The
INSTITUTE of MARINE ENGINEERS
Founded 1889. Incorporated by Royal Charter, 1933.

Patron: HIS MAJESTY THE KING.

SESSION
1937.

Vol. XLIX.
Part 7.

President : STEPHEN J. PIGOTT, ESQ., D.Sc.

Voith-Schneider Propulsion

With particular reference to Vessels having a Common Power Installation for Propulsion and other Purposes.

By Captain E. C. GOLDSWORTHY.

THE principles of the Voith-Schneider propeller are now known throughout the maritime countries of the world and in most of them vessels fitted with this form of propulsion are either in service or under construction. The author does not, therefore, propose to dwell at length with the technical properties of this form of drive, as they have already been published in various technical journals in this country and a paper was read on the subject before the Institution of Engineers and Shipbuilders in Scotland in November, 1935. A film was also shown at The Institute on the 20th February 1936, to the Junior Section, in which vessels fitted with Voith-Schneider propulsion were shown performing evolutions. On the same occasion various slides illustrating the construction of the propeller were also shown.

Briefly the Voith-Schneider propeller consists of a number of blades of aero-foil section rotating in the horizontal plane. These blades are connected through control arms and levers to a centre control collar. This central controlling point can be moved off centre in any direction, by means of the control arm which in turn is moved by the operation of one, or both, of the servomotors which are operated either by the speed lever or the wheel at the control position on the bridge. Thus if the lever and wheel are in their amidships position, the control centre is also in dead centre and the blades revolve without any feathering movement being given to them, that is to say no thrust is given.

If either the lever or wheel or both are moved then the control centre is moved also, and as this revolves, the linkage gear is brought into motion and thrust and counter-thrust are given to each blade in its revolution. The direction and force of this thrust depend upon the amount the control lever or wheel is moved. It will be seen, therefore, that the Voith-Schneider propeller acts not only as a propulsive unit but also as a steering force.

The thrust can be applied for going ahead, astern, for ordinary steering, or for turning the vessel on the spot. With a twin propeller installation placed in the normal position at the stern, the propellers usually revolve outwards, when looking from above, and the movement of both lever and wheel effects the thrust of both in the same direction and degree.

It may be desirable in certain types of ships to be able to move the vessel in a purely transverse direction. This is possible with twin Voith-Schneider propellers, even when placed at the stern, since a third control lever can be fitted which in effect deharnesses the two propellers, so that the thrusts of each are given in a direction that will produce a resultant thrust athwartships from about the centre of the water plane.

The purpose of this article, however, is to show the particular application of Voith-Schneider propulsion to vessels such as firefloats, floating cranes, salvage boats, cable-laying ships, etc. In other words, ships where power is not only required for propulsion but simultaneously for some other specific work.

Before the advent of the Diesel engine, ships which required in addition to the propeller drive a power plant installation for special purposes were commonly constructed so that each drive was obtained from its own steam engine whilst a common boiler plant supplied the steam. This method with the steam engine was technically and economically the best solution.

When the Diesel motor was introduced, conditions were not so favourable. Each propeller and power unit required its own engine unless the choice was given to Diesel-electric plant. The latter from a purely technical viewpoint has an attraction and the following advantages :—

(a) that the current produced by one or more Diesel-driven dynamos can be distributed as required;

(b) that bridge control for propulsion and control of the fire pumps, cranes, salvage pumps, dredger pumps or bucket work can be arranged. Furthermore, by regulating the propelling motor a limited number of revolutions and quite slow speed is possible. Finally, it is possible to use high-speed Diesels on the power unit while the propeller connected to the electric motor can be of low revolutions. The absence of the shafting with electric drive in the types of vessels under consideration is no gain since these special ships have no passenger or cargo space which might be encroached upon by shafting.

On the other hand, electric drive has the great disadvantage that it is expensive, not only in first cost but in operation. The dynamos, motors, cable installation and control gear are higher in initial cost and more complicated than a simple mechanical coupling. But above all, the loss of power in transmission which in the smaller installations may amount to 20 per cent. or more is economically unfavourable. These disadvantages of electric drive tend to weigh against its advantages and the question, whether direct or Diesel-electric drive is better, remains, fundamentally, an open one.

During the last two decades, therefore, ships fitted with engines for special purposes have presented a varied picture. Some owners adhere to steam propulsion by virtue of its being cheapest in first cost, others to direct Diesel or Diesel-electric drive. Only seldom does the engine drive the propeller and a special installation at the same time, since the ship's screw demands very definite conditions of engine revolutions and also change of direction of rotation.

The Voith-Schneider drive provides the ideal solution to the problem confronting vessels of this special type, since the propeller is uni-rotational and of constant speed no matter what may be the conditions of thrust or movement of the vessel. The engine also is of constant speed and uni-rotational. This fact allows of an all through shaft on the fore side of which can be worked the pumps, dynamos or other secondary power requirements. A clutch can be fitted on the engine shaft to cut out the secondary power installation when not required. A similar clutch can also be placed on the propeller shaft to stop the propeller turning if the vessel is to remain in the same position for a considerable time, thereby allowing full maximum power to be used on

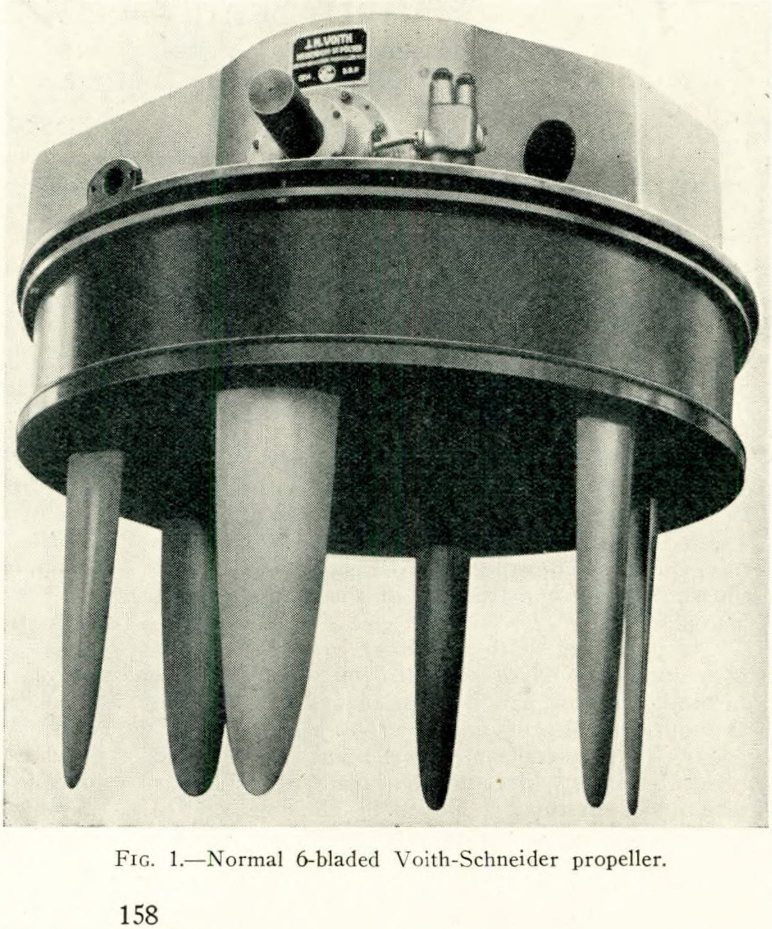


FIG. 1.—Normal 6-bladed Voith-Schneider propeller.

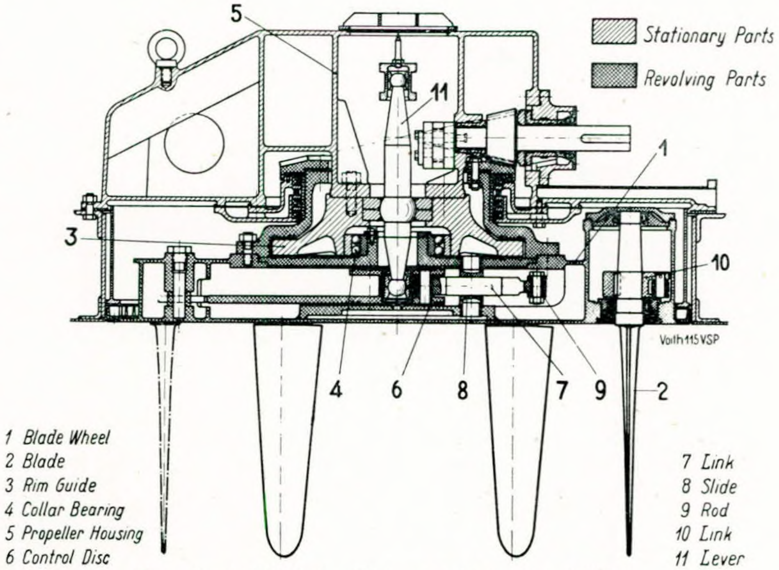


FIG. 3.—Voith-Schneider propeller—type "M".

the secondary installation. This may be desirable since should the propeller be revolving in the neutral position, i.e., giving no thrust, the power absorbed will be about 8 per cent. of the total power.

The Voith-Schneider drive allows both propulsion and the secondary power system being used at the same time, e.g., with a firefloat the float can be moving up to her position and a certain power be absorbed by the propeller whilst the remainder goes to the pumps. With a floating crane, the vessel can be moving and at the same time the crane operated.

The main fundamental advantages, therefore, of the Voith-Schneider drive for the dual purpose ship may be classified as follows :—

1. More effective propulsion can be given, particularly with vessels of limited draft, since the diameter of the propellers can be increased to obtain the proper swept area required. The draft, therefore, can be kept to a minimum and this might be of great value to firefloats working in a tidal area where they might be called upon to fight fires in warehouses and where it would be of vital importance to keep close to the seat of the fire. The London River is a typical example of the advisability of having shallow draft firefloats.

2. The manœuvrability of the vessel is vastly superior to any other type of propulsion and the purely lateral movement which can be obtained with twin propeller installations is of particular importance to firefloats and floating cranes. This latter manœuvre is not possible with any other form of drive.

3. Bridge control is given in all Voith-Schneider ships for propulsion and this control operates direct to the servomotors of the propellers which vary direction and force of thrust from zero up to maximum in any direction. Furthermore, the action is instantaneous, since no heavy moving parts have to be eased up, stopped or accelerated in the opposite direction in order to change the direction of thrust.

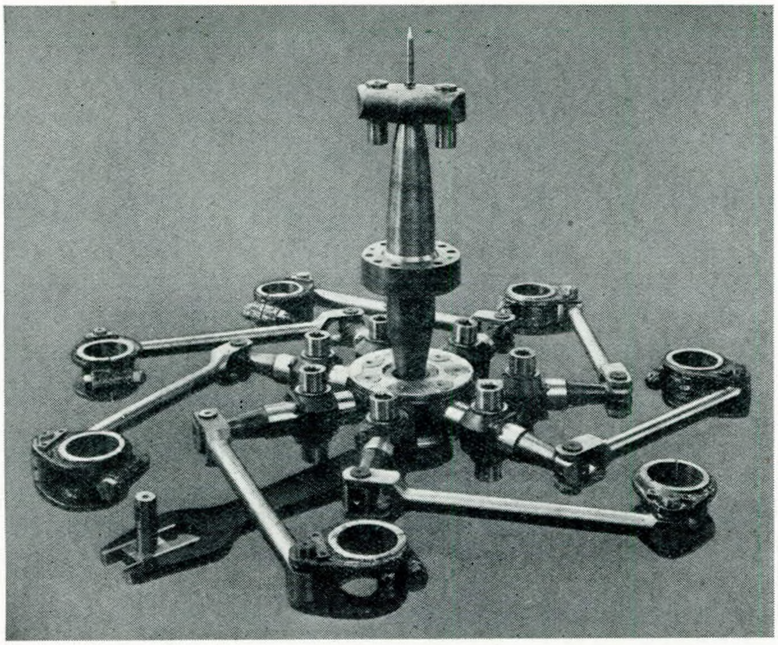


FIG. 2.—Control arm and complete linkage.

4. High-speed uni-rotational engines are used and the same engine can drive both the propeller and secondary power installation, thereby effecting a considerable saving in price and weight of the primary power plant.

The above advantages have been realised by many shipowners throughout the world and the following gives certain particulars of those in operation.

The Japanese Navy ordered some three years ago a 30-ton floating crane having dimensions 92′ × 46′ × 4′ 3″ draft with a displacement of 430 tons and a speed of 5 knots. This vessel has electric drive and two Voith-Schneider propellers of 48″ diameter each with six blades 27½″ in length. These propellers are coupled direct to motors of 75 h.p. running at 1,050 r.p.m. The propellers are placed at the stern and rotate at a speed of 170 r.p.m.

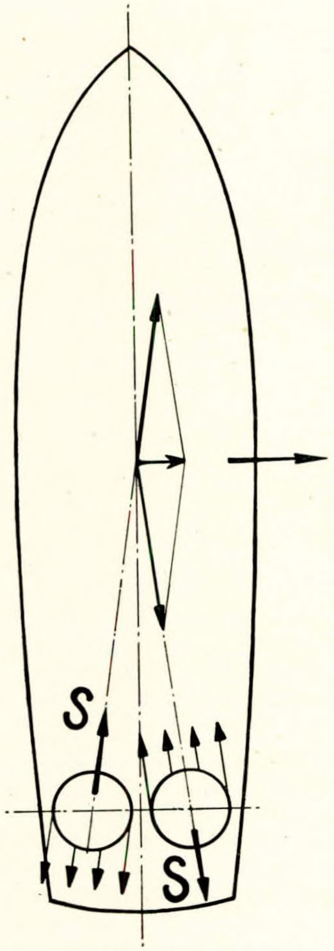


Fig. 4.—Thrusts of twin propellers to give transverse movement.

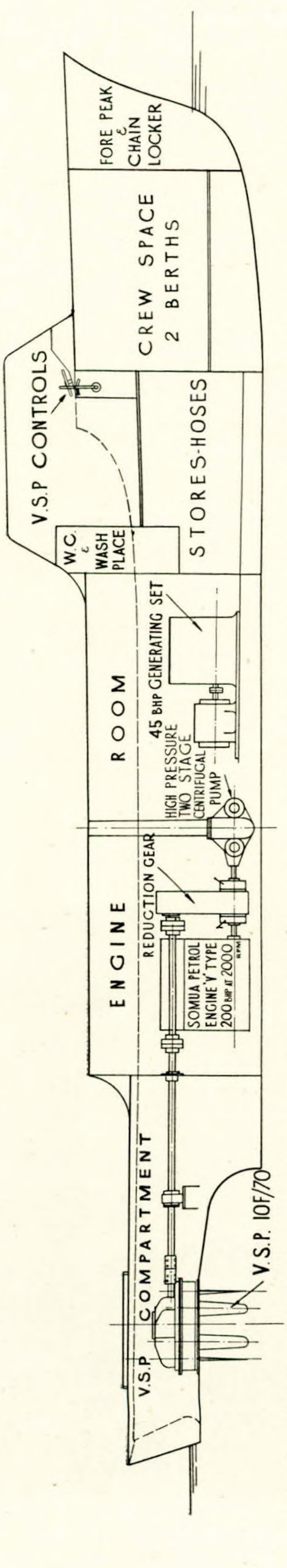


Fig. 5.—Fire-floats (reduction gear has been introduced giving a speed of 1,000 r.p.m. on the shaft, and the gearing integral with the propeller gives the latter a speed of 265 r.p.m.).

The Harbour Authorities at Wilhelmshaven put into commission about a year ago a 100-ton floating crane of about 1,400 tons displacement having direct drive from two Diesel engines of 450 b.h.p. each on to two Voith-Schneider propellers. The practicability of this vessel has been so demonstrated that a similar vessel is now under construction.

A particularly interesting conversion is now being carried out in an 80-ton floating crane having 480 tons displacement, at the port of Gothenburg. This vessel was originally a pontoon having no power for propulsion. In order to carry out the conversion to a self-propelled vessel with a minimum of cost a Diesel engine of 240 b.h.p. has been placed athwartships with all-through shafts directly connected to two Voith-Schneider propellers each of 56″ diameter and 36″ blade length. Sponsons have been built out to carry the propellers and the hull has been cut away for a distance of about one propeller diameter forward to about the same distance aft, so that the hull in way of this portion is raked downwards and inwards to the bottom of the pontoon. This was necessary to allow for the flow of the water when the thrust was being applied in the thwartships direction either for turning movement or transverse movement.

Two firefloats have recently been put into service on the Seine for the Municipality of Paris and visitors to the Paris Exhibition may possibly see these firefloats stationed alongside the Exhibition grounds. They are 68′ in length, having a breadth of 13′ and draft of 3′ 4″ and a displacement of about 36 tons, each having a single petrol engine of 200 h.p. output at 2,000 r.p.m. This engine drives both the Voith-Schneider propeller and the fire pumps. The propeller is of 40″ diameter with a blade length of 27″ and propeller revolutions of 220 r.p.m. Only 150 b.h.p. is absorbed by the propeller, giving the vessels a speed of about 12 knots.

Another very interesting application of the Voith-Schneider drive in what may be termed a dual purpose vessel, namely a cable-laying ship, has recently been put into service by the Imperial Japanese Ministry of Transport. This vessel has two ordinary screws and a rudder giving her a speed of about 14 knots. When she has picked up her cable and requires to steam at a very slow speed, the rudder is unable to hold the vessel to her course. A Voith-Schneider propeller has, therefore, been installed on the centre line aft operating from a 100-h.p. motor at 1,000 r.p.m. The propeller is about 48″ in diameter with six blades about 28″ in length. This is quite sufficient to propel the vessel and to keep her steady on the desired course. When the vessel is proceeding in open sea at full speed, the propeller is disconnected by means of a clutch and the blades revolve in neutral and give practically no resistance.

Another very interesting point of this particular ship is that the propeller and its motor are contained in an airtight chamber so that the propeller can be unshipped at sea and an auxiliary cover plate put into position inside the propeller well.

It will be seen, therefore, that the Voith-Schneider drive, quite apart from its suitability for normal passenger or tug work, has particular advantages where special ships are concerned.

STUDENTSHIP EXAMINATION, 1937.

The following are the papers set for the recent Examination :—

ENGLISH AND GENERAL KNOWLEDGE.

Monday, June 7th, 1937. 7 p.m. to 10 p.m.

Both Sections 1 and 2 to be attempted.

SECTION 1.

Write an essay about 500 words in length on one of the following subjects :—

(*a*) The course of theoretical and practical training that, in your opinion, a marine engineer should have.

(*b*) The eighteenth century in England.

(*c*) The political aims of Fascism and Communism.

(*d*) The influence of rivers on the prosperity of a country.

(*e*) The modern ocean-going ship.

(*f*) China.

(*g*) The English language.

SECTION 2.

Not more than *five* questions to be attempted. All questions carry the same marks.

1. Choose three of the following and explain briefly why their names are remembered: Disraeli, Leonardo da Vinci, Danton, Cicero, Caxton, Galileo, Abraham Lincoln.

2. What countries are the main producers of the following: nickel, radium, mineral oil, wheat, tobacco? Write a paragraph on the production of one of these commodities.

3. Describe briefly the character of one of the following: Falstaff, Oliver Twist, Becky Sharp, D'Artagnan.

4. What are the principal rivers of North America? Mention the main cities to which they give access by water.

5. What are isobars and isotherms? Describe the arrangement of isobars that indicates a period of settled fine weather.

6. State briefly what you know of one of the following :—

(*a*) The discovery and early settlement of Australia.

(*b*) The Romans in Britain.

(*c*) Edward III.

(*d*) Cardinal Wolsey.

(*e*) Martin Luther.

7. Mention two classical and two modern English novels or plays by different authors. Then write a short description of one of the works in your list.

8. In what respect are light, heat and sound similar? Why does a prism divide a white light into its constituent colours?

9. Give four sea routes to Australia and New Zealand from London and state one port on each route at which a ship may call.

10. Choose four of the following and write an explanatory sentence about each term chosen: star, planet, satellite, spiral nebula, comet, meteor.

ELECTROTECHNOLOGY.

Tuesday, June 8th, 1937. 7 p.m. to 10 p.m.

Not more than *six* questions to be attempted. All questions carry equal marks.

1. What do you understand by "Self Induction"? Give two practical instances of its effect on direct current and alternating current circuits respectively.

A coil of wire having an inductance of 0·2 henry when connected across a 440-volt direct current circuit allows a steady current of 25 amperes to flow. What current will flow through the coil if connected across an alternating current supply of the same voltage and having a frequency of 50 cycles per second?

2. What class of cable would you select in the following situations? State the extra protection that should be provided where necessary. Give reasons for your answers.

(*a*) Underground connection to an outhouse for a 3-phase alternating current electric motor.
(*b*) Trailing cable in a workshop.
(*c*) Fixed wiring in an engine room or boiler house.
(*d*) Domestic installations for a housing estate of small houses in course of erection.
(*e*) Main cables on a large passenger ship.

3. A resistance of 25 ohms is connected in series with two coils of 5 ohms and 20 ohms respectively, joined in parallel with one another. The whole combination is connected across a direct current supply of such a pressure that the "drop" down the 25 ohms is 200 volts. Under these conditions calculate:—

(*a*) the current flowing through each resistance.
(*b*) the voltage at the terminals of the 5 and 20 ohms resistances respectively.
(*c*) the voltage of the supply.

4. Make a diagram of a simple circuit consisting of one 150-watt, 220-volt metal filament lamp, a single-pole tumbler switch and an ammeter.

In this circuit are also to be connected three voltmeters. Voltmeter number one is to be connected across the customer's supply terminals, voltmeter number two across the terminals of the tumbler switch, and voltmeter number three across the lamp's terminals.

State the approximate readings of each of the four instruments:—

(*a*) with the switch closed.
(*b*) with the switch open.

5. Define the terms "foot-pound" and "horse power".

A lift raises a load of 2 tons through a distance of 300 feet at uniform speed in 1½ minutes. Assuming the gearing and motor to have a combined efficiency of 55 per cent., determine the horse power input of the motor and the current it takes if connected across a 440-volt direct current supply.

6. Why is the output of an alternator usually stated in kilovolt-amperes (kVA) instead of kilowatts (kW) as in the case of a direct current generator?

Two single-phase alternating current motors each rated at 25 brake horse-power and having efficiencies of 80 per cent. are connected to the same supply at 230 volts. The power factor of one of the motors is 75 per cent., whilst that of the other has been improved to 95 per cent. What will be the kilowatts and the kilovolt-amperes supplied under full load conditions in each case?

7. Give a general description of the chemical actions which take place in a lead-acid accumulator on charge and during discharge.

A secondary battery of 100 cells connected in series is discharged until the electromotive force equals an average value of 1·8 volts per cell on open circuit. The battery is then put on charge and the charging current is maintained at 15 amperes until an average electromotive force of 2·6 volts per cell is obtained on open circuit. Assuming the internal resistance of each cell to be 0·025 ohm, determine the applied voltage required at the beginning and at the end of charge.

8. Make two diagrams of a small electric lighting plant. The first diagram is to show the switchboard with the necessary instruments and control appliances upon it.

The second is to be a circuit diagram showing the actual connections from the compound dynamo supplying the power to the switchboard and from the switchboard to the outgoing circuits.

9. What is meant by the *efficiency* of a machine?

A small single-phase alternating current motor develops 1·7 horse power at the motor pulley. An ammeter, voltmeter and wattmeter connected in the circuit give the following readings respectively: 8·5 amperes, 230 volts, 1,545 watts. Make a sketch showing the connections of the instruments in the circuit, and determine the efficiency of the motor, and the power factor at which it operates.

10. What do you understand by the term *resistivity?*

A pair of 19/·072 inch cables each having a cross-sectional area of 0·076 square inch is used to supply a load of 35kW. at a distance of 150 yards from the company's supply terminals. The pressure at the consumer's load terminals is 400 volts. Determine the "drop" in the mains and the voltage at the company's supply terminals.

(Resistivity $=0{\cdot}67\times10^{-6}$ ohm per inch cube).

MATHEMATICS.

Thursday, 10th June, 1937. 7 p.m. to 10 p.m.

Not more than *six* questions to be attempted. All questions carry the same marks.

1. (*a*) Solve the equation $3z^2-13az+12a^2=0$.

(*b*) From the formula $\frac{f}{2}=\sqrt{d(D-d)}$ find d when $f=2{\cdot}5$ and $D=4$.

(*c*) Two quantities x and y are connected by the equation $y=ax^2+bx+c$. It is known that the following are corresponding values of x and y.

x=	-2	1	3
y=	15	0	10

Find the values of a, b and c.

2. Prove that if $\log_{10}N=x$ and $\log_{10}M=y$, then $\log_{10}(N^rM^s)=rx+sy$.

Use logarithms to evaluate p from the formula

$$\left\{\frac{p^2+0{\cdot}35t^2}{0{\cdot}7071}\right\}^{\frac{2}{3}}=9{\cdot}46 \text{ when } t=2{\cdot}817.$$

3. If N is any positive number and $e=2{\cdot}718$ prove that $\log_{10}N=0{\cdot}4343\log_eN$.

An approximate value for the entropy of water at temperature t °F. is $\log_e\left\{\frac{t+460}{492}\right\}$. The actual value of the entropy of water at 255° F. is 0·3745 and at 365° F. is 0·5447. Calculate the value of the entropy at 255° F. and 365° F. as determined by the formula and in each case find the percentage error in the approximate value thus obtained.

4. The total cost £C of a voyage of 2,000 miles in a certain ship, assuming that a constant speed of v knots is maintained, is given by

$$C=\frac{6000}{v}+\frac{4v^2}{3}$$

Plot a graph to show the relation between C and v from $v=12$ to $v=18$ knots.

From your graph find the value of v for which the total cost is least.

5. The deck of a certain ship is 240 feet long, measured along the centre line. At convenient distances x feet along this line from the bow measurements are taken of d, the width of the deck in feet, measured perpendicular to the length. The results are as follows:—

x=	0	36	60	96	120	156	192	240
d=	1·2	9·7	17·4	26·6	31·8	33·6	30	15·6

Plot a graph to show the variation of d with x, and find the area of the deck in square feet.

6. Prove that in any triangle ABC

$$\frac{a}{\sin A}=\frac{b}{\sin B}=\frac{c}{\sin C}$$

A point A moves on a circle, centre 0 and radius 7 inches, and a second point B which is always 56 inches from A moves on a fixed straight line through 0. Find the angle ABO and the distance OB when the angle AOB=70°.

7. The cross-section of a prism is an equilateral triangle of side 8 inches. One end plane is perpendicular to the length while the other is cut off obliquely so that the parallel edges of the prism are of lengths 14 inches, 15 inches and 17½ inches. Find the volume of this prism, its weight if it is made of material weighing 175 pounds per cubic foot, and the total area of the three trapezoidal faces.

8. In an experiment to find the weight W pounds of water evaporated per pound of fuel, when the fuel was consumed at the rate of S pounds per hour the following results were obtained :—

S=	52	68	78	94	115
W=	13·4	12·2	11·6	11·0	10·4

By plotting a graph with values of W as ordinate and values of $\frac{1}{S}$ as abscissae show that these results are connected by a law of the type $W=\frac{a}{S}+b$, and from your graph find the values of a and b.

9. Prove that in any triangle ABC in which the angle A is acute

$$\cos A=\frac{b^2+c^2-a^2}{2bc}$$

The sides of a triangle are AB, 14·7 inches, BC, 16·3 inches and CA, 18·7 inches. Find the smallest angle of this triangle and the length of the straight line joining A to the middle point of BC.

10. A regular polygon of n sides is inscribed in a circle of radius r. Prove that its area is given by

$$\frac{nr^2}{2}\sin\left(\frac{360}{n}\right)^\circ$$

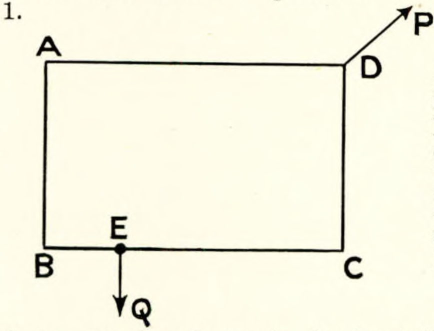
A regular polygon of 10 sides is inscribed in a circle of 6 inches radius and a similar polygon is circumscribed about this circle. Find the difference of the areas of these two polygons. Find also the perimeter of each of these polygons.

APPLIED MECHANICS.

Friday, 11th June, 1937. 7 p.m. to 10 p.m.

Not more than *six* questions to be attempted. All questions carry the same marks.

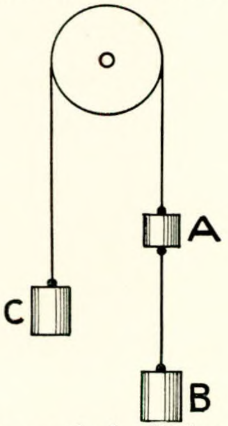
1.



A light rectangular postcard ABCD, 5½ inches by 3½ inches, is kept balanced in a vertical plane with the long edges horizontal by 3 forces, P applied at D, R at A and Q at E. Q has a magnitude of ½lb. and acts vertically downwards. BE is ¼ of BC. The line of action of P passes through E. Find, either by drawing or by calculation, the magnitude and direction of the force at A, and the magnitude of P. Neglect the weight of the postcard.

2. An aeroplane is moving horizontally at 100 miles per hour, at 1,000 feet above a level district, and when vertically above a flagstaff drops a small heavy body. How far from the flagstaff will the body hit the ground, and with what velocity?

3. State Newton's Second Law of Motion.



The bodies A and B are connected by a string and A is connected to the body C by a string over the smooth pulley shown whose inertia may be neglected. The weights are:

A 1lb.
B 2lb.
C 1½lb.

If the system moves freely find the tension in the string connecting A with C and also in that connecting A with B.

4. In a particular lifting mechanism the velocity ratio is 32. An effort of 20lb. lifts a load of 160lb. Calculate the efficiency at this load.

Sketch, and describe the operation of, any lifting mechanism you know which would roughly satisfy these conditions.

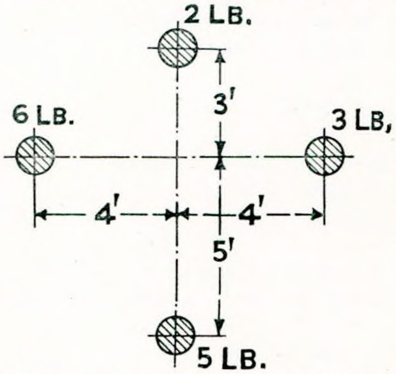
5. The velocity time graph concerning the motion of a particular body moving in a straight line passes through the points :—

Point.	Velocity in feet per second.	Time in seconds.
A	0	0
B	10	100
C	18	200
D	30	400
E	0	600

Plot the five points, choosing suitable scales. You may assume that the graph consists of straight lines between the points.

What is the total distance traversed during the 600 seconds?

6. What is meant by the centre of gravity of a system of masses?



Four bodies are attached to two light bars fixed at right angles to each other as shown. Neglect the weights of the bars and find the position of the centre of gravity of the system shown. You may use either calculation or a graphical method.

7. Give a list of four quantities which you regard as Vector Quantities and state in each case why you include them in your list.

A ship is steaming due west at 20 miles per hour and a wind is blowing from the south-west at 10 miles per hour. What would be the apparent speed and direction of the wind to a passenger on the ship?

8. Describe any experiment you have seen, or have carried out yourself, to determine the value of the Modulus of Elasticity of any material and give an approximate value of the result obtained.

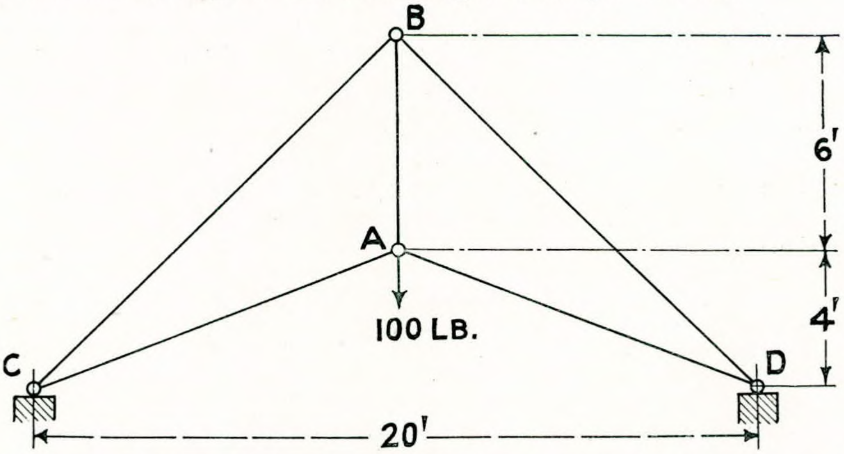
A piece of steel strip $\frac{1}{2}$ inch wide and 1/40 inch thick is originally straight. It is bent round the outside of a shaft 1 foot in diameter. Calculate the maximum stress in the steel strip, assuming that it has not taken a permanent set.

$$E = 30 \times 10^6 \text{ lb. per square inch.}$$

9. A beam of round section 4 inches in diameter rests horizontally on two supports at its ends 8 feet apart. Calculate the maximum stress at mid-span due to its own weight.

Sketch the bending moment and shear force diagrams and give the value of the bending moment and shear force 2 feet from a support. The beam weighs 42·8lb. per foot run.

10.



A symmetrical steel framework is arranged as shown with pinned joints. The supporting forces are vertical. Obtain the force in each member when a load of 100 pounds is applied at the central lower joint A.

MACHINE DRAWING.

Monday, June 14th, 1937. 7 p.m. to 10 p.m.

Attempt Section A and not more than *three* questions from Section B.

Section A.

On the accompanying sheet you are given isometric sketches showing details of an eccentric for a shaft 12 inches in diameter. You are required to draw the following views of the eccentric, properly assembled :—

(*a*) Elevation, looking along the axis of the shaft.
(*b*) End elevation.
(*c*) Plan.

Scale : 3 inches to 1 foot.

Items such as studs, nuts, set-screws, etc., not detailed in the given sketches are to be supplied and shown in place.

In view (*a*) the outline of one of the cotter bolts is to be indicated by dotted lines.

Show about *six* of the main dimensions on your drawing.

Section B.

1. Describe any additional work required to be carried out on the eccentric referred to in Section A before it is assembled in a new engine.

2. What would be the travel of the slide valve operated by this eccentric? What is the purpose of the set-screws which are fitted to the eccentric sheaves at A?

3. (*a*) What precautions are taken in "pulling in" large studs such as those used for securing the upper eccentric strap to the eccentric rod?

(*b*) Of what materials would the various parts of the eccentric assembly be made?

(4) (*a*) Sketch the following types of bolt head, making the bolt shank about 1 inch in diameter :—

(i) cheese, (ii) spherical, (iii) tee, (iv) eye, (v) hook.

(*b*) Sketch *three* methods of locking a nut on a bolt. These sketches need not be dimensioned, but should be properly proportioned.

5. Sketch a simple slide valve in "mid-position" and mark clearly the "steam lap" and the "exhaust lap". What is meant by "lead" and "angle of advance" as applied to valve gear?

HEAT ENGINES.

Tuesday, June 15th, 1937. 7 p.m. to 10 p.m.

Not more than *six* questions to be attempted. Callendar's Steam Tables and Entropy Diagrams are supplied for the use of candidates. All questions carry equal marks.

1. Find the volume of one pound of air at 300 pounds per square inch absolute and at 425 degrees Centigrade if R, the gas constant for air is 96 foot pounds per pound per degree Centigrade. If the one pound of air expands at constant temperature, the ratio of expansion being 3, find the work done and the heat supplied during the expansion. If, after the expansion, the temperature of the air is reduced at constant volume to 100 degrees Centigrade, find the pressure. Illustrate your solution with a PV diagram.

2. The following particulars apply to a test on a compound condensing steam engine :—

Diameter of H.P. cylinder	7 inches.
Diameter of L.P. cylinder	13 inches.
Diameter of H.P. piston rod	$1\frac{3}{4}$ inches.
Diameter of L.P. piston rod	$1\frac{3}{4}$ inches.

Stroke, 20 inches for both cylinders.
Average mean effective pressure H.P. cylinder 40 pounds per square inch.
Average mean effective pressure L.P. cylinder 14·4 pounds per square inch.
Revolutions per minute, 124.
Load on brake, 376 pounds.
Average spring balance reading, 27·5 pounds.
Diameter of brake wheel, 8 feet.
Diameter of brake rope, 1 inch.

Determine (*a*) the I.H.P., (*b*) the B.H.P., (*c*) the mechanical efficiency, and (*d*) the ratio of the work done in the H.P. to that done in the L.P. cylinder.

3. Carefully explain, with the aid of a neatly drawn sketch of the apparatus, how you would determine the calorific value of either a solid or a gaseous fuel. Your answer should include an explanation of the working out of the calorific value from the test data.

4. Describe the throttling type of calorimeter as used to determine the dryness fraction of steam.

A throttling calorimeter was attached to a main steam pipe and the following readings were obtained: Temperature of steam before throttling, 381·8 degrees Fahrenheit; temperature after throttling, 219·5 degrees Fahrenheit; pressure after throttling, 15 pounds per square inch absolute. Determine the dryness fraction of the steam.

5. Explain what is meant by brake mean effective pressure.

A four cylinder petrol engine on test develops a brake mean effective pressure of 108 pounds per square inch. The bore and stroke are $2\frac{1}{2}$ inches and $4\frac{1}{4}$ inches respectively and the speed is 2,000 revolutions per minute. Find the brake horse power, and the engine torque in pounds feet.

6. Sketch and describe *one* of the following:—

(*a*) the fuel valve for an air injection oil engine;

(*b*) a safety valve suitable for a marine boiler;

(*c*) a piston rod gland suitable for the H.P. cylinder of a large marine engine.

7. Briefly explain, by means of a PV diagram, the ideal cycle of operation for an internal combustion engine in which a mixture of fuel with air is drawn in on the suction stroke. Show that the thermal efficiency of the above cycle is equal to $1-\left(\frac{1}{r}\right)^{\gamma-1}$, r being the ratio of compression and γ the adiabatic index.

8. The analysis of a certain fuel oil gave 85 per cent. carbon and 15 per cent. hydrogen. If this oil were used in the furnace of a boiler and the air supply was 40 per cent. in excess of that theoretically required for combustion, estimate how much heat would be carried up the funnel by the excess air per pound of oil fuel burned. The stokehold temperature is 85 degrees Fahrenheit, and the temperature of the gases at the base of the funnel is 500 degrees Fahrenheit. Take the mean specific heat of the air as 0·24. (Atomic weights: C, 12; 0, 16; H, 1. Air contains 23 per cent. of oxygen by weight).

9. Describe, with the aid of diagrammatic sketches, the operation of any type of refrigerating plant.

10. The steam consumption of a turbine is 28,800 pounds per hour. The steam at the turbine stop valve has a pressure of 250 pounds per square inch absolute and the temperature is 601 degrees Fahrenheit (degrees of superheat 200 Fahrenheit). The absolute pressure at exhaust is 0·9 pound per square inch. If the steam at exhaust has a dryness fraction of 0·91 find the approximate horse power developed in the turbine.

INSTITUTE NOTES.

ADDITIONS TO THE LIBRARY.

Purchased.

King's Regulations and Admiralty Instructions (Amendments K.R. 4/37 and 5/37). H.M. Stationery Office, 3d. net each.

Presented by the Publishers.

Lloyd's Register of Shipping, Vols. I and II, 1937-38.

F.B.I. Register of British Manufacturers, 1937-38. Federation of British Industries.

The following British Standard Specifications:—

No. 209-1937. Fuel Oils for Diesel Engines (Petroleum and Shale Oils) including methods of test. (This specification has been revised in order to bring it into line with modern requirements, the development of the modern high-speed Diesel engine having led to a demand for higher grades of fuel than those specified in the 1924 issue. The revision includes a grade of oil suitable for engines for automotive and allied purposes of speeds in excess of 800 r.p.m. as well as for other grades).

No. 742-1937. Fuel Oil for Burners (Petroleum and Shale Oils) including methods of test. (This specification covers oils for domestic purposes, including central heating installations, marine engines and industrial installations of every description. In all, eight fuel oils are specified).

No. 729-1937. Method for Testing the Zinc Coating on Galvanised Articles other than Wire (Copper Sulphate Test and Visual Examination).

"Lloyd's Book of Ports and Shipping Places". The Corporation of Lloyd's, London, E.C.3, 2s. 6d. net, 2s. 8d. post free.

This publication comprises a list, arranged geographically, of ports and shipping places of the world, and is complete with a very useful index. For general purposes no maps should be necessary, although the arrangement is such that the list can be used if necessary in conjunction with any atlas. The publishers' aim has been to include all ports used by oversea shipping throughout the world, and the approximate position of each port is given in latitude and longitude. It can be confidently anticipated that this work will be found exceptionally useful.

"The Fatigue Resistance of Lead and Lead Alloys (Summary Report)", by H. Waterhouse, M.Met. *Research Report R.R.A. 440* of the British Non-Ferrous Metals Research Association. Published by the Association at Regnart Buildings, Euston Street, London, N.W.1, 7 pp., 2s. net, post free.

For a number of years past the B.N.F.M.R.A. have been conducting a research on the properties of lead and lead alloys in relation to their use for cable sheathing, water piping and rolled sheet. In the course of this work extensive information on the fatigue resistance of lead and lead alloys has been obtained.

These results, hitherto available in a large number of separate reports mainly issued to members of the Association only, are now collected and tabulated in the present publication. The materials covered include lead in various conditions and degrees of purity, and lead with small additions of, respectively, tin, antimony, cadmium, calcium, barium, copper, nickel, and bismuth; tin plus cadmium, antimony plus cadmium, tin plus antimony, tin plus cadmium plus copper, antimony plus cadmium plus copper, and bismuth plus magnesium. In addition a few results of tests conducted at 100° C. in air are given as well as some selected results showing the effects of surrounding media and protective coatings on the fatigue resistance of lead and lead alloys.

"Creep of Non-Ferrous Metals and Alloys: A Review of Published Information", by W. A. Baker, B.Sc. *Research Report R.R.A. 449* of the British Non-Ferrous Metals Research Association. Published by the Association at Regnart Buildings, Euston Street, London, N.W.1, 19 pp., 2s. net, post free.

It has long been recognised that metals undergo slow deformation (creep) when subjected for prolonged periods to high temperatures and stresses, but systematic investigations of the phenomenon have been conducted only in comparatively recent years. At the present time extensive studies of the creep characteristics of materials are in progress, and engineers are adopting the data obtained, as a basis for design, in place of those derived from tests of short duration.

The object of the present publication is to summarise the available published information relating to the creep characteristics of non-ferrous metals and alloys. The data presented have been selected critically, and include information on Copper and Copper Alloys, Nickel Alloys, Aluminium and Aluminium Alloys, and Lead. The numerical values are set out in tabular form convenient for reference, with compositions of materials: each table is followed by a list of papers on which the data are based, with a note on the contents of each paper. An index to all metals and alloys mentioned is supplied.

"Refrigeration Engineering", by H. J. Macintire, Professor of Engineering in the University of Illinois. Chapman & Hall, Ltd., 415 pp., 136 illus., 22s. 6d. net.

Unlike the author's "Handbook on Mechanical Refrigeration", now regarded as a standard work on the subject, his new publication has been arranged for the convenience of students. Much of the data has been taken from the Handbook but in view of the experience gained in many years of instruction as a university professor, it has been necessary completely to rearrange the subject matter.

The earlier chapters deal with the development of refrigeration, the theoretical cycles and properties of various refrigerants used including all the better known refrigerants. Useful information is given on the flow of liquids and heat transfer through metal surfaces, heat leakage and insulation. Subsequent chapters relate more to the practical construction of compression machines, the various types of condensers, evaporators and brine systems, all of which have lately been considerably altered and improved.

The industrial applications of refrigeration in recent years have increased enormously, particularly with regard to comfort cooling. The author has treated this important branch of the subject in a scientific manner and deals with the investigation of air conditioning as applied to warehouses, mines, theatres as well as in the household. The book contains many useful tables and diagrams, including larger charts giving the properties of the better known refrigerants and psychrometric charts. The practical applications are based mainly on the latest American practice.

It may probably be disappointing to anyone in this country to find that the author has not dealt with marine refrigeration. This highly important branch in a maritime country deserves a complete chapter to itself. In America, refrigeration as applied to land work is regarded as a most important branch of engineering, but there is very little application for marine work. It must be remembered, therefore, that the book has been written for American students.

"Hydro- and Aero-Dynamics", by S. L. Green, M.Sc. Sir Isaac Pitman & Sons, Ltd., 166 pp., 65 illus., 12s. 6d. net.

This book is intended as an introduction to the theory of the motion of fluids. It is written for students of hydraulics, aeronautics, and applied physics, as well as for those whose interests are mainly mathematical.

The contents of the book include: equations of motion; continuous motion in two dimensions; conformal transformation—discontinuous motion in two dimensions; flow and circulation—theorems and applications; vortex motion in two dimensions; wave motion; motion in general; motion of a viscous fluid; and flow at high Reynolds numbers.

The book is based on lectures given by the author over a considerable period at Queen Mary College, University of London, where he is a lecturer in mathematics. Numerous exercises are included, many of them being questions taken from examination papers set by the University of London. The author also provides a useful list of books for further reading.

"Principles of Quantum Mechanics", by Alfred Landé. Cambridge University Press, 115 pp., illus., 7s. 6d. net.

Although described on the dust-cover as "An introduction to modern physical theories", this book can only be recommended to those whose mathematical knowledge is somewhat more profound than is, in general, necessary in engineering. However, as an introduction to and correlation of the work of Heisenberg, de Broglie, Schrodinger and Dirac, Professor Landé's book is likely to remain the best of its kind for many years.

"The Calculation of Convective Heat Flow", by E. W. Still, B.Sc. Emmott & Co., Ltd., Manchester, 24 pp., illus., 1s. net.

This short monograph contains a deal of data, set out in a very condensed fashion and purporting to cover the calculation of rates of heat flow for:—

(a) Turbulent liquids in pipes;
(b) Turbulent non-condensing gases in pipes;
(c) Streamline flow of liquids in pipes;
(d) Air flow across tube bundles, and
(e) Air flow across gilled surfaces.

The monograph requires very careful study and test before it can be accepted as entirely reliable, but it is one which should be indispensable to designers of new types of heat exchange apparatus, once the graphs and tables have been thoroughly checked and established. Some of the data and formulæ given appear to be open to criticism in the light of other publications. It is a pity that the explanatory matter is so extremely brief.

"Technical Electricity", by J. E. Phillips, M.A., B.Sc., and R. W. B. Stephens, Ph.D., A.R.C.S., B.Sc. The Technical Press, Ltd., 288 pp., 187 illus., 7s. 6d. net.

This book is intended primarily to provide an introductory course in electricity and magnetism for students in technical schools and colleges, and as such it can be recommended to teachers.

The contents include magnetism, electrostatics, the electric current, circuits and effects, cells, magnetic and electrical measurements, instruments, induced currents, and a brief introduction to the dynamo and motor. Useful worked examples are given in the text, though the reviewer must take exception to that on page 199 on the score of practicability.

In addition to being a useful guide on elementary electricity and magnetism, the book includes descriptions of simple experiments dealing with the various principles involved. The authors show that they appreciate the difficulties the subject often presents to students by the way in which they carefully emphasise various points usually casually referred to by writers with less experience in teaching what is really a very difficult subject to many. At the end of each chapter is given a series of questions selected from the examination papers of various educational bodies, and answers are given to the numerical problems included in them.

The diagrams are clear and useful, and the descriptive matter and explanations are particularly precise and commendable.

"How to Patent and Commercialise Your Inventions", by D. B. Miller, M.Inst.P.I. Sir Isaac Pitman & Sons, Ltd., 63 pp., 2s. 6d. net.

This book is written in a popular style and will serve the purpose intended by the author, i.e., that of giving the general public a broad picture of the subject matter of the title. Serious inventors, however, would be well advised also to secure the official publications of the Patent Office in regard to the first part of the title. With regard to the commercialising of inventions, it is generally far harder to commercialise an invention than it is to secure a patent for it.

Channel Trip.

Upon the arrival in the Thames of the new cross-Channel passenger motor vessel "Royal Sovereign" on Tuesday, July 13th, a number of Members of Council and Vice-Presidents of the Institute inspected the vessel at Tower Pier by the kind invitation of the General Steam Navigation Company, Ltd. The latter recently became the owners of the New Medway Steam Packet Company, whose vessels, to which the "Royal Sovereign" has been added, are engaged in the passenger service between Yarmouth and Gravesend and Ostend, Boulogne and Calais.

The "Royal Sovereign", which, like her one year older sister the "Queen of the Channel", was built by Messrs. William Denny Brothers, Ltd., at Dumbarton, embodies a number of features of special interest to marine engineers and naval architects. These are described in an article which is reproduced on pages *149* to *154* of this issue, by kind permission of "The Marine Engineer".

On Saturday, July 24th, a party of 41 members and ladies made the crossing to Ostend and back in the vessel. Of these, 24 travelled from London by rail to Margate, where, with seven others who arrived by road, they joined the vessel and met the remaining members who had embarked at Gravesend and Southend. The crossing occupied 3½ hours each way, the schedule allowing passengers three hours ashore at Ostend. The weather conditions were better than had been forecast, and the trip proved both interesting and enjoyable, the interest being enhanced by the fact that the engine room department was in charge of a member of the Institute, Mr. R. C. Youngs, acting in a supervisory capacity on behalf of Messrs. Sulzer Bros. Mr. C. A. Marriott (Member), assistant to the Superintendent Engineer of the General Steam Navigation Company, was also on board, and both he and Mr. Youngs were complimented on the all-round excellence of the "Royal Sovereign" as regards her design, equipment, and particularly the machinery installation.

◆

ABSTRACTS OF THE TECHNICAL PRESS.

Performances and Prospects of Steam Installations with Coal-fired High-pressure Boilers.

The author reviews recent developments in marine engineering designed to strengthen the competitive position of steam and coal in the medium-sized and small types of merchant ships. Referring to mechanical stokers and pulverised coal installations, he points out that it is essential to adapt the design of the combustion space of the boiler to the firing conditions, and he draws attention to a new design of the Wagner-Bauer water-tube boiler with Babcock pulverisers. This has recently been fitted in a 750 i.h.p. river tug, and it is stated that requirements regarding natural circulation have been successfully met in combination with the most favourable combustion space. The author further alludes to the considerable reductions in steam consumption which have been obtained by combining improved reciprocating engines, such as the Lentz and Christiansen & Meyer types, with Bauer-Wach turbines or by means of the arrangements adopted in the White "Economy" engine, which have resulted in coal consumption figures of 1·05lb. to 1·00lb. at normal pressures and temperatures for powers below 1,500 i.h.p. He considers, however, that further reductions of the steam and coal consumption can only be obtained by means of very high pressures and superheat temperatures and he states that in reciprocating engines the adoption of temperatures exceeding 700° F. to 750° F. involves reheating between the cylinders, as in recent Bauer-Wach Deschimag installations, in which a super high-pressure cylinder is added to a normal reciprocating engine and live steam is employed for re-superheating purposes. In order to avoid the difficulties which arise from the contamination of the feed water of high-pressure boilers by lubricating oil, geared turbines, such as the Parsons Simplex type, can now be substitutes for reciprocating engines at powers between 1,000 h.p. and 2,000 h.p., and by this means coal consumptions of ·92lb. to ·98lb. per s.h.p. per hour can be obtained on a power/weight ratio of 77lb. per s.h.p. The author finally suggests that the gains in space obtainable with modern boilers and turbines of this type can be further increased if the boilers are arranged above such geared turbines or below the machinery in turbo-electric installations. —*By O. Jebens, Hamburg. From "Werft, Reederei, Hafen", Vol. 18, No. 12, p. 182, 15th June, 1937.*

Forty Years' History of the Diesel Engine.

The writer briefly sketches the early history of the Diesel engine and traces its development at the hands of the companies originally associated with Dr. Diesel, namely the M.A.N. and Krupp's, of their principal licencees and of the makers who adopted the Diesel principle in their oil engine designs after the original patents had expired. Referring to the initial stages of the introduction of the Diesel principle, the writer stresses two points: (1) That only in the second patent, taken out in 1893, was the adiabatic process substituted for the isothermal process of combustion contemplated in the original patent of the preceding year. (2) That the successful realisation of the inventor's ideas was largely secured by the technical and financial assistance of his collaborators, viz., the M.A.N. and notably its general manager von Buz, together with two of its engineers, Vogel and Lauster. It is also to be noted that as early as 1893 the firm of Krupp's associated itself with the development work, which four years later resulted in the completion of the first marketable Diesel motor. This 20 h.p. engine was subjected to the first output and consumption tests on the 17th February, 1897, a consumption of ·52lb. b.h.p. hour for the motor alone being obtained. A comparison of this value with the figure of ·35lb. b.h.p. hour obtainable at present, i.e., a reduction of 35 per cent., indicates the progress achieved since then. The relative position of Diesel and steam machinery is illustrated by the fact that whereas in 1897 the consumption of the Diesel engine was by weight 70 per cent. less than that of a coal-fired cylindrical boiler installation, present-day large marine oil engines still consume 30 per cent. less fuel than the best sets of high-pressure turbine installations with oil-fired boilers. In the course of brief reviews of the work done by the leading makers, more particularly in the marine field, the writer in each case indicates the line of advance pursued and the outstanding achievements. Among these the M.A.N. throughout aimed at the realisation of the double-acting two-stroke type, which was finally evolved as a slow-running port-scavenging engine, suitable for the direct drive of propellers. Its production has covered a wide range of propelling sets, both for naval vessels, notably submarines, and merchant ships, including the 30,000 b.h.p. installation of the "Augustus" and those of the German pocket battleships, which develop 56,000 b.h.p. on two shafts. In the marine field the success of Sulzer Bros. is based on the single-acting two-stroke engine, and international importance attaches to the Büchi system of supercharging which they have developed. In 1936 the total output of this firm passed the 5,000,000 b.h.p. mark, covering both marine and stationary sets of various types. In the preceding year they had achieved on the test bed as low a consumption as ·35lb. b.h.p. hour in a 5,500 b.h.p. marine set. Burmeister & Wain have to their credit the first Diesel engines for an ocean-going merchant vessel, namely the two 2,500 b.h.p. motors for the 11 kn. "Selandia" of 1912, which is still in service with the same engines. Up to the end of 1936, this firm has completed marine Diesel engines aggregating

4·4 million b.h.p. together with 267,000 b.h.p. for land purposes, including the largest existing stationary set, of 22,500 b.h.p., which was built for the Copenhagen Power Station. The writer duly recognises and gives particulars of the work done by Carel Freres, Doxfords, Krupps, Deutz and Benz. *—Dr. Ing. E. Foerster, Hamburg. From "Werft, Reederei, Hafen", Vol. 18, No. 12, p. 191, 15th June, 1937.*

Launching Experiments on Two Ship Models.

Of the two models tested, one represented a ship which had already been launched, and the second a prospective launch. The first set of experiments was carried out largely with a view to obtaining a comparison with the known full-scale results, thus making more certain the prediction, from the model results, of the launching run, etc., for the second ship, which was unusually large in relation to the size of the harbour. The coefficient of friction between the fixed and the sliding ways was obtained from the time-distance curve of the first ship, and the retarding forces on the models arranged accordingly, the actual friction between the ways being kept as small as possible by means of rollers. So far as hydrodynamic forces are concerned, there is similarity between model and ship, according to Froude's law, apart from the usual scale effect on skin friction. The pivoting point, at which the stern begins to lift, was observed and found to occur earlier than the calculated position for both the first ship and its model, but the second model lifted at approximately the calculated point. Instead of the usual drag weights, the braking arrangements in the case of the second model consisted of fins projecting laterally from the hull. Since the resistance of these varies as the square of the speed, there is less likelihood of the ship being pulled up too sharply if the speed is low. Fins towards the stern, such as have previously been used, were not very effective, the best positions being at about one-third the length from the ends. Additional braking was provided by rafts, attached to the ship by ropes, and arranged to function when the ship was clear of the ways. Observations of the height of the wave produced by the first ship and its model were in fair agreement; the height of wave produced by the second model corresponded with 4 feet above still-water level, full-scale.—*H. Stemmer, "Schiffbau", Vol. 38, pp. 197-200, 217-9.*

Development of the Sulzer Diesel Engine.

The author discusses briefly such changes as the adoption of supercharging and direct injection, higher speeds and reduced weight per horse-power, and the use of reduction gearing. At the high fuel pressures, of the order of 6,000lb. per sq. in., necessary for direct injection, quality of material and workmanship for pumps and valves is of great importance. The quality of the fuel, particularly asphalt content, also tends to become more important, although the latest engines can use an oil with 8 per cent. asphalt. It may be economical to tolerate the greater frequency of overhaul necessary when the low-grade oil is burnt. At the high injection pressure oil is no longer incompressible, as is demonstrated by oscillograph pressure records, obtained by means of a piezometer.

Over a period of years, the weight per horsepower showed a steady increase up to the year 1925, but it has since fallen, and is now in the neighbourhood of 110lb. per b.h.p. for the larger engines. The adoption of steel castings and of welded construction has tended to reduce weight, but not cost. Increase of speed has also tended in the same direction, and has amounted to about 25 per cent. in the last ten years. To obtain high power per shaft, two engines, fitted with vibration dampers and elastic couplings, have been geared to a single shaft, and powers of 7,000 b.h.p. have thus been reached, using two six-cylinder engines, geared down from 215 to 87 r.p.m.

Direct injection, apart from reducing weight by eliminating the compressor, makes for greater flexibility in manœuvring, and speed in manœuvring has also been increased by direct control from the bridge. Direct injection has also reduced fuel consumption, and 0·33lb. per b.h.p. hr. can now be achieved. Higher speeds have directed attention to the vibration problem, which has been successfully dealt with.—*C. Zublin. "Werft, Reederei, Hafen", Vol. 18, pp. 221-3.*

Reconditioning of the Transport "Republic".

The "Republic", a vessel of 17,900 tons, was built at Belfast in 1907, and was in service as an intermediate liner until 1930, except during the War, when she served as a troopship. The reconstruction which has just been carried out at a cost of over 500,000 dollars consisted principally in replacing the Scotch boilers by water-tube boilers. The original boilers were cut up for removal as far as necessary to avoid disturbing the structure. The boiler room tank top was renewed. There are four boilers supplying steam at 240lb. per sq. in. to the two quadruple-expansion engines, each of 8,000 i.h.p., which give the ship a speed of 14 knots. New independently-driven air pumps, and three-stage centrifugal feed pumps were installed. The after superstructure was rebuilt and extended, and new lifeboat handling equipment, with electric winches, was fitted. The entire ventilation system was renewed, and an extensive loudspeaker installation for routine and emergency use fitted throughout the ship. Two-way communication is provided between the bridge and the engine-room and various operating stations. The steam cargo winches were replaced by new ones, and a fire-detection system installed. The new boilers are of the Foster

Wheeler cross-drum sectional-header type, fitted with air heaters and superheaters.—*"Marine Engineering & Shipping Review", June, 1937, pp. 318-321.*

Transatlantic Air Services.

After giving some figures relating to the initial Atlantic flight of the "Caledonia", the article discusses the possibilities of future flights with increased payload. The "Caledonia" has an all-up weight of 45,000lb., including 18,750lb. of fuel and oil, and 1,000lb. payload. She has a range of 2,500 miles cruising at 160 m.p.h., against a 40 m.p.h. headwind. In the actual flight, the cruising speed was about 150 m.p.h., and there was sufficient fuel left for about 900 miles at the end of the flight. The take-off horse-power is 940 b.h.p. (per engine), and so far as take-off is concerned the weight could be increased to 51,500lb., subject to the size of harbour being sufficient for the increased run, thus giving increased payload. The corresponding increase in wing loading is from 30 to 34·3lb. per sq. ft., but this figure may be exceeded in future aircraft. The normal cruising power is 510 b.h.p. per engine, at which the fuel consumption is 27·5 galls. per hr., but the most economical cruising speed (in still air) is somewhat lower, about 140 m.p.h., and the corresponding consumption 22·5 galls. per hr. This would allow less petrol and more payload to be carried, at any rate on the eastward run, when there is less likelihood of headwinds. The specific consumption should be less with a sleeve-valve engine, and is already as low as 0·38lb. per h.p. hr. for the Diesel, as compared with 0·42 for the petrol engine. The low take-off power of the Diesel would, however, necessitate assisted take-off. Further possibilities of increased payload are opened up by the experiments to be carried out on the Mayo composite aircraft, and on refuelling in the air.—*"The Engineer", Vol. 164, p. 75, 16th July, 1937.*

◆

EXTRACTS.

The Council are indebted to the respective Journals for permission to reprint the following extracts and for the loan of the various blocks.

Dopes for Lubricating Oils.

By Professor J. S. S. Brame, C.B.E., F.I.C., F.C.S.*

"Gas and Oil Power", June, 1937.

For years subsequent to their introduction mineral lubricating oils were employed in what may be termed their virgin purity. Given suitable viscosity characteristics, and a degree of refining which removed components which would affect their reasonably good performance, the mineral oils met the requirements of industry.

For some special purposes to-day, where more onerous conditions are imposed, the improvement of the straight types of mineral oil in one or more characters is being effected by certain special additions.

Similar treatment of fuels for internal-combustion engines probably anticipated the application to lubricants. The success of one of the many "dopes" to motor spirit to stabilise the colour, prevent gum formation, and in general to act as anti-oxidants, naturally suggested similar treatment of the lubricating oils. Perhaps the best known addition has been that of tetra-ethyl lead to petrol as an anti-knock. Additions may be made with two distinct objects. Firstly, the improvement of the lubricating characters; secondly, the improvement of the oil, i.e., a better viscosity temperature curve, improved pour point, greater resistance to oxidation changes, therefore reduced thickening, sludge and carbon formation.

Oiliness.

The addition of a very small quantity of the fatty acids to improve the "oiliness", according to the Wells-Southcombe process, is well known. Of more recent development has been the introduction of lubricants of exceptional film strength—the "extreme pressure" lubricants. Their necessity has arisen through the high tooth pressures and increased rubbing speeds in modern automobile transmissions, particularly through the introduction of hypoid gears. The most viscous straight mineral gear oils fail to meet the requirements. Recent as has been the introduction of this type of lubricant, industry already has to recognise two types—one, a mild "E.P." type, where sulphur, sulphur-chlorine compounds are employed, and the full hypoid gear type, resisting the highest pressures, where a lead soap (lead oleate, for example) is a common addition.

Corrosion.

A further type, not strictly of the nature of these but having certain characters which render it better able to resist extrusion in, for example, the case of gears, is obtained by the incorporation of flocculent zinc oxide, either directly in the oil as a practically colloidal suspension, or in the usual types of lubricating grease. Where corrosion troubles have to be encountered, such as in the presence of water or steam, the anti-corrosive effect of the zinc is very valuable.

Of greatest interest from the point of view of oil engines is the type where a stabiliser—primarily an anti-oxidant—is added. For this type, sludge reduction and reduced acidity are the primary claims. As early as 1872 Baird obtained a patent for treating mineral lubricating oil with two to five parts of sulphur per 100 parts of oil, and afterwards blending with fatty oils, the claim being made that the natural oxidation of the latter oils was thereby reduced. In 1917 Brown patented the treatment with a very small fraction of red phosphorus.

Modern development has been in the direction of using organic compounds which, in general, have considerable affinity for oxygen—thus certain photographic developers have been employed, for example, one part of pyrogallic acid (pyrogallol) in 70,000 parts of oil, and hydroquinone are said to be effective. Some of these, being much more soluble in water than in oil, may be removed by quite small quantities of water which may be present in the sump oil; more frequent use is now made of compounds insoluble in water yet reasonably soluble in mineral oils. Scores of such compounds have been the subject of patents, in general, amines and hydroxy-compounds being favoured. Less than 0·5 per cent. of hydroxy-diphenyl suffices for cylinder oils and for greases. Several do not function at moderately high temperatures; many diamines (e.g., ethylene diphenyl diamine) being more suitable for high temperatures.

Metallo-organic compounds.

Another type comprises metallo-organic compounds. It has been demonstrated that certain metals in contact with oil accelerate oxidation and sludging—copper, for example. On the other hand, tin is an anti-oxidant. An obvious objection to the use of tin, even in the finest state of sub-division, is its insolubility in oil, and this has led to the patenting of soluble organic tin compounds, tin oleate, rincinoleate, etc. Chromium oleate, with or without tin compounds, has also been the subject of patents.

The lowering of the cold test of oils is another direction in which improvement may be attained by suitable additions. In paraffinic types of oil, wax separation on cooling has to be obviated, and is usually accomplished by refrigeration and pressing. Wax, however, has quite good lubricating properties, and its retention therefore, providing, of course, it will not separate, is of value. "Pour

---

* Director, Alexander Duckham & Co., Ltd.

point depressants" added in quite small quantities enable this to be accomplished. The best known is Paraflow, for which it is claimed that 1·5 per cent. added to an oil with an original pour point of 30° F. reduces the point to below 0° F., with no appreciable change in the other characteristics. Paraflow has been described as a condensation product of naphthalene with a high boiling mono-chloroparaffin.

The newer methods of solvent extraction for refining lubricating oils, when applied to paraffinic (wax-containing) types, raise the paraffin content, hence the cold test, and Paraflow may here prove a valuable corrective.

Viscosity index.

The viscosity-temperature characteristics of lubricating oils have received special attention of recent years, and in the U.S.A. the viscosity index has been adopted very generally as a convenient expression of this characteristic. The scale used is arbitrary, a high grade Pennsylvanian oil being given the standard of 100, whilst the heavy asphaltic type is taken as zero. Many specially prepared oils have a viscosity index of over 100, yet this can be still further improved on. A material used for this purpose is Paratone or Exanol, prepared by polymerising the lower boiling fraction of refinery gasoline. A clear readily soluble product of any degree of viscosity can be made, which is stated to consist almost entirely of *iso*-paraffins. While the addition of two or three per cent. of the product raises the viscosity of the treated oil, it at the same time produces a very considerable increase in the viscosity index. Such treated oils have been subjected to extensive car and lorry tests, and it is claimed they "provide a means of economically obtaining better viscosity-temperature characteristics than can be manufactured solely by refining methods. Better low temperature starting is obtained without loss of protection to the other parts of the engine by excessive thinning out or loss of body".

Effect of Welding on Shipbuilding.*

By JAMES B. HUNTER†

"Marine Engineering and Shipping Review", July, 1937.

Shipbuilding practice has undergone many changes in the last decade. Many new materials have been introduced bringing with them the need for new methods, but the general adoption of welding has had more far-reaching effects than any other one innovation.

Some of the effects observed in shipyard practice and methods due to the substitution of welding for riveting will be discussed in the following, as affecting design, mold loft and fabricating shop, erection and fabrication, outfitting and completion.

Design.—The elimination of faying flanges and laps is the most obvious effect and is probably the greatest single weight-saving factor. However, it should be borne in mind that the flanges did provide certain stiffening effects and the panel size is in effect greater with welded stiffeners at the same spacing. On the other hand the elimination of rivet holes in shell and deck connections, gives an approach to 100 per cent. strength through a frame line in place of a value of approximately 85 per cent. usual with riveting. Some revision of methods for standard strength calculations would appear to be in order, particularly where longitudinal framing is concerned and when comparisons are being made between welded and riveted connections. Care should be used in selection of materials, particularly as regards certain of the high-carbon steels which may be attractive because of higher legend physical characteristics, since these qualities may disappear as a result of welding.

In the race for weight saving, built-up sections have come into common use for stiffeners because of the lack of rolled sections designed for welding. These sections entail greater labour both as to design and fabrication and it is to be hoped that new sections will shortly be available. Such sections should be designed to provide variations in section modulus with the minimum of waste.

Welding has produced a new type of structural plan due to the disappearance of flanges and in some cases laps. This leads to simplification. To produce proper drawings it is necessary that a working knowledge of welding practice be obtained by the draftsman since sequence of welding and assembly plays an important part in avoidance of so-called built-in stresses so far as practicable.

One other point in design appears worthy of note; namely, the rigidity of the structure due to the elimination of slippage inherent in riveted joints. This appears to the writer to call for caution in the adoption of welding for the primary strength members, because of the impossibility of relieving any stress in such members after assembly.

The need of modification of design to enable the maximum amount of prefabrication on the ground or in the shop before erection is evident. If carried to its logical conclusion, it is possible to visualize the future ship made up of a series of prefabricated units all ground assembled with only the joints between units left to be made actually on the ship.

Welding has brought about the virtual disappearance of anglesmith work and staples. Rigging and deck fittings, can often be replaced by simple welded parts. Stems are being fitted of built-up design and even in stern frames castings are being replaced by weldments. Piping, tanks and valve manifolds are largely welded, as are hatch, door and airport fittings and boat davits.

Among the major machinery parts affected, reduction gear and turbine casings are now often

---

*Abstract of paper presented at Spring Meeting of The Society of Naval Architects and Marine Engineers held at Chester, Pa., 22nd June, 1937.

† Head of hull technical division, Bethlehem Shipbuilding Corporation, Ltd., Fore River Plant, Quincy, Mass.

made up of a combination of small castings or forgings and plate, particularly when weight saving is important. Welded shells for condensers and other heat-transfer equipment have largely replaced castings. Boiler drums to meet the higher pressures and temperatures called for to-day would hardly be possible without resort to welding.

Mold Loft and Steel Mill.—In the mold loft, no difference is noted in the original laying down and fairing but the types of molds are changing. Those for welded construction show only holes necessary for assembly but they must be marked for registration with adjacent members in addition to bevel cutting on the edges where required. Indicating position and size of welds is common practice in some yards, though not in all.

The omission of connecting members calls for much greater care in making templates so that the close fits, so desirable for good welding, may result.

Many yards are to-day, particularly on the lighter structures, marking templates to show the sequence of welding and erection. In addition to the individual templates it has been found of advantage to prepare an overall mould for use with prefabricated units to ensure correct outline after assembly and welding.

Steel mill and fabricating shop methods have been very definitely affected by the introduction of welded construction. Laying out now means few holes but more marking to take care of accurate outlines and in many cases location of welds, etc. Check marks are necessary for registration, using waterlines, buttocks, etc., to locate pieces properly in erection. The use of built-up sections for stiffeners means, in many cases, straightening after welding and very often double layout, one for individual pieces, another for overall.

Present practice indicates the advantage of more assembly in the shop and, if shrinkage is taken into account, more material lifted from the ship.

These considerations indicate certain definite changes in shop layout and equipment. Elaborate punch tables and high-speed punches are hardly justified but more and better planing equipment is needed. Much greater assembly space is necessary and this should be of the table or platen type rather than the open skids used for shop riveting. Carriage or portable types of machines for drilling and countersinking appear better adapted to this type of work than elaborate fixed machines. Accurate mechanically controlled flame-cutting equipment is a necessity, if costly hand cutting is to be avoided; if production work is of large volume, machine welding with some form of table appears desirable. Some change in furnace equipment also is required to take full advantage of the use of cutting and welding for forming plates, which otherwise would require severe furnace work.

Erection and Assembly.—Erection and assembly procedure has been greatly modified by the use of welding, due primarily to the omission of holes and flanges for fastening individual members together and also because of the various methods adopted to take care of shrinkage and buckling particularly on the lighter structures.

The erection of a welded structure requires various attachments for lifting. These include pads and clips and in many cases additional temporary stiffening to take care of free edges. Shipfitters, burners and tack welders must be available because of the closer clearances and the need of positioning on datum lines rather than by registration and fastening by holes and bolts. After welding is completed, all temporary clips, etc., must be removed. The advantages of greater ground assembly can of course be obtained only if the crane capacities are large enough to handle the units so assembled, so that for any given yard a balance must be struck for economy.

In assembly, welding in most cases requires greater time due to sequence in order to avoid distortion and the introduction of so-called locked-up stresses. Such sequence usually entails the practical completion of one section before starting work on the adjacent section. This, of course, is in decided contrast to the picture with riveted construction, when riveting gangs can be worked all over the ship simultaneously. This particular requirement entails a definite control on production all the way down the line from the drawings to the finished material.

The greater amount of erection time also directly affects shipyard capacity and of course time of delivery. In the final analysis this may lead to a change in the relationship between shop equipment and the number of building berths.

Outfitting and Completion.—In the manufacture and installation of the hundred and one details that go to complete a vessel to-day, welding is not confined to the use of the electric arc but other forms of weld such as the atomic and spot weld are in common use.

Welding has largely replaced other means of fastening hangers and clips of all kinds, also small foundations and seatings; in this field it offers definite advantages, provided the necessary equipment is available.

Power leads and controls are needed on both building berths and outfitting basins. Special precautions against fire are advisable and different types of mechanics are required.

In testing, it will, I believe, be generally found that while leaks are fewer with welded construction their correction will be more costly since it may be necessary to empty a tank to replace a section of defective weld.

The two shops most affected by the use of welding are the sheet metal and pipe shops, particularly the former. The manufacture of small tanks, ladders, wash troughs, metal floor coverings, lockers, dressers, sheet metal doors, sheathing over insulation, metal tables, airport screens and scoops, dresser and counter tops, and the installation of the never ending label plates, to mention only a few items, have been modified until to-day, particularly in yards engaged on Navy work, one is apt to hunt around for the rivet bin after stumbling over a battery of spot welding machines and being warned off from enclosures devoted to arc and atomic welding.

Piping is to-day often welded on vessels and valve manifolds, headers, etc., are built to suit the particular need by welding rather than casting.

Even the shipwrights have not escaped the ever-present welders, as is shown by their work on rail stanchions, booms, side ladder stowage and, perhaps most interesting of all, the fastening of wood decks by means of studs resistance welded to the steel deck.

Supports for joiner work are to-day largely of metal welded in place, while joiner doors, trim and furniture metal are fabricated by means of welding.

Summary and Conclusions.—Different types of vessels require different methods and shop equipment. It is evident that the simple box-shaped barge can be built with a minimum of equipment and tools; in this type of vessel welding entails the smallest initial outlay. However, as soon as we consider larger ship-shape vessels changes in equipment and methods become of increasing importance; if welding takes the place of riveting in the major portions of the structure, definite modifications of shipyard practice appear inevitable.

We have already seen the development of the building cradle in its various forms, the use of large preassembled units and special assembly methods based on the use of automatic machines with tilting tables or other devices. Many designs have been produced having in mind ease of assembly and production and many different types of assembly clips and attachments.

Conclusions are dangerous and difficult, but, at the risk of making controversial statements, it appears to the author that so far the advantages of welding have been greatest in the case of small vessels, particularly those subject to damage against docks, as it has been demonstrated that fewer leaks develop and this is a particularly important point for small vessels engaged in oil deliveries. The trend in vessels of this type appears to be definitely towards welding the tank spaces completely, leaving the more complicated ends still riveted.

In the larger merchant vessels, welded bulkheads, both transverse and longitudinal, also major parts of the framing and small decks and flats, are being generally welded. These members can be largely ground assembled, leaving comparatively little ship welding, and the weight saving will probably justify whatever extra cost is involved. Units, such as bulkheads, also lend themselves to production methods using automatic machines with special assembly methods, although the first cost of such special fixtures must be justified by reduction in cost of the finished unit produced.

The welding of shell and strength decks on larger merchant vessels introduces major problems both as to design and manufacture, and it appears difficult to justify the greater cost and time involved in this. Some weight saving is possible but the difficulties of assembly are serious and the cost increase large.

Welding has advanced recently to a great degree in the building of naval vessels, but in the design of this type the urge to save weight, because of treaty limitations, justifies increased cost, since military characteristics can be provided, which would otherwise be impossible. Such reasoning, however, cannot be applied to merchant vessels except in very special cases.

It appears to the author that ultimately yard equipment for welded construction will become as similar in yards producing the same type of ships as did equipment for building riveted vessels. While undoubtedly in some cases welding has been undertaken where it cannot be justified by economic considerations, it will ultimately find its true place in the building of that inherently complex structure —a ship.

Welding Large Oil Tankers.

Recent Practice in the United States.

By J. W. Hudson and T. M. Jackson*

"The Motor Ship", July, 1937.

For a number of years welding engineers have been engaged in research work which has advanced welding in shipbuilding to the point where it is now recognized by both shipbuilders and shipowners, not with suspicion, but as a natural development, as a means of saving weight, and of securing greater simplification and economy in ship construction. By the elimination of indirect connections, rivet heads, etc., the welded structure provides smooth surfaces, which permit good drainage and easy cleaning and are subject to less surface corrosion. The advantages and possibilities are practically limitless and at present it is hardly possible to say definitely how far they will lead in altering and modifying present structural design. The natural tendency to hold to orthodox design and to modify it only to the extent that present welding technique and knowledge permit is quite evident, but attention will be drawn to a simplified design, which, it is believed, will provide a type of tanker construction both simpler, stronger and more economical than present construction.

The first self-propelled vessel to be electrically welded was the "Fullagar", which was built in England in 1920 and which, to the author's belief, is still afloat and doing excellent work. While this vessel showed that welding could take the place of riveting, no saving in weight was accomplished, as

---

* Extract from a paper presented at the Spring meeting of the American Society of Naval Architects and Marine Engineers. The authors are the Naval Architect and Chief Electrical and Welding Engineer respectively of the Sun Shipbuilding and Dry Dock Co.

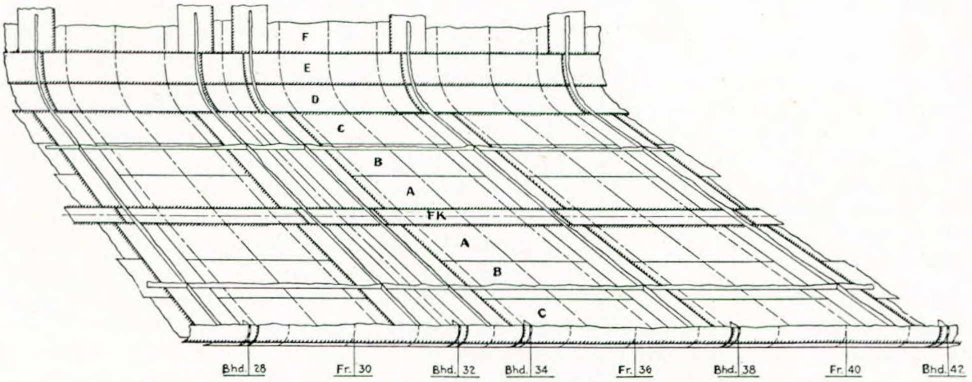


FIG. 1.—Bottom shell plating. Shaded lines indicate field welds.

the vessel was originally designed as a riveted structure. One of the first all electrically welded self-propelled vessels to be built in this country was the "White Flash", a vessel 201ft. 2in. long overall, 34ft. beam, and 12ft. moulded depth with a capacity for 7,500 barrels of oil, which was built for the Atlantic Refining Co. of Philadelphia.

In the earlier designs of welded vessels it was only natural that in the connections to various members the methods used in riveted construction were closely followed. In the case of the "White Flash", however, shapes were entirely eliminated for connections and flat bars were substituted. These sections were thick and, consequently, would have a longer life as regards corrosion than the ordinary angle connection. The contract for the "White Flash" was placed in November, 1930. This was followed three years later by a duplicate ship, the "Franklin". Both vessels evidently more than came up to expectations and showed conclusively that welding could, with confidence, be substituted for riveting.

A bold initiative, both by the owners and by the builders, was undertaken in February, 1936, when the Atlantic Refining Co. placed with the Sun Shipbuilding and Dry Dock Co. an order for a tanker 521ft. long, 70ft. beam, and 40ft. depth, of 18,500 tons deadweight, in which the entire tank space extending from the engine-room bulkhead to the forward end of the tank space for a length of 353ft. was to be of completely welded construction. In March, 1937, the Atlantic Refining Co. placed a repeat order with the same builders, which was followed by an additional contract for a similar vessel for the Sun Oil Co., making at the present time three tankers of over 18,000 tons deadweight with the tank spaces completely welded.

It is now recognized that electric arc welding has become practically indispensable and that it is a sound and logical means of joining metals, to say nothing of the great saving in weight, which, in these vessels, amounts to about 15 per cent. of the total steel. In the design of this vessel, the longitudinal bracketless system was adopted. This system appeared to be the most logical to adopt, as it lends itself more readily to our system of fabrication and erection, is a sound type of construction and relieves the builders as regards design, thus enabling them to concentrate on methods of assembly and of welding procedure. It was evident from the start that welding economy could not be obtained except by machine welding, from which it followed that the welding must be done under cover. This is not only desirable but necessary, as extreme variations in temperature are detrimental, and only under cover could the essential control of uniformity be obtained and the largest assembled sections be safely and conveniently handled, as is the practice in riveted construction at this plant. As a welded structure of this size had never before been attempted, the greatest care and study were given to developing the best method of assembling and erecting the various members in the shop.

Rigidity and Residual Stress.

It is recognized that more intensive study is

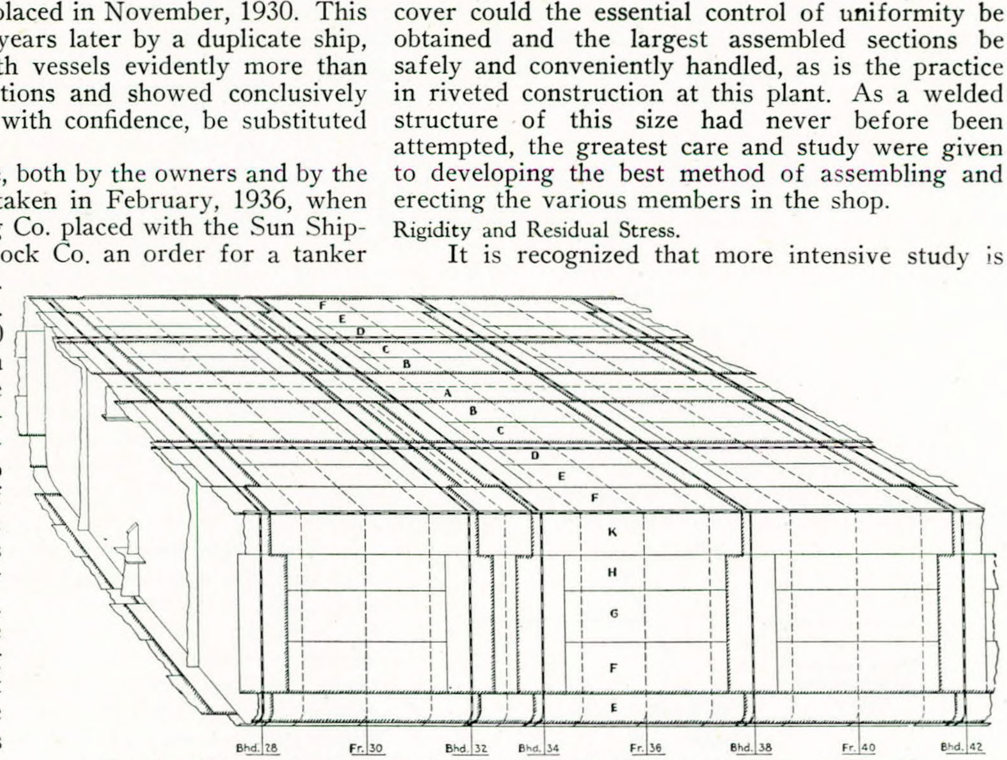


FIG. 2.—Side shell and upper deck plating. Shaded lines indicate field welds.

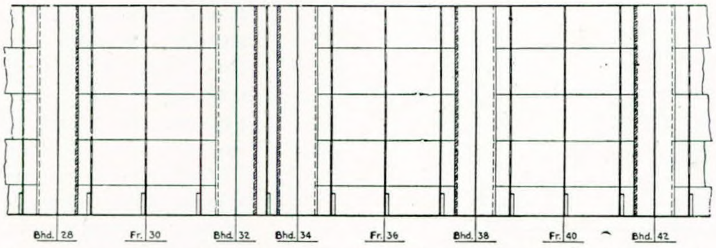


FIG. 3.—Longitudinal bulkhead. Shaded lines indicate field welds.

required in the design of welded than of riveted structures, as the latter have become more or less standardised. In welded structures two very important matters which must be borne in mind are their great rigidity and the residual stresses caused by heat. To obviate the latter as much as possible, all longitudinal members, such as stiffeners and butts, were automatically welded. This method prevents the penetration of various atmospheric elements into the molten metal, as the weld is made in one continuous operation, avoiding distortion and reducing to a minimum residual stresses in the material. At the same time excellent penetration is obtained, which is probably the most important of all the requirements. Butt welding was adopted in all the main structures, lap welding being used only for bracket connections and joggled vertical panel plates at longitudinal bulkheads in way of transverse bulkheads.

As a tanker, for the largest portion of its length, is practically a series of multiple units, that is, similar tanks, it was decided to commence with 117ft. of the structure, consisting of three tanks, each 35ft. long, and a 12-ft. pump room. As previously stated, the longitudinal bracketless system was adopted for this design. A few modifications from the usual riveted design were adopted for the welded ship, the principal of which was the use of heavy wrapper plates at the bulkheads, at the decks and the bottom and side shell, as illustrated in Figs. 1 and 2. In accordance with our usual practice, the longitudinal bulkheads on this vessel were continuous and the transverse bulkheads intercostal, dividing the bulkheads into three pieces, none of which was too heavy or too large to be handled in one piece.

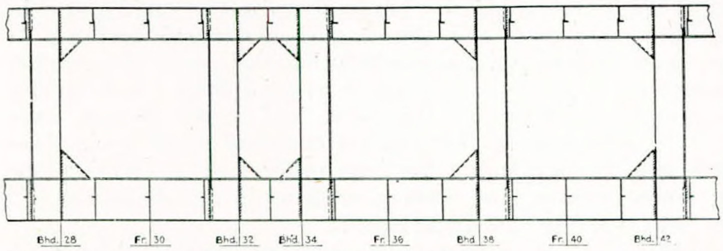


FIG. 4.—Vertical keel and centre deck girder. Shaded lines indicate field welds.

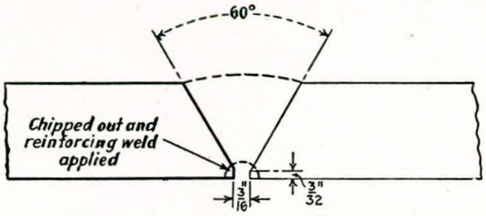


FIG. 5.—Plate edge preparation for manual welds.

All of the different parts of the structure were shop-assembled in one tank length. The centre keelson, rider plate, and flat plate keel with the tranverse brackets (Fig. 9) was one assembly and manually welded. The centre girder at the deck with the deck plate and transverse brackets (Fig. 8) was one assembly.

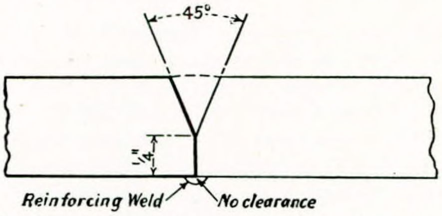
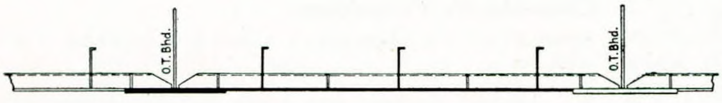
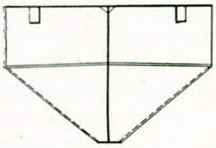


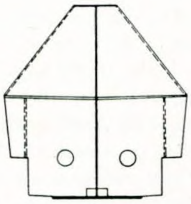
FIG. 6.—Plate edge preparation for automatic welds.

The bottom shell from the keel to the lower turn of the bilge, together with one wrapper plate, transverses and longitudinals (Fig. 1) was one assembly. The longitudinals were machine welded, as were also the shell longitudinal butts; the transverses were welded to the shell manually. From the upper turn of the bilge to the sheer strake, together with the bulkhead wrapper plate, transverses and longitudinals was one assembly. As in the case of the bottom shell, each plate had three longitudinals, machine welded to the plate. The butts were then welded, forming one complete assembly from the upper turn of the bilge to the deck, as stated above and as shown in Fig. 2. The deck plating was treated in a similar manner and was in two assemblies on each side, one from the centre-line strake to the inboard side of the longitudinal bulkhead, and the other from that point to the side of the ship, as shown in Fig. 2. The transverse bulkheads, as previously stated, were in three pieces, the centre position and two wings, intercostal between the longitudinal bulkheads. All horizontal stiffeners and butts were machine welded; the webs, which were assembled with the bulkheads, were manually welded.

The longitudinal bulkhead final shop assembly was one tank length. Each plate was treated separately; that is, the longitudinals were machine welded to each plate and then the longitudinal butts were machine welded to each other, the vertical panel plate was then fitted and welded to the horizontal plates, together with the overhanging longitudinals, which were all manual welded. This vertical panel, as will be noted, is joggled and overlapped on to







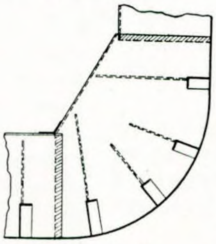


FIG. 7 (top).—Section through forward portion of shell.
FIG. 8.—Centre deck girder assembly. FIG. 9.—Vertical keel assembly. FIG. 10.—Transverse frame at bilge.

the adjacent plates. This is the only overlap fitted in the large assemblies. The reason for this was that this plate was originally intended to be welded to the transverse bulkhead, making it part of the bulkhead assembly; adjacent plates could then be bolted to the overlap in erection. This method, however, was found to be too cumbersome and was abandoned in favour of the assembly finally decided on, as shown in Fig. 3.

Method of Erection.

The erection was carried out in the following order. The first unit was the shop-assembled flat and vertical keel, on one tank space lengths, with frame brackets attached as shown in Figs. 1, 4 and 9. This was followed by the complete bottom shell assemblies, from the flat plate keel to the lower turn of the bilge, port and starboard, in one tank space lengths (see Figs. 1 and 7). In connecting these assemblies to the flat and vertical keel, the bottom transverse frames were bolted to the frame brackets on the keel assembly and the seam of the flat keel and garboard strake was tack welded. Details of construction at the bottom of the webs on both the transverse and longitudinal bulkheads were arranged to permit the entire flat and vertical keel and bottom shell to be placed before any bulkhead was erected.

The complete amidship pump room was next placed in position, the assembly and erection being a modification of that used throughout the tank space. From the amidship pump room the erection was completed one tank space at a time in both directions away from amidships.

For each tank space, the centre-line section of one transverse bulkhead was first placed in position. By tack welding the middle bulkhead web to the vertical keel and by bolting the other webs to the bottom longitudinals, the bulkhead was temporarily self-supporting. This was followed by the longitudinal bulkhead assemblies, port and starboard, as shown in Fig. 3, tack welded to the transverse bulkhead and bottom shell and bolted to the previous section of the longitudinal bulkhead. The webs on the longitudinal bulkhead at the frames were bolted to the bottom transverses.

The centre deck girder assembly, with the centre strake of the deck and the frame brackets attached, as shown in Figs. 2, 4 and 7, was next hung between the transverse bulkheads. This unit was bolted to the middle transverse bulkhead web at one end and tack welded to the bulkhead plating at the other end. After sufficient temporary support was placed under the centre girder, the two side centre deck assemblies (see Fig. 2) were placed in position. The transverse beams on these sections were bolted to the frame brackets on the centre girder and to the frame brackets previously welded to the longitudinal bulkhead.

The two outboard sections of the transverse bulkheads were next erected, the erection of these members being similar to that of the centre-line section of this bulkhead. The bilge plates were not assembled in the shops. These were left until completion of all erection and were the closing-plates of the entire unit. After the outboard section of the transverse bulkheads was erected, the bilge brackets (Fig. 10) were next put in place and bolted to the transverses erected with the bottom shell. This was followed by the erection of the bilge longitudinals. The side shell plating, along with the

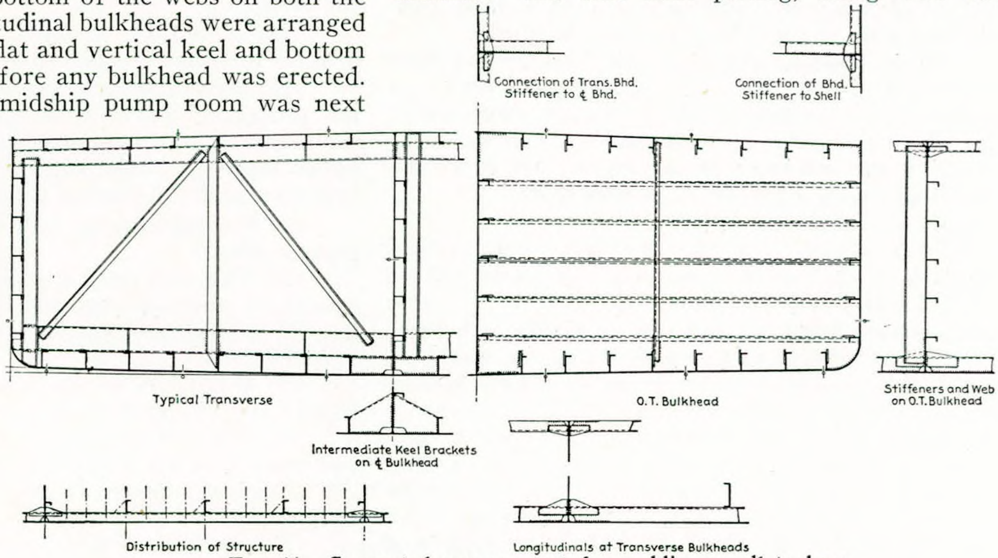


FIG. 11.—**Suggested arrangement for welding small tankers.**

transverses and one wrapper plate, shown in Fig. 2, were next erected in position, the lower part of the transverses connected by bolts to the bilge brackets already in place, and tack welded to the wing transverse bulkheads. The outboard deck section shown in Fig. 2, along with the transverses which were bolted to the frame brackets already in place, completed the 117-ft. unit.

As previously stated, the bilge strakes were the closing plates and were lifted from the ship. Before final welding was commenced, the vessel was well shored, aligned, and checked for length, which was found to be exactly 117ft.

The sequence of final welding the now assembled unit was as follows :—

The flat keel seams throughout, port and starboard simultaneously, were first welded, followed by the longitudinal bulkhead connection to the bottom shell. The transverse bulkhead connection to the bottom shell out to the lower turn of the bilge was the next procedure. Following this, all transverse butts in the bottom shell plating, including the butt of the flat keel, were welded. Then the overlap of the bottom shell longitudinals on the bottom shell were welded in place. Following this, the longitudinal bulkheads were next welded to the transverse bulkhead. The deck plating was next welded, concluding with the welding of the side shell.

In the welding of all butts the back-step method was used; in the case of the flat plate keel, for instance, two welders worked on each seam, working away from the centre towards the ends, backstepping the welding. By so doing, distortion and shrinkage were reduced to a minimum.

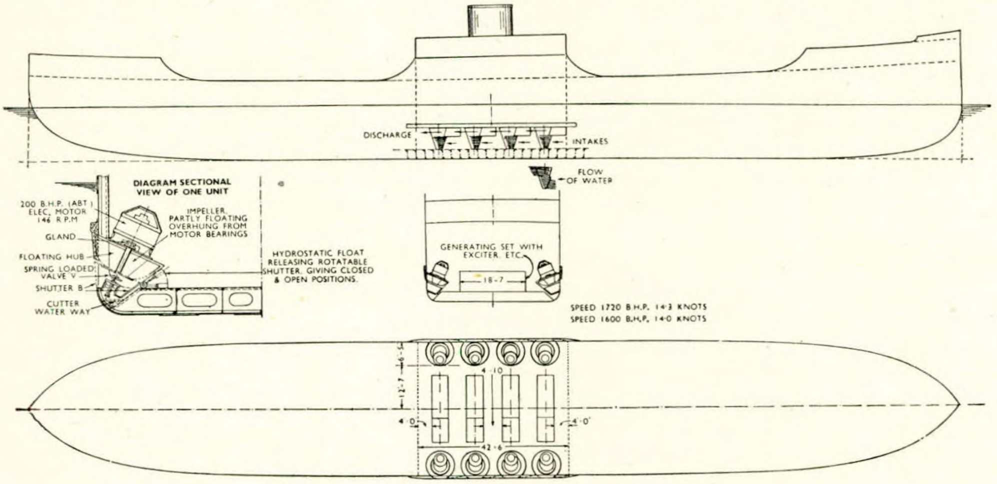
Conclusion

This vessel is to be 100 per cent. welded throughout the cargo space only; the ends will be riveted. It is our opinion that operating results, maintenance costs and savings in weight will more than justify the extra expense, if any, necessary to build such vessels. Ultimately welding must lead to a somewhat different yard personnel, as it is not a strenuous operation; it requires skill rather than brawn. While this vessel represents a decided advance in tanker construction, it by no means represents the ultimate that can be developed for an all-welded ship. Fig. 11 shows a suggested method for welding small tankers.

Cone-electric Propulsion.

Novel Design for Machinery Installation in a 14-knot Vessel.
"The Motor Ship", June, 1937.

During the past few years Hotchkiss cone propulsion has made considerable headway for use with small Diesel-engined craft up to 100 tons deadweight capacity, and, in many instances, has been used instead of steam-driven paddle boats in various parts of the world. In all cases it has been adopted in conjunction with mechanical gearing, which form, of course, may be used in any type of vessel, but does not give the full advantages of the system when large ships are in question. Hence, the layout of machinery, as designed by Mr. Donald V. Hotchkiss for a considerably bigger vessel than has hitherto been equipped, is a matter of interest. It involves the employment of four Diesel-engined generators supplying power to eight electric motors driving cone propellers, four being arranged on each side of the ship.



Design for cone propulsion for a 14-knot ship.

The advantages claimed, when electric transmission is utilized, may briefly be summarized.

(1) Immediate and automatic transference of the propelling power from propulsion to clearing the bilges of water in an emergency. The vessel's speed would be only slightly reduced during the operation and full control would be maintained.

(2) Manœuvring as with twin screws, but with greater effect.

(3) The exercise of side thrust by opposing groups of units on one side.

(4) Steering without the employment of rudders.

(5) Provision of an almost unlimited water supply for fire extinguishing.

(6) Elimination of bilge pumps, steering engine and rudder, screw propellers, shafting, stern tubes, "A" brackets, thrust blocks, reducing gears and shaft tunnels.

(7) Simplification of the stern lines of the vessel.

8. Invulnerability of the propellers.

(9) Absence of vibration, and the elimination of rolling, through gyroscopic effect.

It is claimed that these advantages may be attained at a cost which is lower than that of the installation of electric machinery in a screw-propelled vessel. It may be remarked that during the past ten years over 200 Hotchkiss cone-propelled vessels have been built, and that, in many cases, owners have stated that higher propulsive efficiency has been attained when replacing the screw propeller by the new system.

The vessel for which the installation has been designed is 263ft. overall, with 38ft. moulded beam and 40ft. extreme beam. The loaded draught is 15ft., and the speed, when loaded, is estimated at 14 knots. The total output from the generators is equivalent to 1,740 b.h.p., and electrical and mechanical losses reduce the available shaft horsepower for the cone propellers to a total of 1,440 b.h.p. This figure is not subject to any further losses, the impeller shafts being carried by the main bearings of the electric motors and the thrust taking place on the sides of the cones and not on the impellers.

Propulsion is effected by discharging some 1,200 tons of water per minute from the eight motor-driven cone propellers, and about 600 tons per minute can be pumped from the holds in case of emergency, the action being automatic. There are floats in the hold which rise with the water and release the rotating shutters (B) mounted concentrically in the lower ends of the cones.

These shutters rotate by water friction to a closed position, in which the ordinary sea inlet is closed. The electric motors are thus relieved of pumping load and accelerate, causing the hydrostatic valves (V) to open. Each cone is thus connected to the hold for its supply of water. When the water level falls again, the floats come into operation, releasing the shutters from their "closed" positions and allowing them to make a half revolution by water friction, so that the normal inlets from outside are once more available.

It is claimed that in this way the whole of the propelling horse-power can be suddenly and automatically transferred from propulsion alone to a combination of propulsion and bilge draining. The four Diesel engines driving the dynamos are of the high-speed type. The length of the engine-room is 42ft. 6in.

The claims for high propulsive efficiency are based upon present performance of smaller geared sets used in barges, lighters and small vessels generally, but in the case under notice the discharge fluid is greater in proportion than it is possible to arrange in smaller boats, in which only two or, at most, four cones can be conveniently used. As the pumping efficiency is high it is possible to work with a larger slip loss than with screw propellers, the efficiency of which, as pumps, does not equal that of centrifugal accelerators of the cone-propeller type.

Control can, of course, be effected from the bridge, and any manœuvre independent of steerage way is available. Steering is accomplished by cutting down the electric current on one side and transferring this as an overload to the other side.

The Motorship "Delius".

The First of Three Cargo Liners for the Lamport & Holt Line, Ltd.

"The Shipbuilder and Marine Engine-builder", August, 1937.

One of the most striking vessels to leave a shipbuilding yard recently, departed early in July from Messrs. Harland & Wolff's Belfast works, following the completion of a very satisfactory trial trip. The "Delius", as the vessel is named, is the first of three sister motorships which Messrs. Harland & Wolff, Ltd., had contracted to build for that fine old shipping company, the Lamport & Holt Line, Ltd., and she has entered their trade to Brazil and the River Plate, which was established over 91 years ago by their first ship, a barque of some 677 tons.

Outstanding among the innovations in the design of the "Delius" is the combination of the funnel and bridge in one structure, to which reference has already been made in our pages. The fore part of the funnel has been used for accommodation; while the wireless room and wireless operator's quarters on the navigating bridge, the captain's quarters on the captain's bridge, and the passengers' bathrooms on the bridge deck all extend into the funnel. Another feature which adds considerably to the vessel's smart appearance is the continuation of the band of the Lamport & Holt funnel colours (blue with a white band and black top) through the wheelhouse and bridge superstructure. The funnel itself is stream-lined, as are all the deckhouses; and this, in conjunction with a finely moulded hull form, raked stem and cruiser stern, gives the ship an attractive appearance.

General Arrangement and Equipment.

The "Delius" has the following leading characteristics :—

Length overall, about	456ft. 0in.
Length b.p.	430ft. 0in.
Breadth moulded	62ft. 0in.
Depth moulded to shelter deck	37ft. 9in.
Gross tonnage, about	6,010

The ship has been built under the survey of Lloyd's Register of Shipping to obtain the maximum draught for a complete-superstructure vessel. There are three complete steel decks, as well as bridge and forecastle decks.

The hull, as will be seen from the outline general-arrangement plan reproduced in Fig 2, is divided into nine compartments by eight watertight bulkheads extending to the main deck, and it is noteworthy that the ship is arranged with six cargo

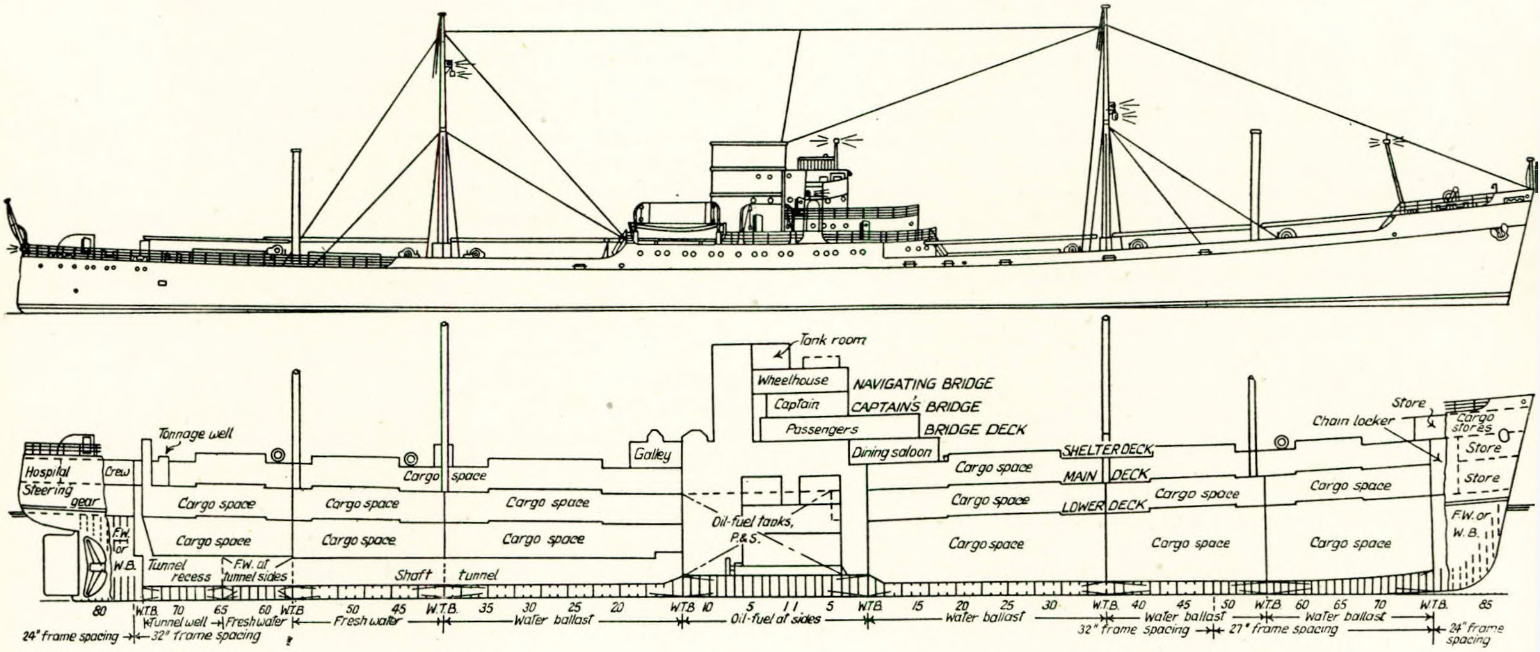


FIG. 2.—General arrangement of the Lamport & Holt motor-driven carg liner "Delius".

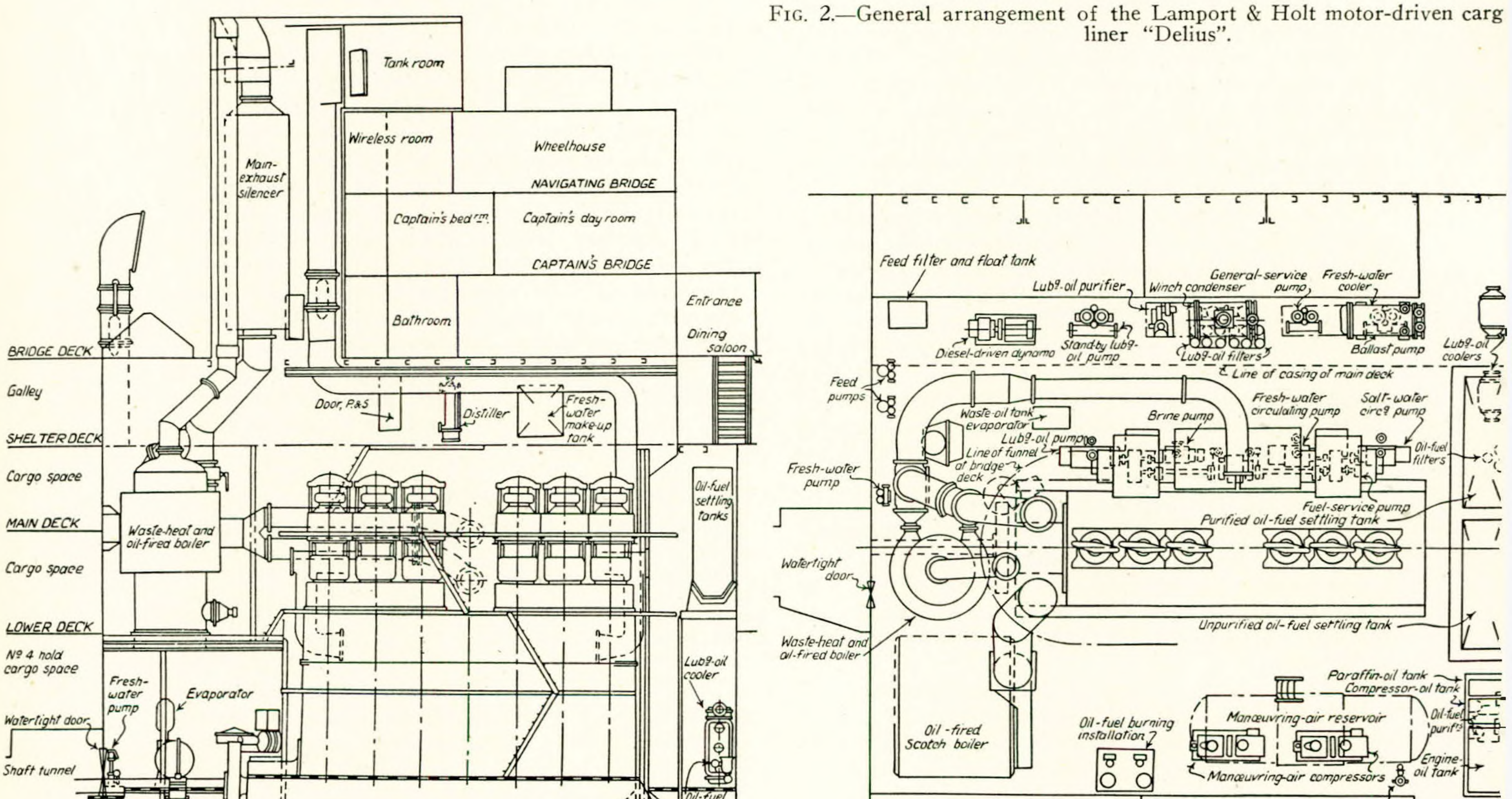


FIG. 3.—Layout of the machinery space of the "Delius".

holds, instead of five as usually found in vessels of similar dimensions. A double bottom, suitably subdivided, is worked fore and aft, and arranged for the carriage of water ballast, fresh water and oil fuel. The forward and after-peak tanks are used for the carriage of fresh water or water ballast.

There is accommodation for 12 passengers (four single and four double-berth rooms), and a tastefully decorated dining saloon, lounge and smoking room are grouped together at the forward end of the shelter deck.

Quarters of a superior type are provided in deckhouses amidships for the captain, officers and engineers.

The three cargo holds forward and three aft of the machinery space are served by large cargo hatchways, while the cargo-handling equipment consists of 19 tubular steel derricks—two each for 5-ton lifts arranged on derrick posts at Nos. 1 and 6 hatchways, three each for 7-ton lifts on derrick tables at Nos. 2 and 5 hatchways, four for 7-ton lifts and one for 35-ton lifts at No. 3 hatchway, and three for 7-ton lifts and one for 10-ton lifts at No. 4 hatchway, all operated by steam winches, of which there are two at each hatchway. Steam fire-extinguishing is provided for the cargo holds and 'tween decks.

A powerful steam windlass is installed forward, and the two winches at No. 6 hatchway are arranged for warping when required.

The stream-lined rudder is operated by a steam steering gear controlled by telemotor from the wheelhouse.

The Polar-Ellarcold methyl-chloride refrigerating plant has been supplied by the Liverpool Refrigeration & Engineering Co., Ltd.

Main and Auxiliary Machinery.

The main propelling engine of the "Delius", which has been constructed by the shipbuilders, is of the Harland-B. & W. double-acting, two-stroke cycle type, with uniflow scavenging, rotary blowers, "tuned" exhaust-pipe system, and exhaust valves operated by eccentrics on the crankshaft. The cylinder covers and jackets are fresh-water cooled, and the pistons are cooled with oil from the forced-lubrication system. The thrust-block is incorporated with the engine bedplate. Pumps for the bilge, fresh-water circulating, salt-water circulating, lubricating and piston-cooling oil, and fuel services are also incorporated with and driven off the main engine.

Seven Wakefield 9-feed D.P. type mechanical sight-feed lubricators, double-compartment, have been provided by Messrs. C. C. Wakefield & Co., Ltd.

Compressed air for starting and manœuvring purposes is stored in a large cylindrical reservoir, charged by two steam-driven manœuvring air-compressors.

There are independent steam-driven pumps for ballast; and the stand-by circulating, sanitary and general service fresh-water, fuel-oil transfer, and stand-by lubricating oil pumps are all steam-driven. Steam is supplied at sea by a Clarkson composite-type boiler, utilising heat from the exhaust gases of the main engine as well as fuel oil, while steam for use in port is generated by a Scotch boiler.

Other auxiliary machinery includes condenser, evaporator and distiller, boiler-feed pump, lubricating-oil coolers, fresh-water cooler, oil purifiers, etc. A workshop, with a lathe and drilling machine, is provided for the engineers' use.

Electric current for the ship's lighting and for power throughout the decks and machinery spaces is supplied by two 20-kW., 220-volt generators, one steam and the other Diesel-driven. For dealing with cargo, six clusters are installed for the holds, and four high-powered lanterns for lighting the decks. Each cabin is equipped with an electric fan, and the vessel is, of course, provided with the latest type of wireless installation.

The layout of the machinery space is given in Fig. 3.

Passenger Motorship "Royal Sovereign".

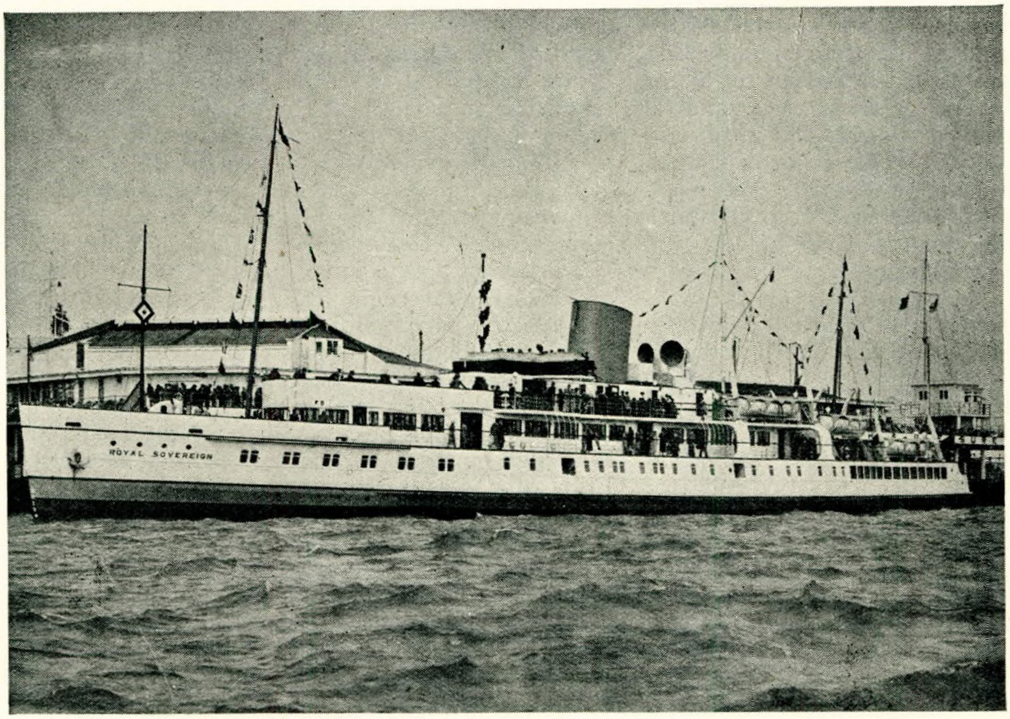
"The Marine Engineer", August, 1937.

The popularity of the handsome Denny-built Sulzer-engined motorship "Queen of the Channel", which we dealt with in our issue of July, 1935, encouraged the New Medway Steam Packet Co., Ltd., now associated with the General Steam Navigation Co., to build a second and slightly larger vessel of this type. Again the company went to Wm. Denny & Bros., Ltd., for the vessel and Sulzer machinery was likewise chosen. Although the new vessel, which many Londoners will be pleased to see has been named the "Royal Sovereign", is very little larger than the "Queen of the Channel" and has a somewhat smaller passenger capacity, her machinery power is 50 per cent. higher than that of the earlier vessel, while it will be noted from the illustration that she has one funnel in contrast with the two of her all-white consort.

The "Royal Sovereign" is a finely-modelled vessel with a cruiser stern and has been built specifically for service between the Thames estuary and such near Continental ports as Ostend, Calais, and Boulogne. Certain features not found in the earlier ship are incorporated in the design of the "Royal Sovereign". Most noteworthy of these is the adoption of a much smaller beam-to-length ratio; in the new ship this is as low as 5·8 beams to the length (on water line dimensions), while in the earlier vessel the corresponding figure is 7·5 beams to the length. This change of design is intended to give greater comfort in bad weather and will undoubtedly be appreciated by the travelling public.

She is 277ft. long by 47ft. broad by 11ft. 9in. deep to main deck, and is designed to carry about 1,600 passengers.

In profile the vessel presents an attractive yacht-like appearance, as the outside of the hull is painted white, with two green ribbon lines above



and a green boot-topping at the water line. Her well-proportioned funnel is painted buff.

The life-saving appliances consist of six lifeboats carried under Columbus davits, together with a large number of buoyant deck-seats, as well as a wireless telegraphy installation and a rocket-firing appliance. There is a hand-operated bow rudder as well as a main rudder.

Fire-fighting appliances are fitted to the full requirements of the Board of Trade, and include a fire-resisting curtain on each side in the main deck alleyways amidships.

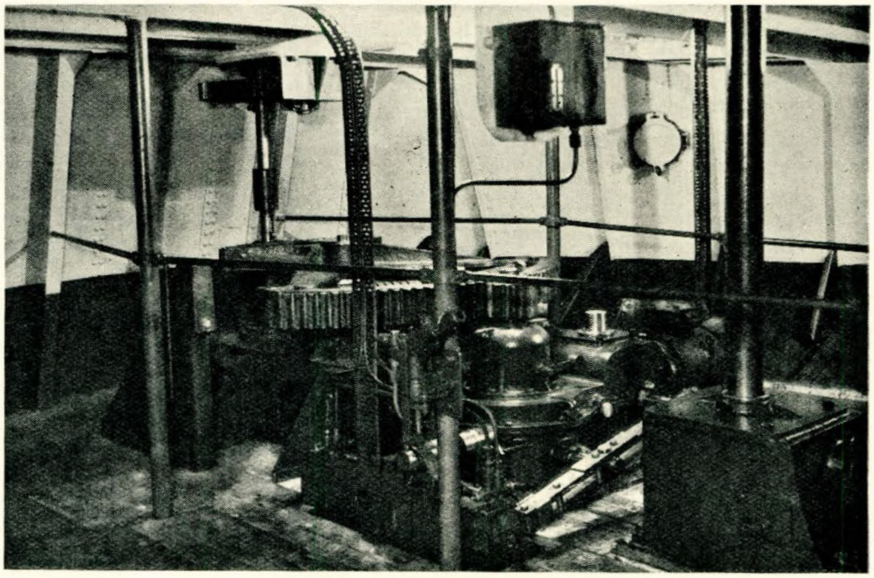
The culinary appliances are of the latest type. The kitchen is fitted with an oil-fired range and a charcoal-fired grill. All other kitchen and pantry appliances, including boilers, coffee percolators, hot presses, refrigerating machines and toasters are electrically-operated.

The main deck contains two fine dining saloons, the forward one seating 95 persons and the after one 132 people. There are two comfortably-furnished smoking rooms on the lower deck, the forward one seating 22 and the after one 27 persons. The sun lounge on the upper deck is a splendid apartment 152ft. 6in. long by 31ft. broad. This is brightly decorated and provided with Lloyd Loom furniture of the latest type. Cocktail and milk bars are provided in the sun lounge. The accommodation is provided with a trunk system of mechanical ventilation which was supplied by the Winsor Engineering Co., Ltd., Glasgow.

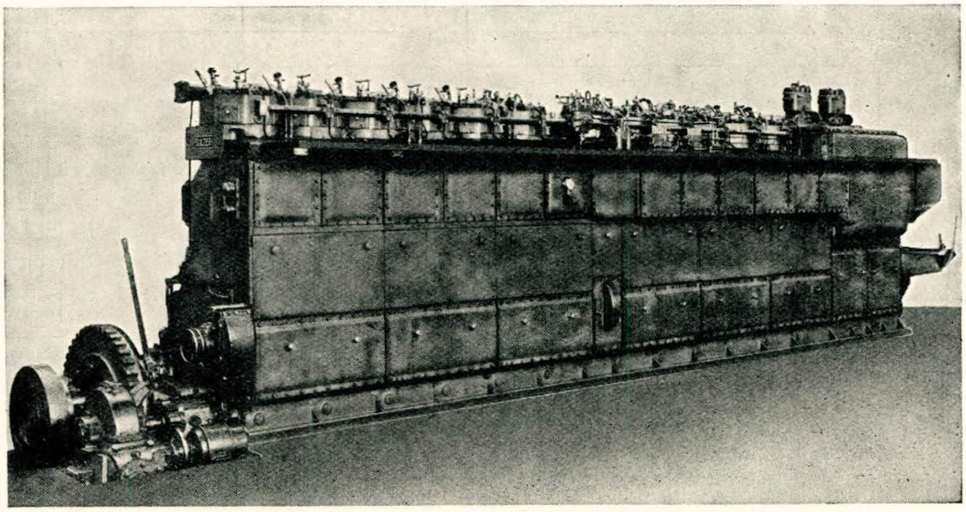
The windlass and capstan are both electrically-driven and the telemotor - controlled steering gear is also of the electrical type. The steering gear was supplied by T. Reid & Sons (Paisley), Ltd., and is illustrated below.

Machinery.

The vessel is propelled by twin screws driven by two sets of Sulzer Diesel engines, each having 12 cylinders 360 mm. in diameter by 600 mm. stroke of the two-stroke cycle type, with airless injection of the fuel. The engines are trunk-piston units and each is rated at about 2,250 b.h.p. at 320 r.p.m. This output gives the vessel a speed of about 20½ knots.

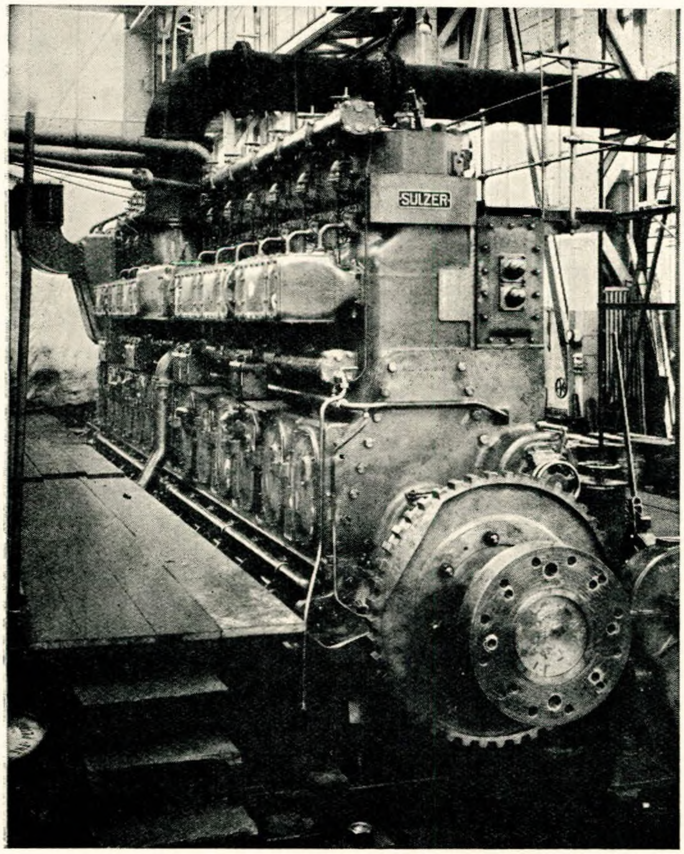


Steering gear compartment.

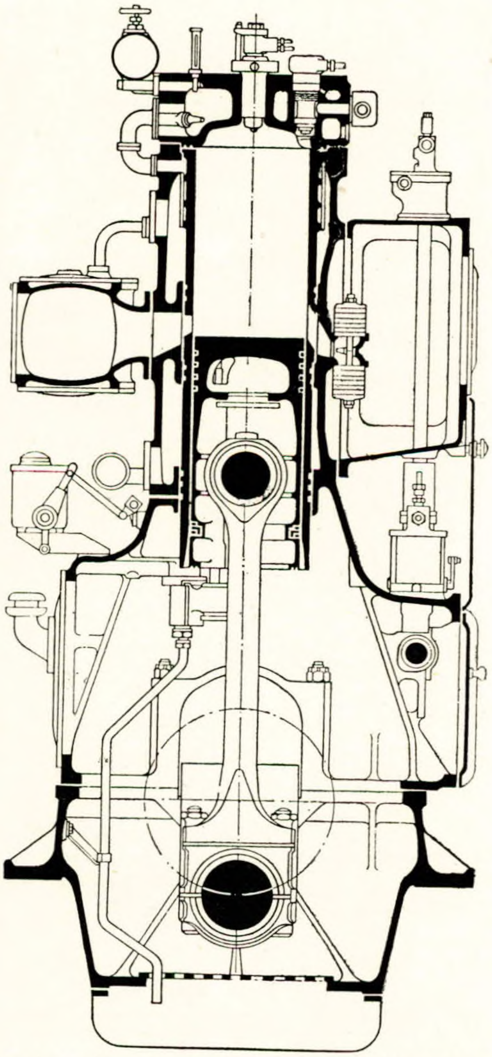


One of the vessel's 12-cylinder main engines, showing twin scavenge pumps and controls.

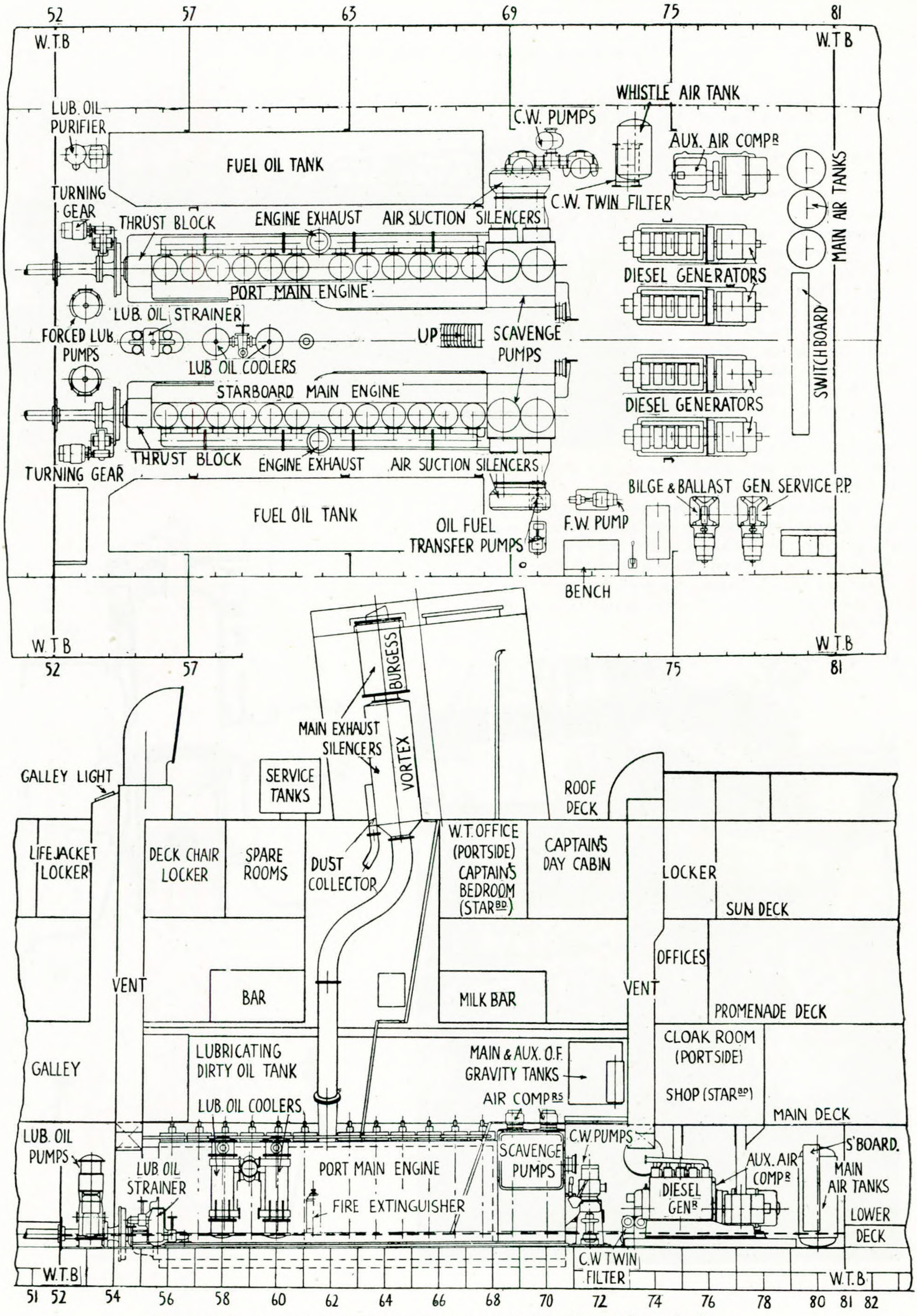
The main engine is of the latest Sulzer two-stroke cycle trunk-piston marine design such as is suitable for the propulsion of yachts, cross-Channel vessels, and the like. Low headroom is a feature of the design and the sectional drawing which accompanies the article shows that the scavenging differs somewhat from the standard Sulzer arrangement, in that there is only a single row of scavenge ports; these ports are controlled by automatic valves and are rather deeper than the exhaust ports, with a view to getting a certain degree of supercharge after the exhaust ports are closed. Certain of the ports are placed at such an angle that streams of air are directed upwards with a view to deflecting the main column of scavenging air towards the cylinder cover.



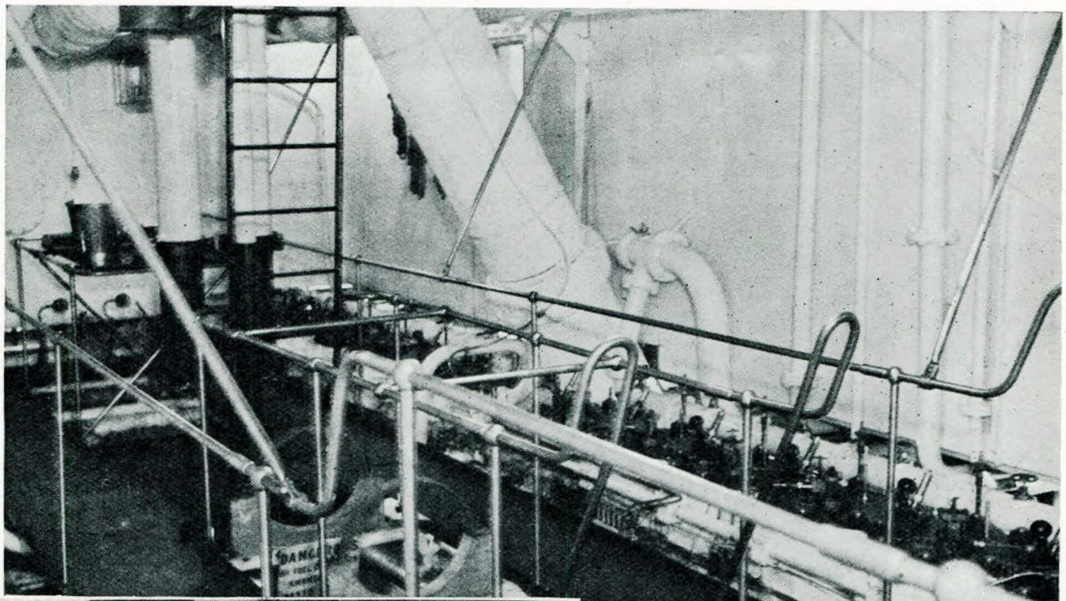
Port main engine on the test bed in Winterthur.

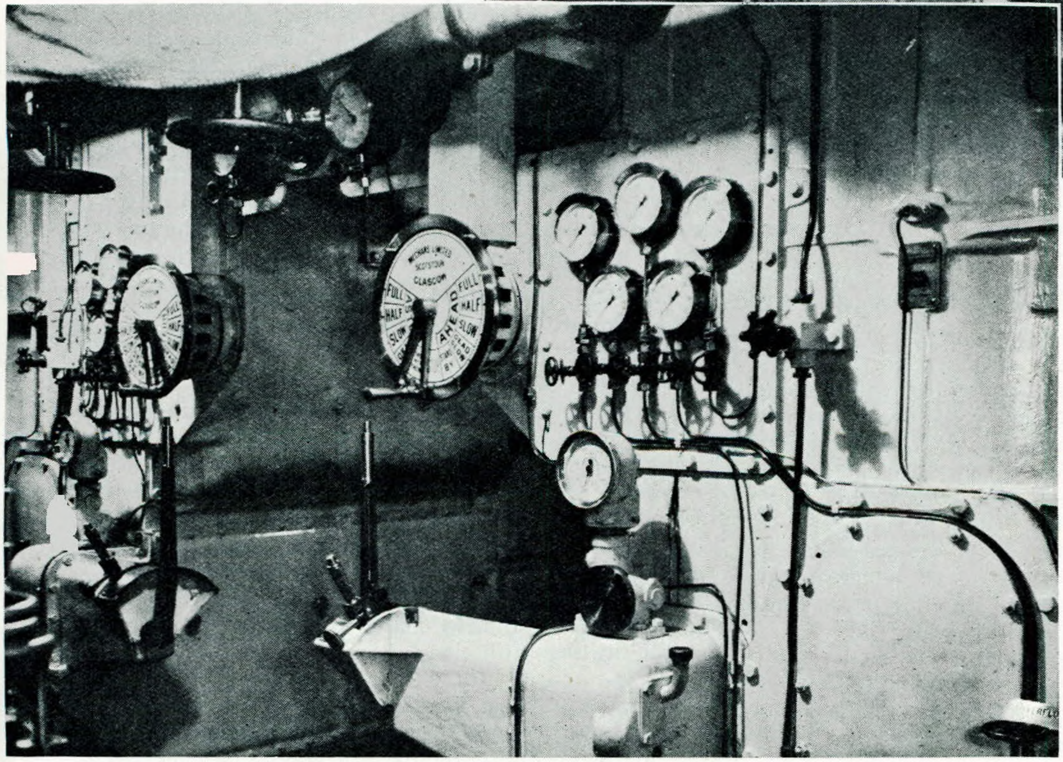


Section through the Sulzer trunk-piston two-stroke engine as fitted in the "Royal Sovereign".



Plan and elevation of the engine room of the motorship "Royal Sovereign".





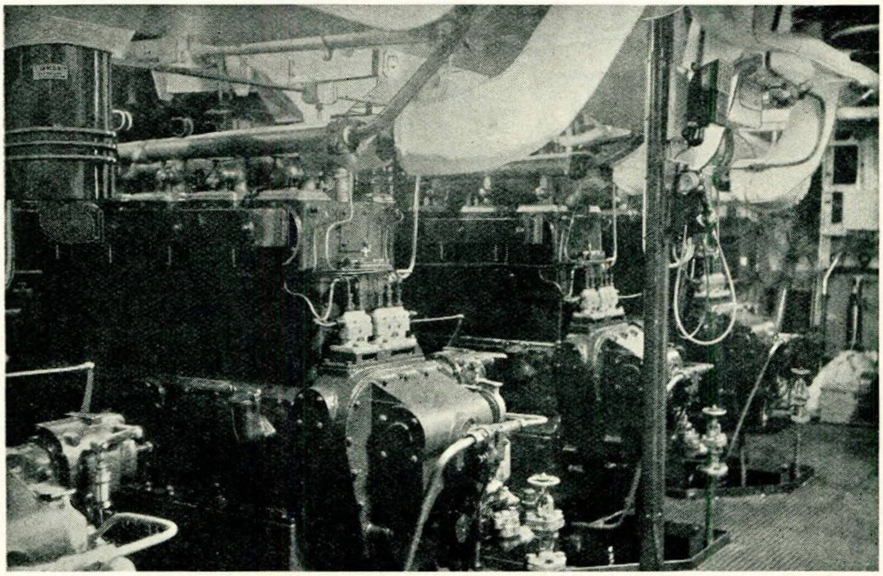
Above: Cylinder tops of the port main engine.

Left: Controls for both main engines are arranged at the forward end.

The main controls are grouped at the forward end of the engine, easy handling and rapid manœuvrability being features of the design. Each engine has its own injection pump located immediately above the camshaft, below the scavenge trunk, the leads between injection pump and automatic fuel valves being of constant length throughout.

Scavenge air is supplied to each engine by two tandem reciprocating type air pumps driven by separate cranks at the forward end of the engine. There is also an air compressor fitted to the top end of each scavenge pump for supplying air for manœuvring the main engines and starting the auxiliary sets.

The engines are forced lubricated by two motor-driven Drysdale Vertoil pumps, one working and one stand-by, each being driven by a Laurence Scott motor. These pumps are arranged to supply lubricating oil through Auto-Klean strainers and



National-engined Diesel-generator sets.

Serck oil coolers to the main, crankpin, and gudgeon pin bearings, as well as to deliver cooling oil to the working pistons. Lubrication of the liners is attended to by Bosch mechanical lubricators, there being four per engine. The temperature of the exhaust gases is shown at each cylinder outlet on a Rototherm dial-type thermometer, these being very easily read, we noted.

Each working cylinder has its own fuel pump delivering a measured quantity of fuel oil direct to the working cylinder, the automatic injection valve being located in the centre of the cover, with the automatic air starting valve and relief valve alongside. The engines are cooled by sea water by two motor-driven, self-priming Sulzer centrifugal pumps, one working and one stand-by. A motor-driven fresh water pump is provided, this being supplied by Drysdale & Co., Ltd.

The engines are started by compressed air which is stored in three receivers at a pressure of 600lb. per sq. in. and pressure is maintained in these receivers by a motor-driven air compressor.

A Michell thrust block is fitted at the after end of each engine to take propeller thrust. This bearing is also forced lubricated from the main engine system.

Auxiliaries.

Fuel oil is supplied to the daily service tanks by two motor-driven oil fuel transfer pumps of Hamworthy make, one working and one stand-by; and the lubricating oil purifier, which is arranged on the continuous purification system, has been supplied by the Alfa-Laval Co., Ltd., and is located to the port side of the engine-room near the after bulkhead.

Motor-driven pumps for bilge and ballast duty and for general service and sanitary purposes are reciprocating units supplied by Dawson & Downie, Ltd.; these pumps are all driven by Laurence Scott electric motors.

For supplying power to the motor-driven pumps, steering geer, electrical cooking equipment, lighting, etc., four generators of 50 kW. are provided. Each is driven by a five-cylinder National high-speed Diesel engine of 75 b.h.p. at 800 r.p.m.

The dynamos as well as the motors for driving the pumps and air compressors are all supplied by Laurence Scott & Electromotors, Ltd., and the starters for the various motors are by E. N. Bray, Ltd., Walthamstow, E.14. The telegraph instruments between navigating bridge and engine-room are supplied by Mechans, Ltd., Glasgow.

The main exhaust silencers comprise two Alexander's Vortex-type silencers with combined dust collectors, these exhausting into Burgess straight-through silencers. Foamite Firefoam fire extinguishers are provided throughout the engine-room, the equipment including a large foam-type fire engine.

Use of Sound Waves for Smoke Elimination.

By H. V. Gottschalk and H. W. St. Clair.

"The Steam Engineer", August, 1937.

A paper of unusual interest was published in the May issue of "Mining and Metallurgy" (U.S.A.) by the above authors entitled: "Use of Sound and Superonic Waves in Metallurgy". The paper describes the work of the Metallurgical Division of the Bureau of Mines, Washington, to whom we are indebted for kindly sending us a reprint of the paper. The paper deals very comprehensively with the work done and we have taken the following extract dealing with the action of sound waves on smoke:—

"When solid or liquid particles are suspended in a medium through which sound waves are passing, attractive and repulsive forces are set up between neighbouring particles. It is upon this phenomenon that the effectiveness of the acoustic smoke or dust flocculator depends. A mathematical discussion of the physical basis of this phenomenon would be beyond the scope of this paper. Fortunately it is possible with the aid of Fig. 1, to give a fairly simple explanation requiring only an elementary knowledge of Bernoulli's principle of hydrodynamics. Bernoulli's theorem states in effect that the pressure in a fluid is least where the velocity is greatest. Familiar examples illustrating the operation of this principle are the aspirator, the injector for steam boilers, or the curving baseball.

"Fig. 1 (a) shows two spherical particles suspended in a vibrating current of air, such as is produced by a sound wave. The line of centres of the two spheres, *A* and *B*, is transverse to the direction of vibration, shown by the double-headed arrow. It is evident that the velocity, *v*, in the constriction between the particles will be greater than elsewhere. Consequently, from Bernoulli's principle, the pressure will be less between the spheres than elsewhere, and the greater pressure on the outside will force them to approach each other. In other words, they behave as though attracted to each other.

"Fig. 1(b) shows the opposite case in which the two particles have their line of centres parallel to the direction of vibration. Here the velocity of the air between the particles is less than elsewhere. Therefore, according to the previous reasoning, the particles will act as though repelled by each other.

"From this elementary explanation it is possible to understand something of the influence of an intense sound field on a suspension of particles such as exists in a fog or smoke. The particles are attracted to each other when their line of centres is transverse and repelled when their line of centres is parallel to the direction of sound propagation. As a result of the action of these forces the suspended particles are collected together or flocculated, forming thin, wafer-like flakes which dispose themselves at right angles to the direction of the sound.

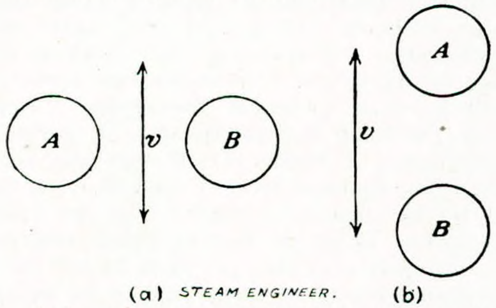


FIG. 1.—Action of intense sound on suspended smoke particles, (*a*) line of centres transverse to direction of vibration, and (*b*) parallel to vibration.

"There is nothing in the foregoing explanation to show that the same forces would not exist for a unidirectional flow or for low-frequency vibratory motion of the gas; in fact, the particles are flocculated even when they are swept along with the gas and participate in its motion. There is a minimum frequency that will flocculate a given smoke, which depends on the size and density of the suspended particles and on the viscosity and density of the surrounding medium. For ammonium chloride and arsenic fumes the frequency should be above 5,000 vibrations per second; for tobacco smoke it should be higher. By using frequencies of this magnitude it is possible to attain surprisingly high instantaneous velocities in the vibrating gas. When vibrating with an amplitude of only 1 mm. and a frequency of 6,000 vibrations per second the maximum velocity is 37.7 m. per sec. or about 84 mi. per hour.

"Flocculation of smoke by means of sound is shown in Fig. 2 (not reproduced) where a glass cylinder containing a dense, white ammonium chloride fume, has been subjected to the influence of intense sound at a frequency of 6,000 vibrations per second for a period of 30 sec. The high-frequency sound is generated by a longitudinally vibrating nickel tube at the base of the glass cylinder. To build up a sound field of sufficient intensity the sound must be confined as nearly as possible to the enclosure in which it is desired to produce flocculation. The dimensions of the enclosure must be adjusted to produce resonance, which is done by adjusting the reflector at the top of the glass cylinder. When the reflector is properly adjusted the transmitted and reflected sound waves will interfere with each other so as to produce recurring zones of maximum and minimum sound intensity along the axis of the tube. At points where the two sets of waves, travelling in opposite directions, are in phase the sound is reinforced and the gas vibrates with a large amplitude. At intermediate points they are opposite in phase and neutralise each other; here there is little or no amplitude. The positions of minimum amplitude are called nodes and those of maximum amplitude, antinodes. The distances between any two successive nodes or antinodes is one-half a wave-length.

"The vibrating nickel tube with the auxiliary electrical apparatus is magnetostrictive vibrator, first described by Pierce. Some metals, such as nickel, iron, and cobalt, have the property of magnetostriction; that is, they become deformed when placed in a magnetic field. By placing a nickel rod or tube in a magnetic field which varies periodically between zero and a maximum, the nickel tube is caused periodically to shorten its length and thus vibrates longitudinally, producing an intense sound. A small aluminium piston head is fastened on the end of the tube to radiate the sound.

"The varying magnetic field is produced by a high-frequency current flowing through the coils surrounding the lower half of the nickel tube. The frequency of the current is 6,000 cycles, or the same as the fundamental frequency of vibration of the nickel tube.

"A simpler type of sound generator, equally effective, is the air-jet generator. Its essential elements are a jet of air having a velocity greater than that of sound and a resonator, or small, hollow cylinder closed at one end. The frequency, or wave-length, is controlled by the dimensions of the resonator. The wave-length is given by the following expression:—

$$\lambda = 4\ (1 + 0{\cdot}3d),$$

where l = depth of resonator,
and d = diameter of resonator.

The resonator of the generator shown is 1 cm. deep and 0·5 cm. in diameter. It has a frequency of about 7,400 vibrations per second at room temperature. This type of sound generator was developed by Hartmann while studying pressure variations in a high-velocity air jet. It is more efficient than ordinary whistles or sirens. Intense sound of any desired frequency from a thousand to several hundred thousand cycles per second may be generated by Hartmann's device. It requires no expensive auxiliary equipment and works well on any kind of smoke regardless of chemical composition.

"The mineral physics group of the metallurgical division of the Bureau of Mines is continuing its investigations of the use of sound waves in settling smoke and fume and hopes to report some results of actual practice in the near future".

Experiments on the Behaviour of Fuel in Diesel Engines.

By Dr. Ing. W. Lindner, M.A.N., Augsburg.*

"The Motor Ship", August, 1937.

The Diesel engine utilizes the energy supplied by its fuel more efficiently than any other heat engine. This is due to the fact that the combustion process, as with all heat engines, occurs directly in the engine cylinder, and that, by the injection of the fuel at the moment when its ignition and combustion can be controlled, the employment of comparatively high compression is rendered possible. For the intermingling and the atomization of the fuel with the available air of combustion, as well as for the ignition and combustion processes, there is available only a very short time represented by a fraction of the engine cycle. It is, therefore, understandable that all the factors which have an influence on the course of this process play an important role in the satisfactory and reliable operation of the engine. The characteristics of the fuel on the basis of its chemical and physical properties are of special importance, since with the steadily growing employment of Diesel engines and the increase in the demand for fuel, the poorer grades of oil come into question. Countries which have no oil are therefore endeavouring to utilize artificially produced fuel, as for instance, from the distillation of coal.

The most important properties that affect the behaviour of fuel in the engine are its heat value, its viscosity, and its ignition and burning characteristics, also its liability to carbonization. Whilst, so far as heat value and viscosity are concerned, thoroughly reliable results from experiments and detailed figures are available, exact values relating to ignition characteristics are difficult to obtain. Such values can be represented by the ignition delay, the time from the admission of the fuel (A, Fig. 1) until ignition, which is indicated by a sudden pressure rise in the indicator diagram (B). The ignition delay, in consequence of the retarded combustion and the injection meanwhile of a considerable quantity of fuel, results in a much steeper pressure rise (B to C) than would occur in the ideal combustion process (the dotted curve) without ignition delay. In the event of too great an ignition delay the operation of the engine would be rendered impossible in consequence of excessive after burning during the expansion period.

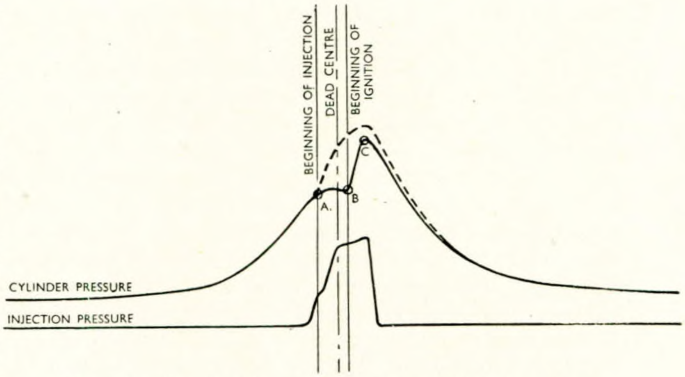


Fig. 1.—Combustion process in a Diesel engine.

The higher the speed at which the engine runs the smaller must be the ignition delay and the greater necessity for a fuel with good ignition characteristics. Concerning the chemical process during the period of combustion, we possess comparatively little practical knowledge. Recently, however, through the employment of spectroscopic measurements, valuable information has been obtained. The ignition delay is controlled, on the one hand, by the chemical constitution of the fuel, and, on the other, by all the factors which influence the heat transmission of the fuel particles and the speed of chemical reaction. It is influenced equally by the compression and temperature of the air and by the air swirl in the cylinder, as well as by the temperature of the walls, which is, in turn,

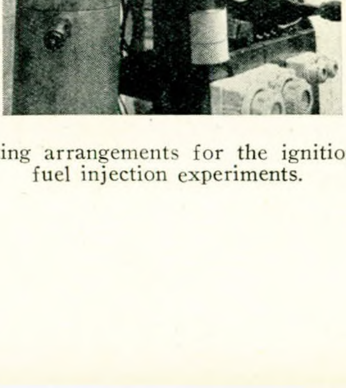
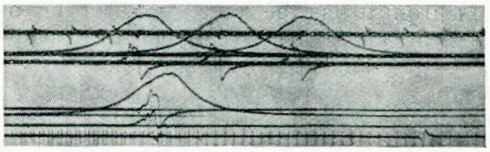


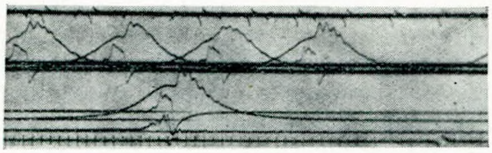
Fig. 2.—Testing arrangements for the ignition delay and fuel injection experiments.

---

* Extract from a paper read before the Hauptversammlung der Gesellschaft der Freunde und Forderer der Hamburgischen Schiffbau Versuchsanstalt.



Gas oil.



Tar oil.

FIG. 3.—Results of fuel tests in a Diesel engine.

dependent on the design of the combustion chamber and on the combustion process. From an understanding of these factors arises the possibility of building an engine to accommodate itself within limits to the ignition properties of a fuel.

If it is desired to use an actual engine for an investigation of the ignition characteristics, in general, comparable values of the ignition delay can only be obtained if the experiments are carried out under prescribed running conditions on similar engines. In order to obtain such results under varying conditions, the measured ignition delay value should be expressed in terms of the proportions of a mixture of a "good ignition" oil and "bad ignition" oil, which, in the engine, has the same ignition delay as that of the tested fuel. Difficulties, however, exist in the choice of the fuel to be used for comparative tests as a chemically standard fuel is not satisfactory.

In order to simplify testing systems, advantage is taken of the dependence of ignition capacity upon the chemical structure of the fuel molecules. Unfortunately, it is not possible by chemical analysis to separate with a satisfactory degree of accuracy even the most important hydro-carbon particles from the combination of which all known liquid fuels are formed. It is, therefore, necessary to adopt indirect means, which enable the chemical compositions to be determined from the standpoint of chemical and physical data such as hydrogen content, analine point, boiling point, density, surface pressure, etc. Even the determination of the ignition temperature of a fuel drop in a heated crucible with free air admission (as in the ordinary ignition temperature test) permits, for various practical purposes, satisfactory information to be obtained on the ignition characteristics of the fuel. Results correlated to the engine can, however, only be obtained when the measurements are made under similar conditions to those which prevail in the cylinder, i.e., on a fuel stream injected under pressure, since the chemical processes at the surfaces of the fuel and air streams exert a marked influence on the ignition process.

An apparatus which enables measurements relating to the ignition delay of the fuel spray is shown in Fig. 2. The injection takes place in an ignition chamber in which the air conditions can be rendered similar to those in an engine at the end of compression. The course of the injection and ignition can be shown on an electrical indicator, and by that means the ignition delay can be averaged out. Apparatus of this nature has the advantage of independence of the numerous external influences and running conditions of the engine. The measurements require, however, a considerable expenditure of time and material.

For the determination of measurements relating to the engine, many experiments can be carried out which, in part, depend directly on the ascertained ignition delay as indicated graphically, and partly upon the understanding in the conditions of the behaviour of the engine when running conditions are altered, as, for instance, variation of suction pressure through throttling, or by altering the compression ratio, representing bases for the evaluation of the fuel. The first means enables more exact results to be obtained, since it simultaneously allows a careful supervision of the engine, and provides also for the manufacturer an idea of the connection between engine and fuel.

In Fig. 3 are seen two oscillograph records obtained by this means on an M.A.N. test engine. They show the pressure variation in the cylinder and in the fuel-injection piping, the needle stroke, the dead point and, finally, the course of time, in degrees of one five-hundredth of a second. The upper figure shows the results of a good gas oil and the lower with a tar oil, which, on account of its chemical composition, is a poor fuel from the standpoint of ignition. These prove that, with a considerable ignition delay, there is a steep pressure rise and also high ignition pressure, both of which are disadvantageous for the satisfactory running of the engine. Further measurements indicate that

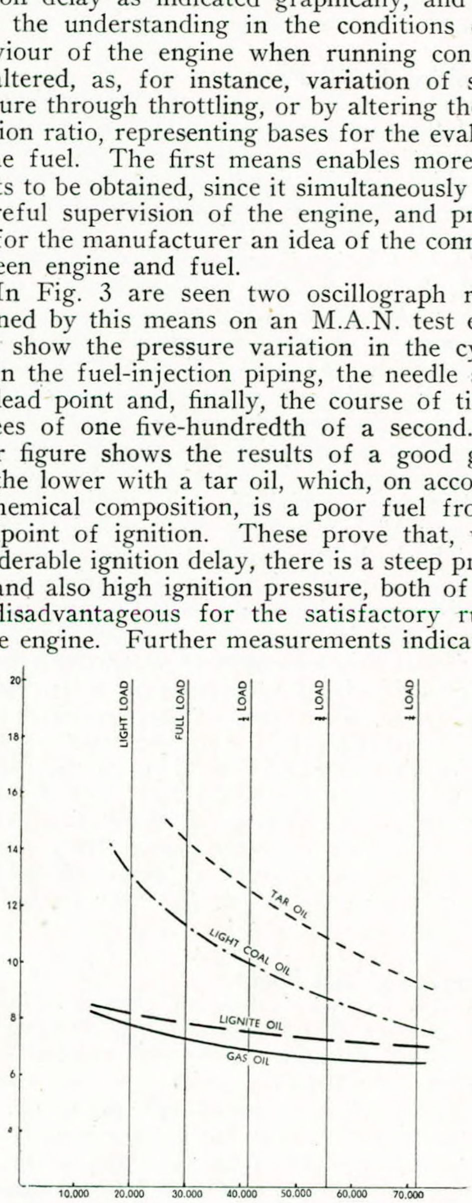


FIG. 4.—Ignition delay curves with various grades of fuel.

the speed of pressure rise is not only dependent on the ignition delay but also on the quality of fuel, and this factor, as well as ignition delay, should be considered.

The results which have been obtained from a number of ignition experiments with various fuels on the test engine are shown in Fig. 4. In order to obtain the most reliable figures, the ignition delay in relation to the load on the engine and the energy delivered to the cylinders by the fuel are indicated. Experiments with various grades of natural and coal-produced fuel provided some valuable information on the interconnection between their chemical and physical properties and their processes of combustion in the engine in matters relating to the pulverization of the fuel, the mixing of fuel and air, ignition and combustion propagation.

Galvanising Small Parts.

"Shipbuilding and Shipping Record", 24th June, 1937.

Of the two processes which are available for galvanising steel plates and fittings to be used on board ship, viz., by dipping or by electrolytic deposition, the former is generally recognised as being the cheaper. It suffers, however, from the disadvantage of lack of uniformity of coating which is particularly noticeable with small parts of relatively complex form owing to the tendency of the molten zinc to drain to the edges. This difficulty is overcome by the use of the electro-galvanising system, and by the use of specially designed electrolytic baths; the cost can also be substantially reduced. In a plant which has recently been completed in Germany, the parts to be galvanised are carried in drums which serve as anodes, and these are immersed in a bath in the form of an annular ring. The bath has a capacity of 660 gallons and the drums, of which there are six, are carried in a rotary frame, the bath itself being rotated independently of the frame carrying the drums. It is claimed that this arrangement is particularly suitable for galvanising such parts as bolts, washers, etc., the thorough mixing of the electrolyte ensuring uniform deposition. Arrangements are provided for the economical handling of the material, the drums containing the finished work being carried on an overhead runway to the rinsing vats and thence to the hot-air centrifuging dryer. In this way the space requirement has been reduced by 30 per cent., while the output has been increased by 50 per cent.

Heat-treating Cast Iron.

"Shipbuilding and Shipping Record", 24th June, 1937.

It is generally recognised that ordinary cast iron cannot stand up to the stresses involved in heat treatment. With certain of the recently developed alloy cast irons heat treatment not only becomes possible, but is very advantageous, particularly where complex castings are involved. An account of an investigation published in a trade journal shows that where small quantities of nickel are alloyed with the cast iron, it has the effect of lowering the temperature at which heat treatment can be effected, while at the same time reducing the critical speed at which the cooling must be carried out. Thus, whereas with a plain iron, full hardening generally necessitates a cold water quench, 2 per cent. of nickel permits of quenching in oil, while with 4 per cent. nickel, cooling in an air blast can be used. It is stated that these cast irons can be softened for machining merely by heating them to a temperature between 600° and 700° C. and allowing them to cool slowly and subsequently hardened to give the maximum resistance to abrasion. As with steel, tempering is recommended after quenching, because although the maximum hardness is obtained on quenching, the actual strength of the casting is greatly improved when the quenching stresses have been removed by tempering. If the tempering is carried out at relatively low temperatures these stresses are released without diminishing the hardness, while the strength of the casting may be improved by as much as 25 per cent. It is this cast iron which is being used for the crankshafts of small engines.

The Effect of Mill Scale on Corrosion Intensity.

"The Steam Engineer", August, 1937.

A paper read by Mr. U. R. Evans, Sc.D., before the Institution of Engineers and Shipbuilders in Scotland had as its title "Some Aspects of Metallic Corrosion", in which the author referred to direct oxidation, wet corrosion, the effect of mill scale on corrosion intensity composition and corrosion, and behaviour of non-ferrous metals. Commenting on the effect of mill scale on corrosion intensity, the author said that one matter about which some disagreement exists is the intense corrosion set up at small breaks in an oxide scale. Let two pieces of the same steel sheet be taken, and one of them be heated to produce a scale. After cooling, a scratch line is ruled piercing the scale, and the specimen is placed in a sloping position in a salt solution, with the side carrying the scratch downward (to allow the corrosion product to fall away from the surface and avoid the tendency for the corroded area to spread); corrosion occurs, and, being localised on the scratch line, is very intense and penetrates rapidly into the metal. The unheated piece, placed in the same position in the same liquid, suffers much corrosion (sometimes more than the scale-covered specimen), but this will usually be more spread out and less intense. In comparative experiments at Cambridge, the scale-covered specimen has suffered perforation after a few months, whilst the scale-free specimen shows no sign of perforation. This difference has been produced, not only with a sodium chloride solution, but with a water drawn from a well-known port.

The explanation appears to be that the scale-covered area is cathodic towards the exposed iron as anode. (It is possible to generate a current from a cell consisting of scale-covered and scale-free iron placed in the same liquid). The strength of the current flowing depends largely on the amount of oxygen (depolariser) reaching the effective cathodic area, that is, the parts of the scale around the scratch. If the scale is nearly complete, the current will usually be considerable, and the whole of the attack produced by it will fall on the small anodic area at the scratch line, and thus the intensity (attack per unit area) will be considerable. This explanation has been queried by McCance on the grounds that the scale consists of a bad conducting substance and is very thin; the resistance of the cell would, he thinks, prevent the flow of any serious amount of current. Apparently he pictures the current flowing edgewise along the scale, but this is not necessary; the current will cross the scale at right angles, and the thinner the scale the smaller will be the resistance of the circuit. It is easy to produce the effect even with a scale of haematite, which is a worse conductor than magnetite—the oxide that McCance has in mind. Actually it should be mentioned that the resistance of an electrolytic circuit has rather less effect on the strength of the current than is sometimes imagined; the current cannot be obtained by dividing a fixed E.M.F. by a fixed resistance, since in a polarising system both the E.M.F. and the resistance depend upon the current flowing.

Whatever the explanation, the facts are not in doubt and are of practical importance. If breaks are present in the scale covering a piece of metal which is then painted and exposed to the weather, then (unless the paint coat is entirely waterproof) the intense attack at the breaks in the scale will lead to a large amount of voluminous rust below the paint, causing it to rise up as a blister and finally to burst off. This failure may occur very rapidly below paint coats which, when applied to scale-free metal, would give admirable protection.

Laboratory Tests in Relation to the Serviceability of Steel and Steel Products.

"The Steam Engineer", August, 1937.

The importance and limitations of laboratory tests on steel are matters of concern to all associated with the engineering industry, and a paper read by Sir Robert Hadfield, Bt., F.R.S., and S. A. Main, B.Sc., before the International Association for Testing Materials earlier this year dealt with this particular question, and the following comments were made by the authors: "It cannot be too strongly emphasised that the only fully satisfactory basis for successful service is, in all cases, actual experience in service of a similar kind. Where the service demanded is of comparatively short duration it is often practicable to submit one or more representatives of a batch of products to such service. Successful performance gives reasonable assurance that the remainder will prove satisfactory. Such procedure is applied, for example, in the production of material used for defensive purposes.

"If the articles are of reasonable size and the working conditions simple enough to be reproduced fairly closely, such tests may sometimes be conducted in the laboratory, and with the same confidence in their indications.

"The difficulties and risks connected with pioneering applications of steel can sometimes be circumvented by a practical trial in which the steel is subjected to the operating conditions without responsibility for sustaining the working loads. This is, for example, a useful expedient with corrosion-resisting steels where knowledge is required of their utility or otherwise in chemical plant for working with certain agents. A similar course may be taken with heat-resisting steels in furnace work under new conditions. The effect of loads may here be ascertained by artificial loading.

"The growing use of special heat-resisting steels for sustaining loads at temperatures far beyond the limits formerly prescribed for steel afford a specially interesting study in the present connection. The advantages given by the modern scientific outlook provide the opportunity for building up in this new field methods of design based rationally on properties mostly determinable in the laboratory, thus improving considerably on those rather empirical methods with large factors of safety which are still maintained to a large extent for design at ordinary and comparatively low temperatures.

"Where the life period required runs into several years, as, for example, in steam plant, no laboratory 'creep' or other tests of shorter duration can as yet give full guidance. So far as changes of a critical nature in the effects of continued stressing and exposure to high temperature are found not to occur after a long period, confidence will then be established in the use of tests covering shorter periods".

A Rotary Air-Starting Motor.

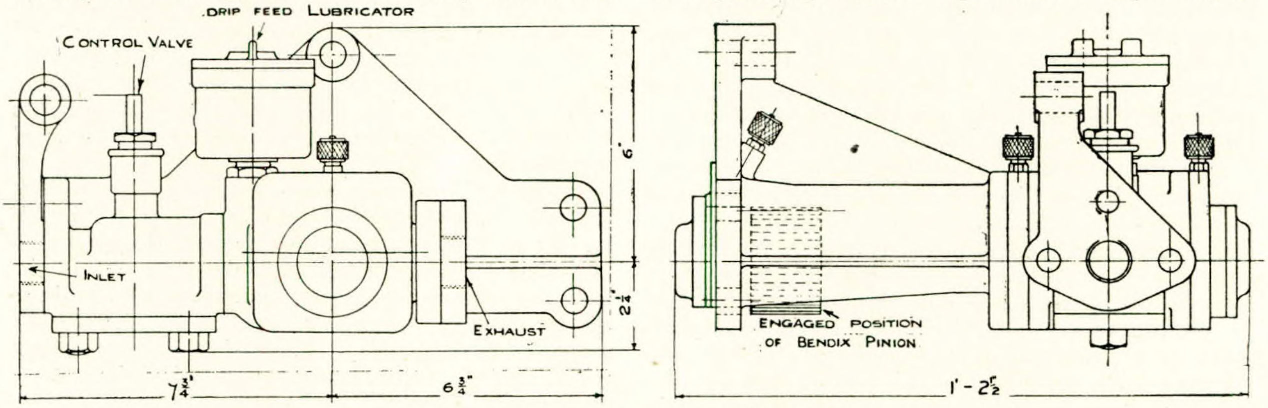
"Gas and Oil Power", June, 1937.

On several occasions in the past we have referred to various forms of air starter which are available for Diesel engines of medium size. A design which we did not deal with at that time was the Reavell starter, this particular make of starter being newer than the others with which we have dealt. It has been fitted to a considerable number of Diesel engines since we last discussed this subject, the National Gas and Oil Engine Co., Ltd., in particular, having made good use of this starter.

The name of Reavell & Co., Ltd., of Ipswich, is, of course, well-known in connection with air compressor manufacture while one of their more recent lines of manufacture is a range of rotary compressed-air engines suitable for driving dynamos, fans, winches, windlasses, capstans, etc.; the range is wide, embracing fractional horse-power motors for fans to units of 100 h.p., either unidirectional or reversible.

Sliding vane principle.

This air engine forms the basis of the Reavell air-starting motor, which is shown in the accompanying illustration. As will be seen from the drawing, the starter is neat and compact, and is suitable for starting oil engines of moderate power by means of a toothed rim on the flywheel. The air-starter motor illustrated is designed to operate at a pressure of 160lb. per sq. in. (gauge), the air being taken from storage bottles which can be charged up to a higher pressure, normally 250/300lb. per sq. in. The air motor is of the sliding vane type, having a rotor mounted eccentrically in a casing with the necessary blades free to operate in slots in the rotor. The air under pressure admitted into the segments acts on the blades causing the rotation of the rotor. The illustration shows the stem of a spring-loaded control valve which when depressed admits air to the rotor. The shaft on which the rotor is mounted is extended and carries a Bendix drive.



The Reavell air-driven starter for Diesel engines.

On the coarse pitched thread of the Bendix drive is mounted the pinion which engages with the toothed rim on the engine flywheel. The first act of starting, when the air-starter motor is set in motion, causes the pinion to progress from the position it takes up at rest adjacent to the air motor itself, and to engage with the toothed rim of the flywheel, that is, to take up the position illustrated in the drawing. The continued rotation of the air-starter motor causes the flywheel of the oil engine to rotate rapidly, increasing in speed until the engine can be fired.

As the oil engine is at rest when the pinion engages on the toothed wheel, a spring is fitted and the pinion, which comes up to an abutment against a collar on the shaft at the engaged position, moves the coarse thread of the Bendix drive towards the right and compresses the spring, thus providing an elastic buffer which takes up the shock of starting.

Lubrication.

The air-starter motor is lubricated by a patented drip lubricator, which gives a definite feed into the suction whenever the air-starter motor is operating. The *illustration of a National oil engine equipped with one of these starters, shows the flywheel with a projecting toothed rim and indicates the lever fitted to operate the control valve referred to above. By raising this lever a cam lever on the bracket of the oil engine depresses the spring-loaded valve and admits air to the air-starter motor. As soon as the oil engine has reached the necessary speed and firing takes place the lever is released and the spring closes the control valve.

The dimensions shown on the drawing are for an air-starter motor capable of developing 14 h.p. at 2,400 r.p.m., and larger units are available, namely, 21 h.p. at 2,400 r.p.m. and 50 h.p. at 2,000 r.p.m. These sizes are suitable for starting engines of from 75 to 250 b.h.p. So far as the question of air consumption is concerned, this naturally varies with the type of engine, its duty, number of cylinders, size of flywheel, etc., but in the case of the average industrial engine of 75/80 b.h.p., using the smallest size of starter, 25 starts should be obtained from a 6¾ cub. ft. air-bottle charged initially to 300lb. per sq. in. The air consumption, it will thus be appreciated, is reasonable.

New Crossley-Premier Diesel.

"Gas and Oil Power", July, 1937.

For some considerable time we have followed the development of this engine, which is new from stem to stern, as it were, and after close study of the design we are of the opinion that this new engine type, which departs from accepted Crossley-Premier design in certain respects, will do much to widen the scope of the firm's products.

The new engine is intended to fulfil a market not covered by the existing range of engines, for it is of lower power per cylinder and higher crankshaft speed than the types with which we are familiar. Furthermore, by being totally enclosed and provided with forced lubrication, the engine complies with the requirements of numerous services where these features are deemed essential. The new engine has only been built in the in-line types up to the present, but orders are in hand for *vis-a-vis* units. It is to be available in both atmospheric- and pressure-charged forms and can operate on a wide range of diesel fuels or on

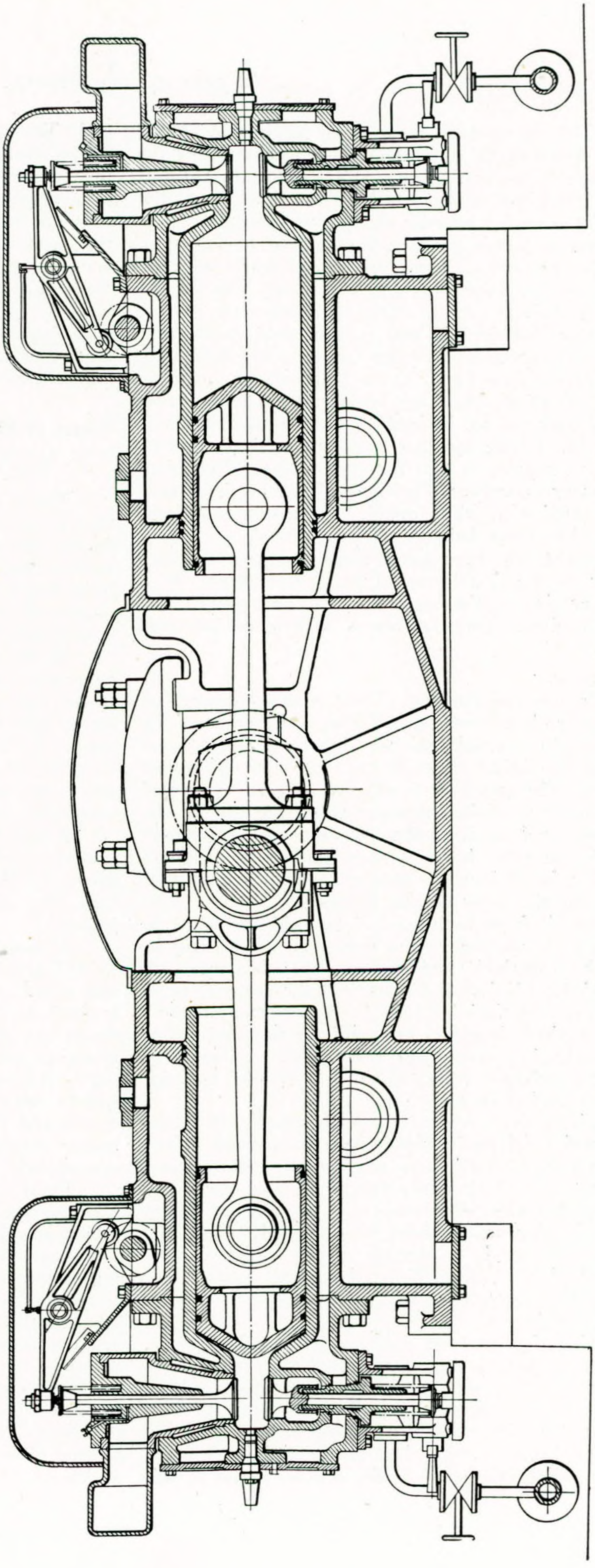
---

* Not reproduced.

suction, natural, town's or sewage gas; conversion from one type of fuel to the other is easily effected with a minimum of delay and tests have already been made with engines running on both fuels.

The engine illustrated is designed to produce 60 b.h.p. per cylinder at 428 r.p.m. and it is the makers' intention to standardise it in six- and eight-cylinder forms with the in-line arrangement, while four- and eight-cylinder *vis-a-vis* engines are to be offered. One of the accompanying* illustrations, however, shows a two-cylinder engine which has been built for a special duty to the requirements of a large county authority. It is interesting to note that this engine is shown running on town's gas, the accessible mounting of the b.t.h. magneto being clearly shown in the illustration. When ultimately installed it will be adaptable for operation on town's gas, sewage gas, or oil fuel.

The accompanying drawing shows that the shape of the combustion chamber and the unique cylinder liner-breech end casting are generally similar to the larger engines in the Crossley-Premier range. The engine bedplate is a rigid iron casting incorporating the main cylinder water jacket. There is a deep channel in the lower part of the bed which acts as a dry sump for the lubrication system, all the oil being drained away into the main sump at one end of the engine. It will be noticed that there is a vertical baffle in the bedplate close to the end of the liner so that the surplus oil from the cylinders, which may be contaminated with fuel oil, etc., is not allowed to mix with the main supply of clean bearing oil. The main bearing shells are white-metal-lined and can be removed without disturbing the crankshaft; main bearing adjustment is thus easily effected. The liner-breech end casting is in a special mixture of wear-resisting 14/15 tons tensile cast iron and the ample and free cooling spaces around the valves and hottest part of the liner will be noted with appreciation. A large circular end door is provided for each breech end to allow of access to the cooling water spaces for scale removal.



Section through the vis-a-vis type of the new Crossley-Premier medium-speed totally- enclosed engine of 60 b.h.p. per cylinder. Such features as the special big-end construction, neat valve gear arrangement, and breech-end design will be noted.

---

* Not reproduced.

The crankshaft is a solid forging of 28/32 tons open-hearth steel, drilled as necessary for the passage of lubricating oil. All the journals and pins are lapped and the scantlings of the shaft are to the requirements of Lloyd's Register of Shipping. The connecting rod is an open-hearth mild steel forging with a phosphor-bronze small end bush and the usual marine-type big end, with four bolts in the in-line engine. For the *vis-a-vis* engines the unique Crossley-Premier big end is employed, with eight bolts. Great care has been taken in the designing and manufacturing of these bolts, which, incidentally, are of an alloy steel having a maximum stress of 45 tons per sq. in. and an Izod impact value of 60ft. lb. Particular care is taken in the finish of the bolt shanks so that they are entirely free from marks or scratches. The big end bearing is of cast steel lined with white metal. The piston is of cast iron, the crown being internally ribbed, as shown. There are only three piston rings, the pressure rings being of the double-seal type, while there is a scraper ring at the bottom of the long skirt. The case-hardened gudgeon pin is secured at one end only.

Valve gear.

In our opinion one of the neatest features of the engine is the valve gear. This is driven from the centre of the crankshaft through large spiral bevel gears, one being of steel and the other phosphor bronze. The camshaft, it will be observed, is carried in a most accessible manner along the top of the engine, the drive from the cross-shaft being through 40/45 ton steel bevel wheels, both sets of gears working in oil baths as well as being provided with pressure oil spray at the points of contact. The surplus oil from both sets of gears drains back to the reserve oil tank at the front end of the engine. All the camshaft and rocker shaft bearings are provided with forced lubrication, the surplus oil in this case also draining back to the reserve oil tank; the camshaft bearings are white-metal-lined. The inlet valve is actuated direct through a rocking lever and the exhaust valve, at the lower side, through rockers and push rod.

The governor is of the high-speed centrifugal type and is driven from the cross-shaft which drives the camshaft. All parts are totally enclosed and lubricated from the main forced feed system. The governor motion is transmitted by a tension rod to an oscillating shaft which is connected to the fuel pumps. There is a speeder spring, which can be controlled by means of a handwheel, located between the two groups of fuel pumps at the front of the engine.

There is a separate fuel pump for each cylinder, the pump barrels being mounted in forged steel blocks to either side of the speeder control wheel. The pumps are accessible and are cam-driven, with an angular adjustment for timing. There is a fine strainer between each fuel pump and its sprayer valve, which is located in the centre of the breech end. The sprayer valve is of tool steel and is fitted in the steel sprayer body without any form of packing; furthermore, the joint between the cylinder and sprayer body is a ground one.

The lubricating oil pump is of the gearwheel type and is driven through gearing from the free end of the crankshaft. The pump is immersed in the return oil tank, while the system is provided with a small semi-rotary pump, the handle for which can be seen projecting from the top of the return oil tank, whereby the bearings can be flooded before starting the engine.

Types of Machinery.

"The Shipbuilder and Marine Engine-builder", August, 1937.

There are now 1,743 steamships of 11,747,788 tons fitted with turbine engines or a combination of steam turbines and reciprocating engines, and 6,763 vessels (including "auxiliary" vessels) of 13,748,713 tons fitted with internal-combustion engines, as compared with 730,000 tons and 234,000 tons respectively in 1914.

While during the past 12 months there has been an increase of 1,458,000 in the tonnage of motorships, and of 193,000 in the tonnage of vessels fitted with steam turbines, there has been a reduction of 619,000 tons in steamships fitted solely with reciprocating steam engines. Since June, 1925, there has been an increase of 11,035,000 in the motorship tonnage.

It may be stated that, of 9,957,140 tons of oil-tankers, excluding vessels of less than 1,000 tons gross, 5,199,870 tons are steamships and 4,757,270 tons are vessels fitted with internal-combustion engines.

Although the total motor tonnage amounts only to 20·7 per cent. of the aggregate tonnage owned in the world, and, in the case of Great Britain and Ireland, to 21·3 per cent. of the tonnage registered there, the highest percentages among the principal maritime countries are to be found in the following:—Norway (56·0), Denmark (48·7), Sweden (39·8), and Holland (38·9). Greece, the United States and France have the smallest proportions of motor tonnage, *viz.*, 0·7, 5·9 and 11·3 per cent. respectively.

There are recorded in Lloyd's Register Book 500 vessels, with a total tonnage of 2,446,407, which are fitted with a combination of steam turbines and reciprocating engines. Another interesting particular is that, in the case of 104 vessels with a tonnage of 612,387, electric propulsion has been adopted, the motors being supplied with current from generators which are driven either by steam turbines or oil engines. It may be added that auxiliary electric drive has also been adopted in a number of other cases. Of the 104 vessels just mentioned, 59 of 286,571 tons are owned in the United States. Of vessels exceeding 20,000 tons in which electric propulsion is employed, five fly the

British flag, two are owned in the United States, and one is owned in France.

Of the 29,524 steamships and motorships of 100 tons gross and upwards recorded in Lloyd's Register Book, 3,736 are twin-screw vessels and 109 have triple or quadruple screws.

Although few paddle steamships are now built, there are still in existence and recorded in Lloyd's Register Book 307 such vessels, of 232,550 tons.

Coal and Oil Fuel.

There are recorded in the new Register Book 3,932 steamships of 19,775,821 tons fitted for burning oil fuel, of which 791 of 5,069,596 tons are registered in Great Britain and Ireland, and 1,499 of 7,782,576 tons in the United States.

The foregoing figures, in conjunction with those given in the preceding section, enable the comparison given in Table IV to be made between the respective employment of coal and oil fuel at the present time and in 1914. It will be seen that less than 50 per cent. of the tonnage of the world's merchant marine now depends entirely upon coal, while in 1914 the percentage was nearly 89. The tonnage of steamships using coal, which in 1914 reached 43,860,000, is now 31,747,000, or more than 12,000,000 tons less. It should be understood, of course, that oil is not necessarily always used in steamships fitted for burning oil fuel, as in a number of cases coal-burning fittings can readily be substituted when occasion demands the use of coal in preference to oil.

TABLE IV.—TONNAGE USING COAL AND OIL FUEL.

	1914. Percentage of total tonnage.	1937. Percentage of total tonnage.
Coal	88·84	47·89
Oil fuel for boilers ...	2·65	29·84
Oil, etc., in internal-combustion engines ...	0·45	20·74
Sailing vessels, non-propelled barges, etc. ...	8·06	1·53
	100·00	100·00

Corrosion as Influenced by Increased Temperature.

"The Steam Engineer", June, 1937.

A paper by Mr. Ulick R. Evans, M.A., Sc.D., was read in London before the International Congress of the International Association for Testing Materials, on the subject of "Corrosion as Influenced by Increased Temperature", from which are taken the following extracts: At high temperatures, the rate of combination between metallic atoms and oxygen atoms is very rapid, and the rate of wastage of metals exposed to hot oxidising gases is usually only limited by the rate of penetration of oxygen inwards through the oxide-coat to the metal, or by the rate of diffusion of metal outwards to the oxygen. The heavy metals, such as iron or copper, occupy a smaller volume than the oxides which they yield on heating; the oxide-scale produced on such metals is usually in a state of lateral compression, which reduces its porosity; in the absence of cracking, the rate of access of oxygen to the unchanged metal below becomes increasingly slow as the oxide-scale thickens. Unfortunately, the tendency to crack or peel is greater for thick scales than for thin ones; for use at the highest temperatures, therefore, it is necessary to employ an alloy capable of giving an oxide-scale which becomes almost impervious to oxygen—even at high temperatures—whilst it is still thin and adherent. Many alloys containing chromium, aluminium and silicon possess these desirable properties; the use of nickel-chromium resisters in electric heaters and that of heat-resisting alloy steels is well known, whilst the use of aluminium-iron alloy layers to protect iron against furnace gases is becoming increasingly common. The protective action of aluminium, chromium and silicon in iron is shown by curves due to Portevin, Prétét and Jolivet. It was hoped that beryllium would prove valuable for the same purpose, but recent work indicates that the presence of beryllium, titanium and vanadium in iron confers only a slight protective action. Corrosion is stimulated by sulphur compounds, moisture and CO_2 in the gas, which renders the oxide-layer pervious, whilst intermittent heating favours the cracking of the scale and is more destructive than continuous heating.

When moisture-bearing gas is cooled below the dewpoint, it will deposit moisture on any metallic surface, producing a form of corrosion unknown at high temperatures. Actually, corrosion of this character may become serious when the relative humidity is still well below 100 per cent.; for vigorous attack of the humid type the relative humidity of the air must, however, exceed a certain critical value. Here, therefore, a *low* temperature may cause more corrosion than a higher temperature. Attack occurs on economiser tubes when moisture from the flue gases, which may contain sulphuric acid or suspended sulphates, is allowed to condense on the surface; there is little trouble if the surface is kept well above the condensation temperature, which lies higher than the dew-point owing to the hygroscopic nature of the deposit. Similarly, in coal-gas appliances, corrosion is greatly reduced if care be taken to avoid condensation of acid moisture by the impingement of the ducts of combustion on cold metal.

The rate of corrosion of immersed metal is often connected with the rate of supply of dissolved oxygen to the metallic surface. A rise in temperature will accelerate the diffusion of oxygen, and favour the electrochemical reactions, but will decrease the solubility of oxygen. Thus the corrosion-rate often first arises with temperature and then diminishes; Heyn and Bauer found a maximum rate for the rusting of iron at about 60° C., but the position of this maximum corrosion-rate depends on the conditions. A fluctuating temperature, by setting up convection currents will facilitate oxygen-transfer and cause quicker attack than a constant temperature under stagnant conditions.

Most types of wet corrosion would be considerably more rapid at 100° C. than at, say, 20° C., if it were not for the fact that oxygen and other stimulators of corrosion are frequently driven out of solution by heat. Corrosion in hot-water systems is much more serious when the design is such that the gas eliminated by the heating continues to circulate with the water. Where heat has to pass through metal walls, the Hot-Wall Effect of Benedicks becomes important. If water containing dissolved air passes through a hot metal container (a boiler or condenser tube), air will be forced out of solution and will adhere in bubbles to the metallic surface at certain points; these bubbles will prevent the water from exercising its normal cooling effect, and locally the temperature may become very high. At the some time the oxygen previously dissolved in the water can still play its part in the corrosion process. Obviously, there is a limit to the total corrosion which the oxygen present in a single air-bubble adhering to a metallic wall can produce, but if all the time other air bubbles are being swept past the wall without adhering, the adherent bubble (long after it has become a bubble of nitrogen) may still play a part in causing the attack to be concentrated at the point of attachment; this may occur by Hot-Wall action, and probably also in other ways.

Large Screws for Efficiency.

"Shipbuilding and Shipping Record", 17th June, 1937.

During the discussion on Dr. Hughes' paper dealing with model experiments on twin-screw propulsion,* Mr. Payne said "it is almost an axiom that you cannot fit a propeller of too large a diameter to a ship". Further, he pointed out that the broad conclusion to be drawn from Dr. Hughes' paper was that large diameter screws at the minimum acceptable spread are to be recommended for good propulsive results. While this may be the case, it is quite possible that, in an effort to obtain good propulsive results, a really serious blunder may be made. For example, two or three well-known vessels were fitted with Diesel engines running at about 90 r.p.m., which number had been determined from considerations of propeller performance. Investigation showed that the propulsive result *for given power* would be measurably higher than with engines running at from 110 to 120 per minute. The weight of the slow-running machinery was high per unit of power and *for the same total weight* it would have been possible to have had a considerable increase in power with the adoption of a higher number of revolutions. From the speed point of view this greater power, with propulsive results not quite so good as that possible with the lesser power at slightly better propulsive efficiency, could have given better results. Consequently, any investigation into power, revolutions and speed must take into consideration the weight factor as well as propulsive efficiency. In modern Diesel-engined liners the revolutions have not been determined from considerations of propulsion alone, but also by the power possible on given machinery weights.

Miniature Ball Bearings.

"Shipbuilding and Shipping Record", 17th June, 1937.

The ball bearing is recognised as possessing certain well-defined advantages over the usual form of sleeve bearing, but hitherto the former have not been available in very small sizes. A Swiss firm specialising in the manufacture of watch parts has, however, recently patented a miniature ball bearing which, it is claimed, can be substituted for the jewelled and plain bearings used in all forms of clockwork, recording and measuring instruments. These bearings, which are now being manufactured on a commercial scale, range in sizes from 1·5 millimetre upwards in overall diameter and it is hoped to produce a complete bearing of 1 mm. overall dimension. These miniature bearings contain three balls for the smallest size, rising to eight in the largest, and they are said to be capable of operating at speeds up to 10,000 r.p.m. Tests carried out to determine the reduction in friction resulting from the use of these bearings instead of jewels and pivots, showed that the mean damping time for rotational motion under identical conditions was eight times longer than for plain, and 20 times longer than for tapered pivots, while oscillation tests gave similar results. Moreover, ball bearings of this type have an extremely low coefficient of friction, approximately the same force being required for starting as when running. It may be mentioned that a British firm has already acquired an exclusive agency to deal with these bearings in this country.

Anti-Vibration Bolts.

"Shipbuilding and Shipping Record", 17th June, 1937.

A considerable amount of investigation has been carried out in recent years with a view to reducing the effects of vibration in the vicinity of reciprocating engines. In particular, on ships equipped with Diesel engine driven auxiliary generators endeavours have been made to reduce the effects of the vibration in the accommodation adjacent to these machines. While the correct dynamic balancing of the engine itself and the use of correctly-designed foundations may be very effective, it is seldom that vibration is entirely eliminated and it is therefore of interest to consider the use of anti-vibration bolts for securing the engine to its foundations in addition, of course, to the above measures. A type of bolt has recently been placed upon the market in which by an ingenious arrangement of steel tubing and indiarubber bushing there is no metallic contact between the bedplate of the engine and the foundation, and as it might be imagined that such bolts were suitable only for lightweight machinery, it may be stated that the mountings are made for loads up to 8 tons. Briefly,

---

* *Transactions*, Institution of Naval Architects, 1936.

the principle adopted is to cut a relatively large hole in the foundation plate, to which is secured the flanged steel tube, the lower end of the tube being closed except for a smaller hole, which is a clearing fit for the bolt. An indiarubber pad is placed in the tube and the bolt which passes through the pad is provided with a washer rounded on its underside through which the weight of the engine is transmitted to the indiarubber.

The Latest P. & O. Liner.

Launch of the "Stratheden" of 24,000 tons and 21 knots speed at Barrow.

"Shipbuilding and Shipping Record", 17th June, 1937.

The "Stratheden", of about 24,000 tons gross, for the P. & O. Company's express service between the United Kingdom, Bombay and Australia, was launched from the Vickers-Armstrongs Yard at Barrow-in-Furness on 10th June, and is expected to be in commission next November.

The "Stratheden" is the fourth ship built in recent years for the P. & O. Company by Vickers-Armstrongs, Limited, and the thirteenth ship they have launched for the P. & O. and its associated companies.

Unlike the earlier ships of this series, and following the style of the "Strathmore", which was launched by the then Duchess of York, the "Stratheden" will have one funnel and will be propelled by geared turbines. She is about 630ft. long b.p. and will be capable of a speed of about 21 knots.

Accommodation will be provided for 448 first-class passengers in 216 single and 116 two-berth rooms. A considerable number of the cabins will have a private bathroom attached and the remainder of the cabins will have both hot and cold running water.

One of the passenger amenities which will distinguish her and her sister ship the "Strathallan" which is to follow, from the earlier ships, will be the provision in all first-class passenger cabins of telephones connected to a central telephone exchange. Additional telephone call boxes will be situated on several decks.

The *de luxe* apartments will include two vice-regal suites, each comprising a dining room, sitting room, verandah, bathroom, and bedroom, and there will be six cabins *de luxe*.

The first-class dining saloon, which measures 86ft. by 68ft., will provide seats for 260 passengers and will be specially air-conditioned.

Public rooms and promenades for first-class passengers will comprise a reading and writing room, lounge, and covered dance floor. A sports and games area 275ft. long by 82ft. wide will be provided, supplemented on the deck below by the further provision of the ship's "Lido" comprising a swimming pool, verandah café and bar, with seating round the pool and ample space for sunbathing. When desired, portable screens will be fitted on each side to form a sheltered enclosure in way of the swimming pool.

There will be a children's dining saloon and a nursery with suitable open air space for play.

The 563 tourist passengers will be accommodated in 233 cabins, each cabin being attractively furnished. All the washbasins are to be provided with hot and cold fresh water. The tourist dining saloon will extend throughout the ship's width and measures 82ft. by 68ft., seating 332 persons.

There will be a nursery, lounge, a swimming pool, a verandah and a covered dancing space. Promenades will be provided and a sports and games area.

The "Stratheden" is to be propelled by twin screws, each driven by a set of Parsons turbines, through single reduction gearing, each set comprising one high-pressure, one intermediate-pressure and one low-pressure turbine, working in series and driving separate pinions engaging with the main gear wheel.

The high-pressure turbine is of the impulse-reaction type, the first stage consisting of an impulse wheel with two rows of blades, and the remainder of this turbine comprising six stages of reaction blading mounted on a hollow drum of forged steel. The intermediate-pressure turbine is of the reaction type, having seven stages of blades mounted on a hollow forged-steel drum. The low-pressure turbine is of the single-flow type, having sixteen rows of reaction blading mounted on forged-steel disc wheels.

The astern turbines for each set comprise one high pressure and one low pressure, working in series.

All the turbines are designed to run at 1,715 r.p.m., while the gear ratio is such that with this turbine speed, the propellers run at 112 revolutions, the total shaft horsepower to be developed on trial by the two sets of turbines at these revolutions being 24,000. The power developed astern is approximately 70 per cent. of the ahead power.

The nozzle vanes and blades forming part of the impulse section of the turbines are of special stainless steel supplied by the English Steel Corporation, Sheffield, which firm also manufactured the steel forgings for the main gearing, turbine rotors and propeller shafting.

The main condensers are of the Weir's Regenerative type, suspended from the low-pressure turbine casings, spring supports being fitted to relieve the load on the turbines. The total cooling surface in the condenser is 25,000 sq. ft., capable of maintaining a vacuum of 28in. of mercury with the barometer at 30in., with a sea water temperature of 86° F.

The steam generating installation is to consist of six Babcock & Wilcox high-pressure marine-type boilers. There are four large boilers and two small boilers, and all are fitted with superheaters and tubular air heaters. The blow-off pressure of the boilers is 450lb. per sq. in., and steam temperature 725° F. The steam drums of the boilers are of seamless steel and were manufactured by the English Steel Corporation, Sheffield.

The total generating surface of the four large boilers is 29,860 sq. ft., with a total superheating surface of 4,600 sq. ft., the total generating surface of the two small boilers being 7,170 sq. ft., with a total superheater surface of 1,350 sq. ft. The air heating surfaces for the large and small boilers are 32,000 sq. ft. and 8,000 sq. ft. respectively.

The boilers are arranged to burn oil only, under forced draught closed air duct system with open stokeholds. Air is supplied to the boilers by five double inlet electrically-driven fans of Howden's make.

It is anticipated that the "Stratheden" will be ready for service before the end of this year.

The Flow of Metals.*

By Professor E. N. da C. ANDRADE, F.R.S.

"The Engineer", 7th May, 1937.

Flow is most easily observed in the liquid state, but whereas there is a satisfactory theory of gases, and the structure of crystalline solids has been elucidated by the methods of X-ray analysis, very little is known of the actual behaviour of the molecules in the liquid state. It lacks the regularity of the crystal, and the molecules are too close to show the simplicity of behaviour that characterises gases. A liquid has about the same density as a solid, and can be regarded as a solid in which the heat agitation leads to a slow movement of the molecules from their places, a molecule travelling through a distance equal to its diameter after something less than but approaching a hundred impacts.

Andrade has put forward a theory of liquid viscosity on the basis that the momentum is transmitted from layer to layer not, as in a gas, by the passage of molecules from one layer into the other, but by instantaneous association of the molecules when they touch, so that at any nearest approach two molecules share their momentum. On this basis a formula can be derived which gives the viscosity of a simple liquid at its melting point, and another which gives the temperature variation of the viscosity.

Molten metals are particularly suitable for experiments designed to throw light on this problem of viscosity, because they constitute liquids which consist of one kind of atom only, and they are not, in general, associated. The viscosity is conveniently measured by sealing up the molten metal in a sphere suspended in vacuo, and observing the damping of the torsional oscillations of the sphere about a vertical axis due to the enclosed liquid. The method has already been used for the alkali metals, and is being extended to other metals.

The flow of solids is perhaps at first sight even more troublesome theoretically than the flow of liquids, for single crystals of metals exhibit plastic flow under very small stresses, whereas a perfect crystal should, first, be strong, and, secondly, be brittle. Again, single crystals of metals show a very marked hardening with flow. The mechanical properties of metal crystals have been elucidated by the work of Polanyi, Schmid, G. I. Taylor, and others, and it is now known that the factor which initiates plastic flow is the shear stress in a certain crystal plane and in a certain crystal direction, which can be found by experiment, but there is no general rule, applicable to all crystals, which enables us to decide beforehand what the plane will be, whereas the direction is always the direction in which the atoms are packed most closely. The glide direction seems to be more significant and fundamental than the glide plane.

To explain how it is that metal crystals can flow at all, various workers have suggested, with different detail, that in the ordinary crystal places exist where the atoms are out of step for a small distance with their immediate neighbours, such regions being called "dislocations" by Taylor. It can be shown that quite a small shear stress will cause such a dislocation to run along, leaving the atoms in the region through which it passes advanced by one. The weakness and the flow of single crystals is explained along these lines. Other internal flaws have been involved to explain the time factor in the flow, and the hardening. It cannot be said that there is any fully satisfactory theory of the flow of single crystals of metals, but a good beginning has been made.

It is, of course, a far step from the single metal crystal to the poly-crystalline metal of industry, but we can see that any crystal boundary is likely to stop the propagation of a dislocation or glide in general, and so will make the metal less weak and less liable to flow. Industry cannot, of course, wait for theory, but the only really satisfactory way to approach the problem of the strength of metals is by way of the single crystal.

National Physical Laboratory.

"The Engineer", 25th June, 1937.

The inspection by the General Board of the National Physical Laboratory took place on Tuesday last, June 22nd. About 2,000 visitors were received in the high-voltage laboratory by Sir William Bragg, President of the Royal Society; the Right Hon. Lord Rayleigh, Chairman of the Executive Committee; and the Director, Sir Frank E. Smith. As mentioned in a recent Journal note, Professor W. L. Bragg has been appointed Director of the National Physical Laboratory. In the physics department the visitors were shown, among other exhibits, a portable apparatus for the measurement of noise, in which a numerical value of loudness is given by the movement of a pointer over

---

* Abstract of the Twenty-seventh Annual May Lecture before the Institute of Metals, Wednesday, 5th May.

a dial. The Ministry of Transport has used this instrument for a study of the noise from motor vehicles. Among the many exhibits in the aerodynamics department was apparatus which showed the technique developed for the study of wing flutter by means of a cathode ray oscillograph; while in the William Froude laboratory experiments were demonstrated with a partially immersed ship's propeller, the data from which will be directed towards modifications in propeller design. Also demonstrated were experiments which have been carried out in the ship tanks with a view to improving the seaworthiness of ships' lifeboats. Ability to avoid shipping seas in rough weather is important in ships' boats, and the work has shown the importance of correct design of the bow. In the engineering department the general testing equipment was on view. Among the special exhibits, the methods and machines used in a research into the effects of combined fatigue stresses on materials for cast crankshafts were demonstrated. A special combined fatigue stress-testing machine has been designed at the Laboratory for the purpose of this research. A film illustrating a study of coloured street lights was shown by the electricity department. It has been suggested that the eye may work more efficiently by the light of some particular colour than it does by light of any other colour. In order to examine this question experimentally the cinema film has been prepared wherein objects appear and disappear at different points. The time of observation under different lighting conditions is noted. The afternoon was concluded by the meeting of the visitors at tea in the largest of the aerodynamics wind tunnel buildings.

Iron and Steel Foundry Progress.

"The Engineer", 25th June, 1937.

Grey and malleable irons, alloy irons, and steel castings were all discussed in various aspects at the annual meeting of the American Foundrymen's Association. As to grey iron, furnace temperature has an important effect on the final structure and iron up to 3 per cent. carbon melted at 2,900° will show ferrite. Any given iron has a range of cooling rates within which a normal pearlitic structure will result, but outside of which there will be formation of ferrite. This may be controlled by treating the molten metal with carbon dioxide. In small gears the ferrite trouble has been overcome by adding 0·30 per cent. of chromium. In cupola practice, there is increased attention to the sizing of coke, which in some cases has resulted in 10 per cent. increase of capacity, and 2,800° in pouring temperature. For the two-cupola process producing high-test iron, the mixture is 80 per cent. steel scrap, 10 per cent. return scrap, 1 to 3 per cent. pig (having 2 to 3 per cent. silicon), and 2 per cent. ferro-silicon. In the spout is added 3lb. of ferro-manganese-silicon for each 1,000lb. of metal in the ladle. In steel production some attention is being given to the Perrin process for speeding up the reactions between slag and metal by producing an intimate mixing; it is applicable to both Bessemer and open-hearth processes, but its suitability for steel for castings remains to be determined. The Association is preparing a guide for mechanical engineers, discussing design from the viewpoint of the foundryman, as so many difficulties and failures result from defects in the design of steel castings, especially those of large sizes. Many designers seem to consider only uniformity of section and avoidance of sharp corners, to the exclusion of other important factors. Contraction stresses, especially, are often overlooked. In some cases it may be better to lighten heavy sections than to increase light sections in aiming at uniformity. Then the foundryman should not be too restricted by specifications as to composition, but allowed to use his judgment for a composition that will produce a satisfactory casting. An idea not yet largely developed is that of making a difficult casting in two or three simple parts and uniting them by welding.

Cast Iron Steam Pipes.

"The Engineer", 25th June, 1937.

In his observations on a report on the explosion of a cast iron steam pipe at a colliery, the Engineer Surveyor-in-Chief to the Mercantile Marine Consultative Branch of the Board of Trade stated that "cast iron is the least reliable of the materials commonly used for steam pipes. Steel pipes, now in general use, are far more reliable than cast iron pipes, and having regard to the defects to which castings are liable, it is very disconcerting to learn from the report that a pipe made of inferior material and by an inferior process could have been put into service without the close inspection and hydraulic test invariably applied to steel pipes".

Genoa Airport.

"The Engineer", 2nd July, 1937.

It has recently been decided by the Italian Council of Ministers to grant 18,000,000 lire towards the construction of an airport at Genoa. Difficulty has been experienced as the town is placed on a narrow strip of land between the sea and encircling mountains. In consequence aircraft have had to choose between the seaplane base and the emergency landing ground of the local aero club. It is now proposed by the engineer in charge of the scheme, Signor Albertazzi, to make the necessary space by enclosing a portion of the sea and building a platform over it to act as a landing ground. The project is estimated to cost about 22,000,000 lire and involves clearing the coast to the west of the Polcevera around Castello Raggio and enclosing a strip of sea in the shape of a trapezium in front of this coast.

A Naval Fight of Sixty Years Ago.

"The Engineer", 16th July, 1937.

A naval action in which two British-built warships fought one another for a period of three hours with little damage to either side was recorded and discussed in our issue of 20th July, 1877. A revolution was in progress in Peru. One side had seized the Peruvian ironclad "Huascar", a turret ship built by Lairds of Birkenhead. Those in charge of the ship proceeded to commit certain depredations on English merchants. The Commander-in-Chief of our naval forces in the Pacific was Rear-Admiral De Horsey. Whether the accusations against the "Huascar" were true or not, the gallant Admiral saw no reason why he should doubt their substantial accuracy. Forthwith he detached her Majesty's ships "Shah" and "Amethyst" in pursuit of the culprit. After great difficulty she was found and was asked to surrender at discretion. She refused and an action began late in the afternoon off the coast of Peru near Iquique. The "Huascar" was a vessel 200ft. in length plated with 4½in. armour backed by 14in. of teak. Her turret of 5½in. plates with the same thickness of teak backing contained two 300-pounder Armstrong muzzle-loading rifled guns. Two 40-pounder and one 12-pounder Armstrong guns completed her armament. She drew 14ft. of water and had a free board of 5ft. Her speed was 11 knots. In action her skylights and hatchways were replaced by 2in. iron plates. Boiling water could be thrown from three fire mains on to the upper deck for the purpose of repelling boarders. The "Amethyst" took little or no part in the action, her "pop-gun" ordnance proving to be of little use. The "Shah" was an unarmoured cruiser 342ft. in length drawing 22ft. and having a nominal speed of 16½ knots. Her armament consisted of two 18-ton guns, sixteen 6½-ton guns and eight 64-pounders. Her 18-ton guns alone seem to have been of much service in the action although once she managed to get sufficiently close to her foe to riddle her funnel with Gatling gun bullets, and once a Whitehead torpedo was discharged—for the first time in naval warfare—ineffectively across the "Huascar's" course. A great quantity of powder was expended by both sides but the "Shah" suffered no damage, while the "Huascar", although struck seventy or eighty times, survived to steam away. The 64-pounder shell only left marks on her hull. A 7in. projectile struck her turret but penetrated only to a depth of 3in. A 9in. shell struck the hull, broke through the armour and wooden backing, and, breaking into fragments, came to rest against the inside of the opposite skin. The fact that the "Shah" escaped without damage is apparently to be attributed to the demoralisation of the Peruvian ship's crew. Under an incessant rain of small projectiles the "Huascar's" men lost their courage and her officers had to work her guns. We considered that the endurance exhibited by the Peruvian ship would do much to reinstate "thin" ironclads in favour, and that the fight went far to show that the old "Warrior" and "Minotaur" might still prove exceedingly useful vessels in a naval action. The engagement, we added, left the value of rifled guns for naval use still undecided. We were apparently inclined towards the view, then held by many authorities, that in an engagement at sea smooth bore guns could give as good results as rifled guns.

Welding Developments in Shipbuilding.

By W. D. Strathdee*

"Marine Engineering and Shipping Review", July, 1937.

Welding of all kinds has practically revolutionised the large shipbuilding industry throughout the world. Fundamentally the general shape of vessels may be the same, but to make the best of arc welding and effect savings in weight and cost, it is usually necessary completely to re-design.

Arc welding began to be introduced into the larger United States yards during 1915, 1916 and 1917. The welding units of that day were not as stable in operation and were more bulky, heavy and difficult to use than present-day outfits. Some of the early sets were multiple-operator units without provision for non-interference between operators which added to the difficulties. The sets were far from portable, making it necessary to bring the work to the welder.

A typical job at that time was the welding of shell staples to replace the cumbersome riveted staples then the practice in ship construction. From this operation, welding advanced to the fabricating of inserts in the corners of angles to butts in mast and king post rings. This eliminated smith welding and was much faster and cheaper. Other jobs of this type developed and the yards began to obtain portable welding units which could be moved from place to place in the yard to fabricate parts which could not be moved.

Welding applications began to increase so rapidly that many yards resorted to the old water-barrel type of unit to cover the high spots as single-operator sets at this stage of the game were expensive, and deliveries slow. These units served well in developing some of the skilled operators of the day.

Single-operator sets of more modern construction soon replaced the water barrels and still are used in large numbers. However, as welding inincreased even further, many factors such as investment costs, operating charges, wiring costs, power factor correction, and space factors caused the shipyards to install large numbers of modern multiple-operator sets supplying power to large numbers of operators.

Automatic welding had its place in this industry in the welding of certain types of bulkheads and decks, but gave way as coated electrodes for manual welding came in. However, at the present time new developments in automatic welding machines, new improvements in methods and re-designs are making it possible again to effect large savings by the use of automatic welding.

This entire programme of development was

---

* Welding Specialist, Westinghouse Electric and Manufacturing Company, Boston, Mass.

relatively slow from 1915 to 1929, because equipment, electrodes and knowledge were limited. In 1929 heavily coated or shielded arc electrodes were brought into the field and clearly demonstrated that properly welded joints could be made to meet the same requirements for the most part as the parent metal.

Government specifications calling for welded construction gave added impetus to welding design. Having proved an economical and safe means of construction, welding began to be specified by private builders.

Up until 1929 all the welding had been done with bare electrodes. The tensile strength of bare wire welds could hardly be guaranteed to be over 80 to 90 per cent. of the mild steel while the ductility would amount to 2 to 3 per cent. elongation in 2 inches of weld metal. As a result, welding was confined to outfitting work such as pipe and electrical hangers, rail and awning stanchions, ladder clips and rungs, flanges on low-pressure pipe, hinges on doors and hatches, and non-strength members.

With the advent of the coated rod and the consequent high tensile strength welds and elongations of 20 to 30 per cent., welding was applied to strength members and rolled steel sections to replace large steel castings. In many cases combinations of steel castings and rolled steel are welded together to make a better and cheaper job than either straight casting or rolled steel by itself. Shell frames and transverse frames, inner-bottom floors, shell butts, masts, spars and booms, foundations of all kinds, deck houses, port lights and covers, high and low-pressure piping or steam, oil and water lines, deck fixtures of all descriptions are all being welded. In fact, welding can be safely applied from stem to stern and from keel to mast head.

Development of a special welding electrode to handle light weight alloys and non-ferrous metals has opened new channels for welding advancement in shipbuilding. Excess weight in every form is objectionable, because it decreases the pay load of larger ships and the speed of naval vessels.

In addition to the arc welding developments, rapid strides have been made in gas welding with developments in gas apparatus for both welding and cutting. Also, spot and sea welding of light gauge sheets of special alloys are made practical by the latest developments in electronic timing apparatus. Atomic hydrogen welding has also a place for certain classes of work. New automatic welding processes might be called a combination of thermite and arc welding.

Welding in every form is practically indispensable to the shipbuilding industry to-day. If all the arc welding sets were taken out of any yard either those working on new construction or specializing in repair work, the yard would be completely crippled for some time at least.

To what lengths welding will develop further in shipbuilding is impossible to forecast. It is the writer's opinion, however, that the developments, particularly of the last eight years, will be greatly outdone in the next ten.

American Tanker Practice.

"Shipbuilding and Shipping Record", 3rd June, 1937.

The growing demand for tanker tonnage and the consequent increase in the number of vessels of this type which are being built in the shipyards of this country, gives added interest to the paper, entitled "Oil Tankers", by Mr. John W. Hudson, which was read at the recent meetings of the American Society of Naval Architects and Marine Engineers. It should be recognised in the first place that as regards size, at least, American practice is ahead of that in British shipyards and in the shipyards on the Continent. The average size of American tankers ranges from 12,000 to 13,000 tons, as compared with an average of about 11,000 tons for European tankers, while vessels of 18,000 tons are being built. In these large vessels, the rule of Lloyd's Register, that tanks must not exceed a length of 30ft. each, is being considerably exceeded, some vessels with centreline bulkheads, having 35ft. tanks, while a few special vessels have tanks up to 45ft. in length. This is because long tanks lead to a saving in weight by reducing the number of hatches, ladders, operating valves, etc., although it may lead to an increase of total weight due to the heavier scantlings required. As regards the system of construction adopted for the hull, it is noted that certain large operators of tank tonnage prefer the twin-bulkhead type because of its greater longitudinal strength, its saving in steel, the reduction in the area of steel liable to corrosion, flexibility in loading and trimming, and the possibility of using the centre tanks for water ballast. Strength calculations as between the twin-bulkhead type and the centre bulkhead type with summer tanks, showed that with a 7 per cent. reduction in the area of the midship section, there was a gain of over 2 per cent. in the section modulus in favour of the former type; further, the bracketless system is more efficient than the original bracketed longitudinal framing. It is worthy of note that the author anticipated a great increase in the use of welding for the hull construction of tankers in the near future, and he mentioned that one well-known American firm of shipbuilders had received a contract for a tanker 521ft. long, in which the entire tank section was to be completely welded, as well as part of the ends.

On the subject of the most suitable form of propelling machinery for oil tankers, there appears to be as much divergence of opinion in America as there is on this side of the Atlantic. Thus, of 20 tankers under construction in the United States, three are to be propelled by Diesel engines, one has the steam turbo-electric system of propulsion, while 16 are equipped with high-pressure geared steam turbines. This is rather the reverse of practice in this country and elsewhere, since of 81 tankers building or completing other than in the United States, 17 have steam propelling machinery and 64 are motorships. Of all the propulsion systems available, the author asserts that the Diesel-electric is the most flexible since the generator units can be split as desired and made to drive one or two motors.

The present forms of high-pressure high-superheat steam installations, he suggests, lack the simplicity which is so desirable in marine engineering and, in particular, they are the least suited to an arrangement aft in a restricted and irregular space. They possess, however, the advantage in first cost, while the available personnel is better able to deal with this type of propelling machinery than with the Diesel installation. It is these reasons, coupled with what the author terms "the greater aggressiveness of the steam machinery builders", which is responsible for the preponderance of the steamer as against the motorship in the United States. On the subject of speed, it is found that, except in Japan, where the 18-knot tanker is not uncommon, the average speed does not generally exceed 11 knots, although there is a tendency towards higher speeds and with improved hull forms, streamlined rudders, and more efficient propellers, it is possible to obtain these without any undue increase in the power of the propelling unit. On the subject of protection against the risk of fire, the author suggests the use of air-conditioning equipment for the officers' and crews' quarters, so as to eliminate the use of electric fans. All electrical fittings should be so fixed as not to require the use of flexible leads and plug-in sockets, which could produce a spark, and some companies go so far as to light the pump rooms entirely from outside sources, either through heavy port lights or by using explosion-proof portable lights which are carried in as required. The general practice, however, is to use vapour-proof fixtures of 100 watt capacity in the pump room and to operate them by switches placed outside. The usual voltages are 230 for motors and 115 for lighting, the latter being obtained through motor-generator sets or balancer sets; but balancer sets have been prohibited by the American Bureau of Shipping, since they required to be "earthed". This, the author suggests, is a step in the right direction.

BOARD OF TRADE EXAMINATIONS.

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

Name.	Grade.	Port of Examination.
For week ended 1st July, 1937 :—		
Cheape, Henry R.	2.C.	Glasgow
Johnston, William	2.C.	,,
Moon, Robert	2.C.	,,
Nelson, David A. K.	2.C.	,,
Paterson, David	2.C.	,,
Platt, Shelburn K.	2.C.	,,
Scott-Young, Brian	2.C.	,,
Thoms, James McI.	2.C.	,,
Melrose, James	2.C.M.	,,
Stratton, John A.	2.C.M.	,,
Catterall, Robert A.	2.C.	Liverpool
Morris, Emrys	2.C.	,,
Taylor, Robert	2.C.	,,
Wood, Albert E.	2.C.	,,
Cook, Wilfred A.	2.C.	London
Hicks, Stanley G.	2.C.	,,
Thorpe-Smith, Geoffrey	2.C.M.	,,
Aadahl, Alfred N. G.	2.C.	Newcastle
Jameson, James E.	2.C.	,,
Johnson, Alexander K.	2.C.	,,
Jones, John E.	2.C.	,,
Oliphant, Ronald	2.C.	,,
Newton, Sydney J.	2.C.M.	,,
Sayer, Robert	2.C.M.	,,
Staincliffe, Thomas R.	2.C.M.	,,
For week ended 8th July, 1937 :—		
Earle, Arnold	1.C.M.	Newcastle
Foley, William R.	1.C.M.	,,
Robson, Joseph V.	1.C.M.	,,
Thornton, Henry N.	1.C.M.	,,
Bell, David M.	1.C.	Glasgow
Crossan, Charles McG.	1.C.	,,
Morison, George G.	1.C.	,,
Ross, Bertie E.	1.C.	,,
Taylor, William A.	1.C.	,,
Skinner, Richard W.	1.C.M.	,,
Brown, Angus P.	Ex.1.C.	,,
Elliott, Edgar T.	Ex.1.C.	,,
Mathews, Sylvester	Ex.1.C.	Liverpool
Tod, Donald S.	Ex.1.C.	,,
Belcher, John R. S.	Ex.1.C.	London
Short, John F.	Ex.1.C.	Newcastle
Rose, John A. F.	1.C.M.E.	Glasgow
McNeil, Alastair McD.	1.C.M.E.	,,
Ramsdale, Gerald S.	1.C.M.E.	Newcastle
Jordan, Edwin C.	1.C.M.E.	,,
McIlwaine, Thomas S.	2.C.	Belfast
Thompson, James C.	2.C.	,,
Allen, Thompson McW.	2.C.M.	,,
McCallum, Thomas	2.C.M.	,,
Veighey, Gilbert	2.C.M.	,,
Letchford, Harold E.	1.C.	London
Nicholls, Philip	1.C.	,,
Smith, Harold V.	1.C.M.	,,
Seymour, Thomas	1.C.	Liverpool
Sloan, John I.	1.C.	,,
Starkey, William	1.C.	,,
Thompson, William	1.C.	,,
Kilgour, Eric	1.C.M.	,,
Arthur, Lawrence K. B.	1.C.	Newcastle
Dunville, Edward	1.C.	,,
Robertson, Alan	1.C.	,,
Swinburne, Albert H.	1.C.	,,
Boll, Clement	1.C.M.	,,
Crouch, George	1.C.M.	,,
Griffiths, Griffith W.	1.C.M.E.	Liverpool
Dowling, William P.	1.C.M.E.	,,
McFarland, Alexander	1.C.M.E.	Belfast
Charlton, John	1.C.S.E.	Newcastle
Maclarty, Hugh T.	1.C.M.E.	London
Benson, Leofric H.	1.C.M.E.	Newcastle
Henshaw, Henry	1.C.M.E.	Liverpool
Reid, Robert H.	1.C.M.E.	London
For week ended 15th July, 1937 :—		
Bryce, Wilfred	2.C.	Newcastle
Drummond, Leslie	2.C.	,,
Kerridge, Edgar I.	2.C.	,,
Lockey, Henry T.	2.C.	,,
May, Robert W.	2.C.	,,
Purdy, William	2.C.	,,
Taylor, Gilbert B.	2.C.	,,
Batey, Thomas W.	2.C.M.	,,
Beasley, Joseph H.	2.C.M.	,,
Matthews, Thomas	2.C.M.	,,
Thorne, Alfred	2.C.M.	,,
King, Ivor V.	2.C.	Cardiff
Sexton, John Q.	2.C.	,,
Simpson, James	2.C.	Glasgow
Eckles, Harold T.	2.C.	Liverpool
Goyen, Raymond K. L.	2.C.	London
McCririck, James	2.C.	,,
Roberts, Llewelyn O.	2.C.M.E.	Cardiff
Smith, William	1.C.M.E.	Newcastle