fortune with them.

The following are from "The Shipping World and Herald of Commerce," of December 12th:—

RELIEF OF INDUSTRY.—The official explanations which have been given of the Government's derating policy have dispersed the cloud of misrepresentations which have been circulated within the past few weeks. The scheme emerges as a well-considered attempt to supersede a system of local taxation which has for years seriously handicapped those who are responsible for the conduct of some of the most important industries of this country. The Government was undoubtedly well advised to limit relief to the trades which have been most seriously crippled by the war. Those who are connected with shipbuilding and ship repairing, as well as coal exporters generally, can look forward with confidence to an easing of the unjust burdens which hitherto they have had to bear. It is estimated that relief amounting to £24,000,000 will be afforded by the measure, and of that sum £10,000,000 will go directly to the depressed heavy industries, export coal benefiting by 7d. a ton, and iron and steel coal by 10d. a ton. If the money available had been, as has been suggested, used for the general relief of all industries, the heavy industries would have gained little advantage. On the other hand, if an attempt had been made to distinguish between prosperous firms and firms less prosperous, the result would have been, in many instances, to place a premium on inefficiency. As it is, every firm which comes under the scheme can look forward to being relieved of 75 per cent. of the rates which it has hitherto had to pay on its own premises, and it will be the gainer by cheaper rail transport. The measure is a practical attempt to give financial help where help is most needed, to revive the most depressed industries, and to stimulate our overseas trade.

The scheme could no doubt be amended in details, but generally it must be regarded as an honest effort to deal with what was little less than a scandal, since business firms struggling to make ends meet were compelled, whether prosperous or otherwise, to set aside a large and ever increasing proportion of their revenues to pay local rates in accordance with a system of assessment which discouraged enterprise and efficiency. The Government can claim that in the course which it is taking it has responded to the most urgent plea made to it on behalf not only of those concerned with shipbuilding and coal export, but by miners and coal owners. A year ago, as Sir Philip Cunliffe-Lister recently recalled, a deputation representative of the miners and the mineowners came to him from South Wales, and pressed upon him two things. "If," they said, "you want to do something which will be of substantial benefit to the coal trade of the country, tackle railway rates and tackle local rates." That is what the Government is doing to-day. On the other hand, the relief which is being afforded is not to be regarded as a national subsidy to the mining industry or any other industry. It marks an important stage in a new derating policy which is associated with the rationalisation of our system of local government.

When the scheme was originally put forward it was proposed that all kinds of coal should benefit equally. It was at the unanimous request of the coal industry that the Government decided to concentrate the benefit on the export coal. What can be fairly urged against this change? It is a superficial view to suggest that this is helping our foreign competitors. British coal is little used in foreign industries; much of it goes in bunkers and to foreign power stations and railways. The industry that complained most of foreign competition, as Sir Philip Cunliffe-Lister has remarked, was iron and steel, and iron and steel joined in supporting the proposal to concentrate on export coal. There is consequently no cause of grievance.

Nothing is to be gained by niggling criticisms of the Government's proposals. The general trend of the scheme reflects demands which have been made time and again. It is an endeavour to right a grave injustice in rating which has most seriously affected our shipyards and engine shops, and has been a handicap on our coal export trade. The benefits will not be confined to these particular industries, but will react on the whole industrial position in this country.

STEAM OR DIESEL?—Tramp shipowners generally remain loyal to the steam engine, and loyal also to coal. Most of the orders which have recently been placed for tramp tonnage show that there is no inclination to adopt oil fuel or to instal internal combustion engines. It is not that these owners do not realise that under certain conditions, and on certain routes, oil fuel offers advantages over coal, but, taking a wide survey, they have come to the conclusion that economies in first cost as well as in operation, are to be secured with the coal-fired boilers and reciprocating engines. High-pressure steam and other developments, all making for greater speeds and lower costs, have influenced the judgment of these shipowners. There is, indeed, a movement, so far as cargo-carrying vessels are concerned, away from oil fuel and the internal combustion engine. The chemist, in association with the engineer, is, it is realised, bringing about a revolution. There are experienced marine engineers who already prophesy that the output of Diesel engines has reached its zenith, and that in the lifetime of the present generation, few orders will be given for ships with internal combustion engines. That is probably an exaggeration. But such statements will render the statistics of Lloyd's Register during the next few years specially interesting, not only to shipowners, but to all who are associated with the coal industry.

CHINESE PIRACY.—That no effective check to piracy in Chinese waters has yet been found was proved by the attack which was made on the steamer *Anking*, on her voyage from Singapore to China ports, with the loss of the lives of the officers who resisted the pirates. In spite of the recommendations of the Hong Kong Commission which enquired into the *Sunning* piracy, it is evidently still possible for armed Chinese to board ships in Singapore in the guise of innocent passengers, and, at a selected moment, to overcome the officers and take possession of the vessels, then escaping with their booty without fear of capture or punishment by the Chinese authorities. The "Singapore Free Press," in commenting upon this latest outrage, suggests that the matter requires further consideration. It will be recalled that the Commission which sat at Hong Kong not only advocated the recession of the Piracy Regulations, but recommended that the bridge should be protected by grilles and dodgers, and that guards should be stationed at the entrance; that subsidiary grilles should be provided, isolating the officers and the first-class cabins as far as possible; and that lights on the ship should be arranged so as to assist a defence, and that there should be a system of alarm bells to ensure the concentration of Europeans in the event of an attack.

Another Burden on Shipping.—This represents another burden on shipping. It is not perhaps to be wondered at that, in the circumstances these precautions have not been taken on all vessels passing through the danger zone. But the *Anking* outrage shows that a scheme of defence on some such lines is essential to safety. "Owners cannot be blamed," our contemporary states, "for taking the view that it is not their duty to bear the whole brunt of antipiracy precautions."

The position is one in which the authorities have a big responsibility, and we would suggest a full consideration of the problem by a body representative of the authorities here and in Hong Kong, the Chinese civil authorities, and the shipowners themselves, in order that a remedy shall be found for a danger which gives this part of the world a reputation as unique in these days of generally safe transit by sea as it is undesirable.

A Pulverised Coal Engine.—Sixty years ago Dr. Otto invented his gas engine, which was designed to use the lightest of all fuels. Thirty years later, Dr. Rudolph Diesel brought out the internal combustion engines, which bears his name. This was intended to make use of coal in a powdered form, fine dust, but to-day the engines built on his principle use oil fuel. In an article in an American contemporary, "Power"—a summary of which appeared in the November 21st issue of "The Shipping World"—Mr. R. Pavolikowski claims that after 15 years of development, an engine burning pulverised coal directly in the cylinder is in commercial operation. This engine would, therefore, appear to fulfil Diesel's original conception. The Diesel engine using oil has disadvantages, not the least of which, as far as British shipping is concerned, being that oil is not a British product. The steam reciprocating engine or steam turbine has also disadvantages, as, for instance, that it seems impossible to obtain from any steam installation the full calorific value of the fuel used. The advent of pulverised fuel has rendered the task of increasing the efficiency of boilers easier. Is it not conceivable that pulverised fuel is the missing link between Diesel machinery and steam machinery, in that utilising the advantages of both it may prove to have the disadvantages of neither?

The following is from the "Syren and Shipping," December 18th:—

A REMARKABLE FEAT.—The story of the reconstruction of the Royal Mail motor-ship *Lochmonar* was the subject of an address at last week's meeting of the Belfast Association of Engineers by Mr. James Harney, of Messrs. Harland and Wolff's drawing office. He gave a most interesting account of this engineering feat, and to indicate the accuracy with which it was carried out at Harland and Wolff's, he stated that the difference between the Board of Trade measurement of the length of the ship when she was built and that made by the same authority after the joining of the two parts was only ·025 ft., or roughly a quarter of an inch, which is so slight that the variation could easily be accounted for by using a different tape line. After describing the preparations that had been made on board the new fore part of the ship, Mr. Harney said that the Thompson Graving Dock was flooded, but with just sufficient water to float the bow section six inches clear of the keel blocks, which, of course, was not deep enough to float the after portion. The winches were brought into operation and the bow gradually drawn up to the stern until the side logs brought up on the stops. The two shores at each side of the stern bar and at the after-end of the bow portion were carried along the deck with the ship, and there was never any chance of the latter getting more than a fraction of an inch out of position either way. The water was then pumped out of the dock until the aft end of the keel slab was just touching the blocks. The bow was then checked and corrected for list by means of the inclining weights, which were placed on the upper deck for this particular purpose. The sight lines on the deck were also checked for alignment and corrected where necessary by means of the side shores already mentioned. The dock was pumped dry, the bilge shores fitted, and the keel sights checked. There only remained now the removal of the temporary wood bulkhead on No. 17 frame, which was fitted for the towing of the after portion from Liverpool to Belfast, and the cutting out of the closing plates on the shell of the fore part, which were there temporarily for water-tightness at launching. The permanent shell plates, beams, deck plates and girders bridging the gap were then fitted and the bow and stern portions made into one. The first docking of the two portions took place on August 6th, and they were successfully brought into position and joined together on August 10th. On September 12th all work was completed, and the vessel as a whole undocked, the joining up only occupying 28 working days. The ship is still at Belfast receiving machinery alterations.

Belfast Shipbuilding in 1928.—It is obvious that the Belfast shipyards are not going to break any records this year in the matter of launching output. The official particulars are expected to be available in the course of the next fortnight and will, as usual, be published in our New Year number, but an approximate estimate shows that, including vessels yet to be launched, the total tonnage of the port will be in the neighbourhood of 80,000 tons, made up by 14 vessels from Messrs. Harland and Wolff and one from Messrs. Workman, Clark. Last year the Queen's Island firm launched 62,313 tons of shipping and Messrs. Workman, Clark 48,911 tons, making a total of 111,224 tons. The falling off is entirely attributable to the fact that the last-named suspended operations at the beginning of the year and the new company did not reopen until May 1st. They have already launched one small vessel, but next year the undertaking will be restored to its old position high up in the records of British yards, as at the present time it has, either on hand or on order, 11 vessels aggregating close on 80,000 tons. So far as the Queen's Island is concerned, the position is more satisfactory than it has been for a long time, because, quite apart from the expectation that the 60,000 ton liner will be proceeded with early in 1929, there is an imposing array of high-class tonnage on hand at the present time, including a 26,000 ton White Star liner, two 20,000 ton Union Castle liners, three 14,500 ton Nelson liners (two of which are in the water), one 17,000 ton Pacific Steam Navigation liner, one Elder Dempster vessel of 10,000 tons, and three passenger ships for the Belfast Steamship Company. All those mentioned, with the exception of the giant White Star liner, whose prime movers have yet to be decided upon, are to be motor driven.

From the "Journal of Commerce," January 3rd:—

Safety for Bearings. Automatic Emergency Lubricating Device.—Mr. Thomas Buchanan, M.I.Mar.E., is responsible for an ingenious invention designed to safeguard bearings against overheating and its attendant troubles. The device has been favourably considered in engineering circles, and there is every prospect that it will be employed on engines where absolute reliability over long periods of time is a necessity.

The device is described as a cartridge made of special metal, surrounded by a predetermined air-space, securely screwed into the brass containing the bearing metal. It is then tightly filled with two different greases of high quality lubricating properties. Each grease has a widely different melting point, and the one forms a complete seal against the other. The greases are made round in the form of a stick (like a candle).

The cartridge at the top is hermetically sealed. The lower end is open and near the running surface of the shaft. The upper grease has the lower melting point and the lower one the higher. Should the bearing temperature rise too high, the high melting point grease acts in the same manner as a fuse for electric wires, for it gradually melts by the rising temperature, either checking the heat or flooding the lower melting point grease into the bearing.

When this occurs, ample warning is given, for the grease is made purposely odoriferous, throwing off a strong smell that permeates the engine room and right up to the deck, calling for attention if damage is to be avoided. The advantage in fitting this simple device where foolproof positive lubrication is not used is obvious.

The inventor, Thos. Buchanan, M.I.Mar.E., who served his apprenticeship with Messrs. J. G. Kincaid and Co., is negotiating the manufacture of the emergency lubrication device. He is at present manager for Scotland for a well-known firm of oil manufacturers and refiners.

The following notice appeared in the " Glasgow Herald " of February 5th, and appears to indicate that steps are on the eve of being taken to ensure that the officers of the Merchant Service, both deck and engine room, should be recognised at the true value, long due to them and without prejudice, it may be added to Engineer Officers especially:—

Mercantile Marine Officers.—A small non-party committee has been formed by Members of Parliament to look after the interests of Officers in the Mercantile Marine and endeavour to obtain improved conditions of service. Mr. Hore-Belisha, Lieutenant-Commander Kenworthy, and Commander Southby, are the representatives of the three parties in the House of Commons, and Earl Howe has been requested to represent the committee in the House of Lords.

In the "Shipping World" of January 19th, it is stated that the Combustion Engineering Corporation of America has recently secured an order for two combustion steam generators for the Philip Carey Magnesia Company. To operate at 1,800 lb. per sq. in., these boilers will be the highest pressure units in regular practice in the world. The furnace volume will be 8,400 sq. ft., and each boiler will have an actual evaporation of 150,000 lbs. of steam per hour, with a final steam temperature of 815° Fahr. The steam is to be used in back-pressure reciprocating engines, the exhaust from which will be used for process purposes.

Pulverised Fuel.—According to "The Morning Post" of February 14th, confidence in the use of pulverised fuel is growing. The Berwin Moor Steamship Co.'s steamer being built by the Blythswood Shipbuilding Co., Glasgow, is well in hand to be fitted with the Clarke Chapman System. An order has been placed with Messrs. Wm. Ropner and Co., West Hartlepool, for a cargo steamer of 9,000 tons to be fitted with the B. and L. system—Engineer-Capt. J. Brand, A.R.N.—which many of our members witnessed the demonstrations of at Stratford.

Notes have appeared in the Press recently pointing out that steel supports for a bridge or certain bridges have shown failures, and on enquiries into the nature and quality of the steel it has been traced to manufacturers outside the British Isles. This may be so, but there still remained the important engineering question as to the testing of the material and the specification setting forth the quality of the steel to be used in order to meet the service demanded, it would appear that the material supplied was short of the mark set forth in the design passed in the drawing office.

The large number of bricks imported for building material, points to a want of understanding of how to uphold our own brickmaking to advantage.

The dangers associated with the use of ethyl petrol have been pointed out to users by the suppliers, and these should not be overlooked at any time but should be emphasised more and more due to the great increase of cars and transport wagons lining roads and streets, vitiating the atmosphere by the exhaust gases expelled; some of these are not so harmful and obnoxious as others.

Attention has been called to a new type of power mover for aircraft, which calls to mind the "Waterwitch" and the method of hydraulic propulsion for water transport. It is proposed to draw the air into an area of the craft at the bow, thus creating a partial vacuum and tending to cause a forward movement and to expel the air aft, thus tending to force the craft forward—by double action.

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Boiler Explosion Acts.

No. 2854. S.S. *Essex Chase*.

Prepared by Mr. E. F. Moroney, Board of Trade Surveyor, Cardiff. This report deals with an explosion on a main boiler on the S.S. *Essex Chase*. The explosion was not of a violent nature. One of the stays supporting a furnace crown fractured and the end which was screwed through the furnace, being slack in the thread, was blown out, leaving a hole $1\frac{1}{8}$ inches diameter through which the contents of the boiler escaped. The Second Engineer was slightly scalded.

The explosion was due to the failure of a stay supporting one of the furnace crowns. The working of the furnace due to expansion and contraction was the probable cause of the stay becoming brittle and snapping off short, close to the crown of the furnace.

This vessel is a general trader of 2,891 tons gross, and is fitted with two-single-ended main boilers. She was bought from foreign owners in 1923. The stiffening rings and stays for the furnaces were already fitted when taken over by the present owners. The Superintendent Engineer for the Company, Mr. H. J. Savage, has been with the firm for less than twelve months, and he was not aware that the furnaces were fitted with stiffening rings until the accident happened. The first opportunity he had of inspecting the boilers was in Belfast recently.

The stiffening rings were of channel section, 3 by $3\frac{1}{2}$ by 3 inches, made out of steel plate 5/16th inch thick. These were placed partly around the circumference of the furnaces, leaving a clearance space of about two inches, as shown on the plate. The supporting stays, which were of steel, $1\frac{1}{8}$ inches diameter, screwed with a fine thread, were spaced about seven to eight inches apart and put in from the fire side, screwed through the furnace, and some of them through the stiffening rings also. A cap washer and nut were fitted to each stay and the ends of the stays were riveted over on the fire side. The stiffening rings, situated about two inches away from the furnace and surrounded by boiler water, would remain at a comparatively uniform temperature, whilst the stays with the ends screwed through the furnace would be frequently subjected to severe changes of temperature, and would therefore suffer severe working stresses, which eventually caused a number of them to break off short. Some of the stays which have been found broken, but remained in the furnace, were overlapped as much as $\frac{1}{4}$ inch.

A record found in the late chief engineer's room after he had left the vessel at Barry, shows that 15 of these stays in the port boiler and 18 in the starboard boiler had been renewed at Malta in August, 1926, to which port she had put in on account of the end of a broken stay being blown out. This is the only record available, but it is sufficient to show that a lage number of the stays were faulty at that time.

This method of stiffening furnaces is sometimes suggested, without proper investigation being made of the cause, where signs of weakness or deformation occur.

As the furnaces were of good shape and of sufficient strength for the working pressure, 160 pounds per square inch, it was decided, after consultation with Lloyd's Surveyor, to remove the rings and stays from the port boiler at Belfast. Afterwards, on arrival of the vessel at Barry Dock, those fitted to the furnaces of the starboard boiler were also removed and the stay holes were closed with rivets, having the heads on the water side of the furnaces.

The present owners realise the necessity for keeping the furnaces clear of scale and are particular in recording the gauging of all furnaces in their boilers, and for this purpose supply printed forms to those in charge of their steamers, and it is not anticipated that any further trouble will arise.

Observations of the Engineer Surveyor-in-Chief.

Stays had been screwed through the furnace to support the crown from a channel girder. A considerable number of these stays appear to have been renewed from time to time after breaking off short at the furnace plate, so leaving a screwed plug in that plate. In the instance reported in this case, the threads of the plug were so wasted as to have no holding power, and the broken end was blown out.

The Owners and Classification Society Surveyors are now of the opinion that these furnace supports are unnecessary and have removed them all, plugging up the stay holes in the furnaces. No further trouble should now be experienced if these plugs are well fitted and are watched to guard against leakage.

No. 2857. S.S. *Wollaton.*

Report No. 2857 deals with a manhole door explosion in the main boiler of the S.S. *Wollaton*, the details of which were investigated by Mr. W. E. McConnell, London.

The joint of the bottom manhole door blew out and the contents of the boiler escaped through the space left by the displacement of the jointing material. Wm. Brown, fireman, was scalded on the legs, but not seriously.

The explosion was caused by the corrosion of the manhole door and of the boiler end-plate flange which fitted into it. From the effects of this corrosion the door had become a very slack fit, and the face of the spigot formed by the boiler end-plate flange was not level, so that the jointing material could not be retained in its correct position.

The *Wollaton* is a steel single screw cargo steamer engaged in general cargo trade between King's Lynn and Rotterdam. On the morning of 20th February the vessel was on her way down the Lynn Channel, outward bound, when at 9.45 a.m. the joint of the bottom manhole door blew out. It was evident that the joint would have to be remade, and as there was only one boiler the ship had to be detained at a suitable anchorage whilst the boiler was emptied and a fresh joint made. After remaking the joint, steam was raised on the boiler, and at 7.45 a.m. on the following morning, 21st February, an attempt was made to proceed; but the joint failed again, and by 8.30 a.m. the leakage was so serious that it was decided to return to King's Lynn for permanent repairs. The old door was found to be half an inch slack horizontally and $\frac{3}{8}$ of an inch vertically, and it was therefore condemned and a new door with a bossed rim and a straight flat flange for the jointing surface was supplied. The corroded face of the spigot and the surfaces adjacent were built up by the electric welding process and suitably dressed to form a good jointing surface.

All this work had been completed before I saw the boiler, and the particulars given as to the extent of the corrosion are from the evidence of the present chief engineer, Mr. J. M. Petty, who only joined the vessel on the day before the explosion; the previous chief engineer died within a few days of leaving the ship. I examined the manhole door joint faces when the boiler was empty; the wasted material had been replaced by electro-deposited metal and a good and fair surface made, so that with due care there should not be any recurrence of the defect which caused the explosion.

Observations of the Engineer Surveyor-in-Chief.

The amount of slackness reported suggests that the manhole door had been in an unsatisfactory condition for some time. The danger of allowing boiler manhole doors to be used in such condition has frequently been pointed out in these reports, and it is important that those responsible for the maintenance of boilers should ascertain that the doors are a good fit when making their inspections.

The vessel was disabled, but luckily at a position where anchoring was possible.

No. 2858. Steam Trawler *Rowsay*.

Report No. 2858 deals with an explosion which took place in the combustion chamber of the boiler of the Steam Trawler *Rowsay*. The causes leading to it were investigated by Mr. R. W. Gunston, Hull.

The explosion was not violent. A hole about $\frac{3}{8}$ inch long by 1/16th inch wide developed in the back plate of the starboard combustion chamber, through which the contents of the boiler escaped until the fires were drawn and the boiler blown down.

The explosion was caused by the back plate of a combustion chamber corroding on the water side at the flanging.

This trawler makes regular trips from Hull to the Dogger Bank fishing grounds, the trips lasting about six or seven weeks. On 10th February, 1927, the vessel left Hull on such a trip and arrived at the Dogger Bank on the 12th February, 1927. At 12.30 p.m. on this day a hissing noise was heard inside the starboard furnace, and water was seen running from the ash-pit. It was at first thought a tube was leaking, and it was decided to draw the fires and blow down the boiler so as to insert a stopper in the defective tube. On going into the combustion chamber, however, it was found there was a hole right through the solid plate. This hole was in the flanging and about level with the grate, as shown on the Plate. No attempt at repair was made by the ship's staff, and the ship was towed back to Hull by the steam trawler *Endon*.

In September, 1921, it was found that the back plate of the combustion chamber was wasting round the stays on the water side, and that the stays were thus losing their hold on the plate. All the stays in the third row from the bottom were therefore removed, and the plate was built up on the fire side by electrically welding on pads about $\frac{1}{2}$ inch in thickness, and new stays were then fitted. This was a warning that the plate might be wasting in other places, and it appears it was inspected every three months when the boiler was opened out for a thorough cleaning. It was impossible, however, to see the part that eventually failed, and the comparatively small but deep pit-hole was overlooked.

Repairs have been effected by electrically welding a pad on to the fire side of the plate, covering the hole and taking in the adjacent stay. The vessel has since done two trips, and the repairs have proved quite satisfactory.

Observations of the Engineer Surveyor-in-Chief.

The necessity for thorough examination is illustrated by the comparatively trivial nature of the defect which put the boiler out of action and disabled the ship. Fortunately the casualty occurred under such conditions that the vessel could be towed back to port.

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Books Added to Library.

" The Journal of Commerce, Annual Review of Shipping, Shipbuilding, Marine Engineering and Allied Industries, during the year 1928."

The articles contributed to the " Review " cover the range of all shipping interests and the usual standard of excellence is maintained. In particular the engineering contributions are most interesting. The increasing popularity of Diesel machinery has had the effect of spurring steam engineers to greater efforts to obtain economical results from the methods at their disposal and to seek new material to meet the competition. The results of their labours are that the new steam turbines associated with refinements in the stokehold are once again likely to lead in economy and reliability. The progress made during the year and the prospects in this respect are authoritatively discussed in more than one of the articles.

The successful application of pulverised coal burning to a number of vessels is dealt with and some interesting figures on the possible economies in this direction are quoted. The complete practical and economical success of pulverised coal burning would be of inestimable value to the country, and would undoubtedly save a considerable portion of the forty odd millions of pounds that are spent annually on foreign oil.

The "Annual Review " is particularly fortunate in its contributors, and should be read by all interested in ships and shipping.

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Election of Members.

List of those elected at Council meeting of February 4th, 1929 :—

Members.

William Murray Calder, Lt. (E.), R.N., 22, Watling Street, Gillingham, Kent.

James Montgomery Crawford, 5, Ailsa Place, Ayr, Scotland.

Ernest Henry Myles Davies, 27, Laltoun Road, Brixton, S.W.2.

William Ross Deane, 33, Restalrig Terrace, Leith.

Archibald Stuart Askew Duncan, 155, Norman Road, Leytonstone, E.11.

Dewi Gwynne Evans, China Navigation Co., Ltd., Butterfield and Swire, Shanghai, China.

Arthur Thomas Griffith, 1, Thornhill Gardens, Sunderland.

Harry Edward Hearnden, 37, Hertford Road, Barking, Essex.

Karl Otto Keller, 3, West Mount, Sunderland.

Arthur Sutherland, 53, South Park Road, Wimbledon, S.W.19.

Companion.

David Alexander Weir, M.B.E., 1, Pier Head Chambers, Docks, Cardiff.

Associate-Members.

Frederick Melvin Atkins, 12, Branksome Road, Redland, Bristol.

Arthur James Sambell, 16, Cambridge Street, St. Thomas, Exeter.

Associates.

Robert Gibson Gray, 201, Kentwood Hill, Tilehurst, Reading.

Peter Arthur Montgomerie Simpson, Q.M.S., R.E., Military Cold Stores, Marsa, Malta.

Transferred from Associate Member to Member.

Alfred Dennison, Eastcliffe, The Promenade, Whitley Bay.

Charles J. Hampshire, Matthew Keenan and Co., Bow, E.3.

N. G. Rutherford, *c/o* British Star Contra Propeller and Rudder Co., 9, Mincing Lane, E.C.3.

Transferred from Graduate to Associate Member.

Robert Cyril Prowse, 1, Northcote Street, South Shields.

Board of Trade Examinations.

List of Candidates who are reported as having passed examination under the provisions of the Merchant Shipping Acts.

For week ended 5th January, 1929:—

NAME.	GRADE.	PORT OF EXAMINATION.
Booth, Tom P.	1.C.M.E.	Liverpool
Osborne, Matthew D.	1.C.	,,
Smith, Gilbert T.	2.C.	,,
Forbes, Thomas H.	1.C.M.	,,
Renwick, Henry M.	1.C.M.	,,
Mitchell, Ian M.	1.C.	Glasgow
Muir, John	1.C.	,,
Shearer, Daniel	1.C.	,,
Milne, James M.	2.C.	,,
Buchanan, James C.	2.C.	London
Neve, Herbert	2.C.	,,
Wilson, William J.	2.C.	,,
Bach, Patrick F.	2.C.	North Shields
Holme, Thomas	2.C.	,,

For week ended 12th January 1929 :—

Atkinson, Thomas	1.C.M.E.	London
Gould, Ernest A.	1.C.M.E.	,,
Raimes, Percy H.	1.C.M.E.	North Shields
Widdas, Gordon	1.C.M.E.	,,
Cook, George W.	2.C.	,,
Aves, James E.	2.C.	Sunderland
Frame, William C.	1.C.M.E.	Glasgow
Crawford, James M.	1.C.	,,
Hunter, Donald H....	1.C.	,,
Gardner, John	2.C.	,,
Stone, Robert McA.	2.C.	,,
Finnie, Robert	2.C.M.	,,
Bennett, Arthur C.	1.C.	Hull
Evans, John E. C.	2.C.	,,
Harrison, Richard H.	1.C.	Liverpool
Jackson, Richard	1.C.	,,
Kendrick, Ronald	1.C.	,,
McKenzie, Robert A.	1.C.	,,
Jones, Percival F.	2.C.	,,
Steward, John	1.C.M.	,,
Foster, George F.	1.C.M.E.	,,
Osman, James	1.C.M.E.	,,
Thomas, Timothy E. L.	1.C.	London
Moir, Norman F.	2.C.	,,
Coley, Harry R.	1.C.M.	,,
Burt, Kenneth	2.C.M.	,,

For week ended 19th January, 1929:—

Dunn, John M. M.	1.C.M.E.	Glasgow
Tasker, Wilfred E.	1.C.M.E.	,,
Bull, Leslie S. C.	1.C.	,,
MacKinnon, John	1.C.	,,
Duff, Robert E.	2.C.	,,
McMillan, Alexander C.	2.C.	,,

For week ended 19th January, 1929—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Anderson, Edward W.	1.C.	Leith
Craigie, Ernest W.	1.C.	,,
Kelly, James W.	1.C.	,,
Littlejohn, Thomas B.	1.C.	,,
McIntosh, James	1.C.	,,
Anderson, George	2.C.	,,
Leisk, Thomas R.	2.C.	,,
Lumsden, James D.	2.C.	,,
Morrison, James F.	2.C.	,,
Stark, David	2.C.	,,
De-Snoo, Sidney	1.C.	Liverpool
Proctor, Sylvester	1.C.	,,
Roberts, Robert A.	1.C.	,,
Simpson, Arthur F.	1.C.	,,
Sparkes, Leonard A.	1.C.	,,
Carmichael, Arthur	2.C.	,,
Foggo, George T.	2.C.	,,
Masser, Robert S.	2.C.	,,
McFall, Albert	2.C.	,,
Kneale, John E.	1.C.M.	,,
Lea, Arthur	2.C.M.	,,
Duncan, Achibald S. A.	1.C.	London
Harrington, John J.	1.C.	,,
Simmons, Harold J.	2.C.	,,
Richards, Charles P.	1.C.M.E.	,,
Wood, George T.	1.C.M.E.	North Shields
Bramley, Percy	1.C.	,,
Gargett, Ralph S.	1.C.	,,
Manderville, William H. ...	2.C.	,,
Robinson, Sidney	2.C.	,,
Sterling, John B.	2.C.	,,
Brown, Leslie L.	2.C.	Southampton
Johnson, Lewis D.	1.C.	Cardiff
Kerr, James L.	1.C.	,,
Richings, Charles W.	1.C.	,,
Clark, James E. M.	2.C.	,,
Griffiths, Trevor L.	2.C.	,,
Llewellyn, Reuben J.	2.C.	,,
Symmons, Walter	2.C.	,,

For week ended 26th January, 1929:—

Couch, Kenneth G.	1.C.M.E.	London
Cropley, Horace E.	1.C.M.E.	,,
Sibbald, James	1.C.M.E.	Glasgow
Wallace, Robert B.	1.C.	,,
McGinnis, Edward P.	2.C.	,,
Millar, John H.	2.C.	,,
Crowther, Henry T.	1.C.	London
Davies, Ernest H. M.	1.C.	,,
Beavis, Ronald C.	2.C.	,,
Paxton, Kerr	2.C.	,,
Shields, George F.	2.C.	,,
Watt, Adam S. F.	2.C.	,,
Wood, Arthur W.	2.C.	,,
Berry, George W.	1.C.	Liverpool
Westbury, Charles H.	1.C.	,,
Crook, Harry	1.C.M.E.	,,
Dobson, Stanley H.	1.C.M.E.	Sunderland
Hartness, James G.	1.C.M.E.	,,

For week ended 26th January, 1929—*continued*.

NAME.	GRADE.	PORT OF EXAMINATION.
Sedgwick, John L.	1.C.M.E.	Sunderland
Hodgetts, John	2.C.	,,
Staincliffe, John	2.C.	,,
Dennison, Alfred	1.C.M.E.	North Shields
Robinson, Sidney	1.C.M.E.	,,
McMullen, Charles L.	1.C.	,,
Lawson, William	2.C.	,,
Clinch, John M. C.	Ex.1.C.	London
Charlton, John G.	Ex.1.C.	North Shields
Craigie, John A.	Ex.1.C.	,,

For week ended 2nd February, 1929:—

Matthews, John A.	1.C.M.E.	London
Scott, Gilbert W.	1.C.M.E.	,,
Reid, Robert	1.C.	,,
Ginzler, John R.	2.C.	,,
Thompson, Ernest L.	2.C.	,,
White, Francis W.	2.C.	,,
Murray, William F.	2.C.M.	,,
Baird, John C.	1.C.	Belfast
Meares, Henry W.	1.C.	,,
Evans, Leonard V.	1.C.	Cardiff
Lovell, Harry W.	1.C.	,,
Davies, Howard G.	2.C.	,,
Fishleigh, Frederick T.	2.C.	,,
Hooper, James S.	2.C.	,,
Saunders, Howard R.	2.C.	,,
Naylor, John V.	2.C.M.	,,
Yates, John P.	1.C.	Leith
Gerrie, Norman R.	2.C.	,,
Johnstone, Ian I. B.	2.C.	,,
Witts, John W.	Ex.1.C.	Liverpool
Reid, Archibald McA.	1.C.	Glasgow
Cameron, Duncan	2.C.	,,
Cooper, James D.	2.C.	,,
Wilson, Georgefi McD.	2.C.	,,
Bald, James	1.C.M.E.	,,
Horrey, Wilfred S.	1.C.	North Shields
Scarth, George R.	1.C.	,,
Begg, David	2.C.	,,
Hay, George	2.C.	,,
Wilson, Alfred W.	1.C.M.E.	Southampton
Harvey, Oliver T.	1.C.	,,
Lowe, Arnold J.	2.C.	,,
Mathews, Charlie G.	1.C.	Liverpool
Gaunt, Benjamin	2.C.	,,
McFarlane, Sydney	2.C.	,,
Johnson, Albert G.	1.C.M.E.	,,
Wood, John	1.C.M.E.	,,

For week ended 9th February, 1929:—

McFarlane, Walter	1.C.M.E.	Glasgow
Miller, John P.	1.C.M.E.	,,
Cairns, Hugh G.	1.C.	,,
Johnston, William	1.C.	,,

For week ended 9th February 1929—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
McCallum, William	1.C.	Glasgow
Buchanan, Robert T.	2.C.	,,
McKendrick, James W.	2.C.	,,
Watt, Robert T.	2.C.	,,
Williamson, Alexander M. ...	2.C.	,,
Jamieson, James A.	2.C.M.	,,
Hogg, Henry	1.C.	North Shields
Kay, Robert	2.C.	,,
Briggs, John	2.C.M.	,,
Dowzer, Thomas H. R.	1.C.M.E.	Liverpool
Ellis, Fred	2.C.M.E.	,,
Lucas, John H.	1.C.M.	,,
Collister, John H.	1.C.	,,
Copland, Thomas C.	1.C.	,,
Hallowell, Edward	1.C.	,,
Powell, Hugh	1.C.	,,
Shuck, William	1.C.	,,
Charlton, Horace T.	2.C.	,,
Ellison, Edward	2.C.	,,
Macadam, James	2.C.	,,
Brighty, James W.	2.C.	Hull
Carr, Edwin W.	2.C.	,,
Jacklin, Enoch E.	2.C.	,,
West, Leonard J.	2.C.	,,
Broadley, Albert E.	1.C.	London
Brown, Frank H. S.	1.C.	,,
Hooker, Frederic H.	1.C.	,,
Whitwam, Sidney G.	1.C.	,,
Awbery, Arthur E.	2.C.	,,
Dowling, William P.	1.C.	,,
Purse, William	2.C.	,,
Bruce, James H.	1.C.M.E.	Sunderland
Crisp, Frederick	1.C.	,,
Storey, George S.	1.C.	,,
Turnbull, Matthew R.	1.C.	,,
Thompson, Harold	2.C.	,,
Edden, George R.	2.C.M.	,,

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Durban—JOHN STEWART.
San Francisco—F. G. ARCHBOLD.

* G. W. Buckwell, retired.

NOTICES.

1929.

Tuesday, April 9th, 6.30 p.m.—"The Relative Merits of Pulverised Fuel and Mechanical Stoking and their Application suitable for Marine Purposes," by Mr. W. E. Woodeson, Junr., B.Sc., (for Pulverised Fuel); Mr. J. S. Gander (Member), (for Mechanical Stoking).

Saturday, April 13th.—Juniors' Social and Dance,

Tuesday, May 7th, 6.30 p.m.—"Developments in Marine Steam Reciprocating Engines," by Mr. W. J. Muller.

October.—Engineering Congress, Tokyo. Representative. Mr. A. Watt (Vice-President), Kobe. Papers arranged for are:—

> **"Modern Tendencies in Oil Engine Design," by Mr. W. S. Burn., M.Sc. (Member).**
>
> **"Modern Developments of Marine Steam Propulsion." by Mr. G. R. Hutchinson (Member).**

Light Refreshments provided at 5.30 in the Library prior to the Meetings.

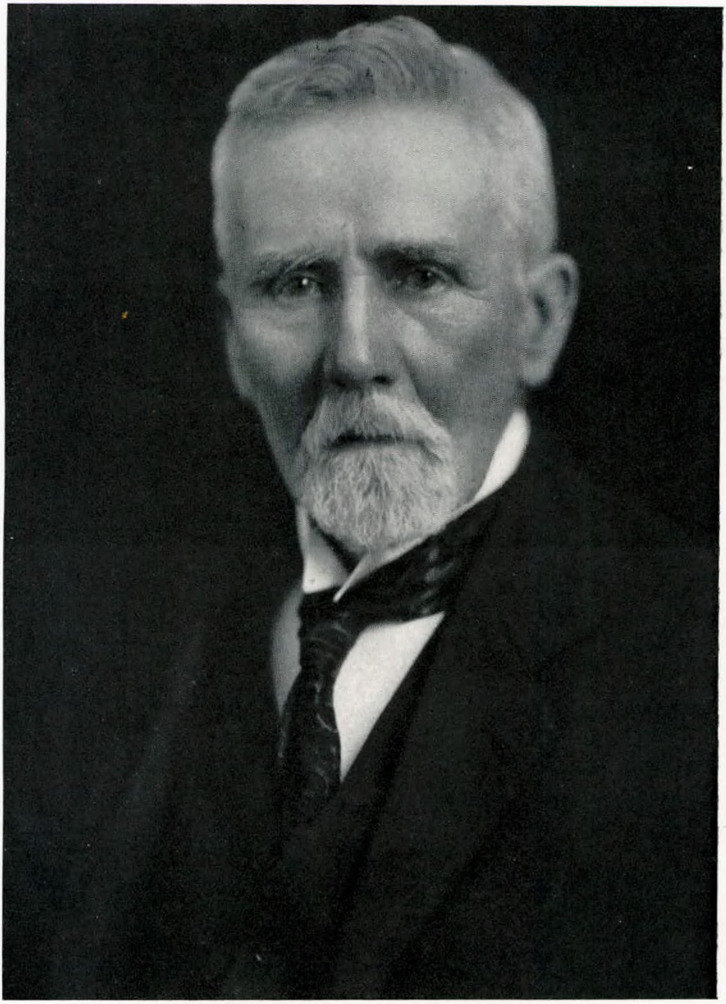
THE AKROYD STUART LEGACY.—Under the terms of this Legacy, an award of approximately £56 is offered for the best paper read at the Institute before May 31st, 1929, and subsequently during consecutive two-year periods, on "The Origin and Development of Heavy Oil Engines." Full particulars may be obtained on application, also *re* Essays for Awards.

The Association of Engineer Surveyors meets in our premises on the first Saturday in each month at 7 p.m.

The Oil Engine Trials Committee Reports, Nos. I.-V, in Booklet Form, are now available at 4/- each, plus postage 2d. per copy. Copies may be obtained from the Institute.

The London Shipping Orchestra meet for practising in the Lecture Hall on Monday evenings.

In response to an Invitation received from The Scientific and Technical Club, 100, Fox Street, Johannesburg, South Africa, it has been arranged that any of our Members calling at Johannesburg may visit the Club, and any Members from South Africa calling at London, may visit our Premises.



ALEX. BOYLE (Vice-President).

It is with keen regret that we record the death of Alex. Boyle, Vice-President, which took place at his home, "Cartsburn," Northwick Park Road, Harrow, on February 27th. The funeral was at the City of London Cemetery, Ilford, on March 4th, when members of his family circle, several of his old associates and friends were present. His son, Engr.-Lieut. Com. H. A. Boyle, D.S.C., having been recently transferred from Southampton to S. Africa as Lloyd's Register Surveyor, was unable to be present. His son-in-law, Revd. W. Tatham, conducted the service at the grave.

Alex. Boyle was born and educated at Greenock, then served his apprenticeship with Messrs. Rankin & Blackmore. He went to sea in 1872 in the Bibby Line and the Leyland Line, and served in the "Albanian," "Arabian," "Bulgarian," and other steamers in the line. He was promoted to Chief-Engr. in 1875 and it is interesting to note that he served in one of the steamers that Jas. Weir, one of the founders of G. & J. Weir, Cathcart, had served in and this resulted in a friendship between them.

He was Assist. Supt.-Engr. in the Leyland Line, Liverpool, for about 18 months, until he was appointed Surveyor of the Board of Trade in 1884, and was in the London area till about 1892, when he was transferred to Dover, and returned to London about 1897. He was afterwards appointed to Southampton as Senior Surveyor. In 1905, in succession to J. A. Rowe, who followed after J. Macfarlane Gray, he was appointed Chief Examiner and came back to London. In 1909 he was promoted to the office of Engineer-Surveyor-in-Chief, Victoria Street, Westminster, and was retired in 1916.

During the time he was Surveyor, he was well-known around the Docks, and residing at Forest Gate, he was interested in the foundation work and progress of the Institute, in which he also lent a helping hand and served as Member and Chairman of Council. While at Southampton where a centre had been established, he also gave a helping hand.

On his return to London he continued his interest and help and was well worthy of his election as a Vice-President of the Institute.

To Mrs. Boyle and the family circle our sympathy is extended.