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The Air Supply to Boiler Rooms.

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CHAIRMAN: MR. B. P. FIELDEN (Vice-President).

IN dealing with the subject of the air supply to boiler rooms for the combustion of fuel, either coal or oil, there have been in the past many methods, each probably being satisfactory from the point of view of the shipowner, depending entirely upon the type of ship and its trade, and the arrangement of the boiler rooms.

Messrs. Howden's forced draught system is the best known, where the air is drawn from the upper decks through steel casings and delivered by mechanical means through an enclosed system direct to the furnaces of the boilers.

In some ships of large sizes Messrs. Howden's system has been varied. The air has been taken from the engine room in order to obtain free ventilation, then delivered through casings by mechanical means and delivered to the furnaces of the boilers.

In other classes of ships the air supply has been obtained by natural draught only, and this has been modified in some cases by assisting the natural draught by providing mechanical-driven fans to augment the air supply, the air being drawn from the upper decks and delivered to the open stokeholds.

The induced draught systems of Messrs. Ellis and Eaves and others have been adopted quite successfully on a small scale.

Where closed stokeholds are employed and oil fuel is used exclusively, this is another system offering considerable scope for investigation and improvement.

The author wishes to make clear that this paper deals only with some of the investigations which have taken place during the last few years, on certain classes of ships where closed stokeholds are adopted.

The author has purposely refrained from mentioning the advantages or criticising this or any other system.

The object of this paper is to place on record the difficulties encountered in the past and the many improvements resulting from this experience.

The closed-stokehold system has been adopted in many classes of vessels of varying powers. It is a well-known fact that in burning oil fuel higher air-pressures are required than for coal, and consequently the power absorbed by the fans is considerable. Any improvement which can be effected by increasing the efficiency of the system, with a consequent saving in steam consumption, reduction in weight and space occupied, will have some influence on the speed and economy of the ship.

In order to deal with this question in a comprehensive manner and to direct attention to the system in detail the subject is dealt with under the following headings:—

(1) Air Pressure and Air Velocity.

(2) Loss of Air Pressure in Boiler Rooms due to Suction.

(3) New design of Deck Intakes, Weather Flaps, Centre Guide and Nozzle.

(4) Stream-line Gratings.

(5) Stream-line Fan Inlet Shutters.

(6) Inlet Rings on Fan Entrances.

(7) Design and Construction of Fans.

(8) Design of Fan Casings and arrangement of Deflectors.

(9) Uniform Distribution of Air in Boiler Rooms.

(10) Oil Fuel.

(11) Steam Turbine driven Fans.

(12) Conclusions.

(1) Air Pressure and Air Velocity.

Theoretically an air pressure of 1 inch water produces 67 feet per second air velocity, but this does not allow for any practical losses. It will therefore be more correct to work on the basis of 1 inch water gauge pressure producing 54 feet per second. Within the range of speed and of air pressure actually employed on board ship, the speed varies as the square root of the pressure difference.

Assuming the calculation to be made for an exit nozzle, consisting of a short cylindrical pipe P P_0 in Fig. 1, with ends not rounded off, we should find that an air pressure of 1 inch water gauge would produce approximately a speed of 54 feet per second.

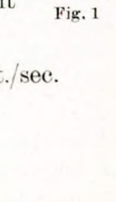


Fig. 1

The expansion of the formula, with the co-efficient underlying our calculations, is as follows :—

V = Exit Velocity	$= C\sqrt{2\ g\ v\ (P - P_0)}$ ft./sec.
g = Acceleration due to gravity.	$= 32{\cdot}2$ ft./sec./sec.
v = Specific volume of atmospheric air (at about 70°F.)	$= 13{\cdot}2$ cubic ft./lb.
$P - P_0$ = Pressure difference	$= 5{\cdot}2$ lbs./sq. ft. for 1 in. W.G
C = Co-efficient of flow :	
For flow without loss	$= 1{\cdot}0$ (theoretical).
For cylindrical pipe without rounded ends	$= {\cdot}8$ (practical).
∴Exit velocity due to 1 in. W.G.	$= 1\sqrt{2 \times 32{\cdot}2 \times 13{\cdot}2 \times 5{\cdot}2}$
	$= 67$ ft./sec. (theoretical).
	or, $= {\cdot}8 \times 67$
	$= 54$ ft./sec. (practical).

On the basis of the above formula (with C = ·8), the following table gives the corresponding air pressures in inches water gauge required to produce given air speeds in feet per second:—

20 feet per second ...	... ·13 inch W.G.
25 ,, ,, ...	... ·202 ,,
30 ,, ,, ...	... ·29 ,,
40 ,, ,, ...	... ·52 ,,
50 ,, ,, ...	... ·81 ,,
60 ,, ,, ...	... 1·16 ,,
70 ,, ,, ...	... 1·58 ,,
80 ,, ,, ...	... 2·07 ,,

The speeds to be recommended for air shafts are from 20 to 25 feet per second according to shape. The pressure required to produce this velocity in relatively small, viz., ·13 inch to ·20 inch W.G., but increases in the ratio of the square of the velocity, so that to produce double the air speed four times the pressure is necessary, and to produce four times the speed requires sixteen times the pressure.

It frequently happens that most of the velocity energy of the air is lost, which means that the fan must be designed for the extra pressure corresponding to the air speed, if the required output is to be obtained. For this reason a low air speed is desirable, as it reduces the work to be performed by the fan for a given air pressure to be produced in the boiler room.

It must be remembered that to obtain a speed of air a pressure difference has first to be set up; this pressure energy then is converted into velocity energy, the greater part of which subsequently gets lost, as very little of the speed is converted back to pressure.

Therefore, the higher the air speed, the greater will be the loss. As stated, it is a difference of air pressure that causes a flow of air, and expressed in this way the statement applies equally to suction or discharge, i.e., to pressures above or below the atmosphere.

(2) LOSS OF AIR PRESSURE IN THE BOILER ROOM DUE TO SUCTION.

If a loss of air pressure, say of 1 inch water gauge, occurs in the passage from the deck entrance to the fan inlet due to high speeds, sharp corners and sudden enlargements, then in order to draw the air into the fan room a suction or vacuum of 1 inch water gauge must be produced by the fans. Therefore, if a fan designed for 4 inch water gauge of pressure in the boiler room has first to produce 1 inch water gauge of vacuum in the fan compartment in order to draw the desired quantity of air through the air passages, then obviously it can only maintain 3 inches on the discharge side, i.e., in the boiler room, instead of 4 inch water gauge.

Exhaustive tests have been carried out which prove that the air pressure in the boiler room equals the total pressure exerted by the fan less the amount of suction at the fan inlet. The tests were conducted on a forced draught fan, 60 inches in diameter, and typical readings are as follows:—

R.P.M.	Cub. ft. Air per min.	Total Press. inches W.G.	Suction. inches W.G.	Discharge Press., inches W.G.	
450	10,000	3·75	·25	3·5	Suction opened and discharge throttled
450	9,000	3·74	3·5	·24	Suction throttled and discharge opened

The results show that, for a given speed of revolution and quantity of air, the total pressure across a fan is constant, and if a resistance is placed in the fan inlet, causing a rise in vacuum, there will be a corresponding fall in discharge pressure. It is therefore proved that:—

1 inch W.G. vacuum on inlet side means 1 inch W.G. drop in discharge pressure.

2 inch W.G. vacuum on inlet side means 2 inch W.G. drop in discharge pressure.

3 inch W.G. vacuum on inlet side means 3 inch W.G. drop in discharge pressure.

The readings given in the table below are the outcome of tests on board ship, and they show that of the total air pressure which the fan installation on this ship is able to maintain at maximum output fully one-third is wasted in losses of flow through the intake shaft, making only two-thirds available for the boiler room.

R.P.M.	Total Press. across Fan, inches W.G.	Loss in Intake Shaft inches W.G.	Press. in. Boiler room, inches W.G.	Volume of Air entering Stokehold.
430	4·6	·1	4·5	Gradually increased to the maximum as a greater number of furnace flaps were opened.
450	4·4	1·1	3·3	
435	4·2	1·4	2·8	
430	4·2	1·6	2·4	
430	3·8	1·55	2·25	

Taking into consideration the characteristic curves of the performance of centrifugal fans, it would be desirable when there is any risk of air shortage to specify fans designed for increased air pressures, instead of increased quantities as is frequently done. By this means there would be a reserve of pressure to overcome resistances in intake passages if they occur. At the same time a greater supply of air to meet emergency conditions would still be available.

(3) New Design of Deck Intakes, Weather Flaps, Centre Guide and Nozzle.

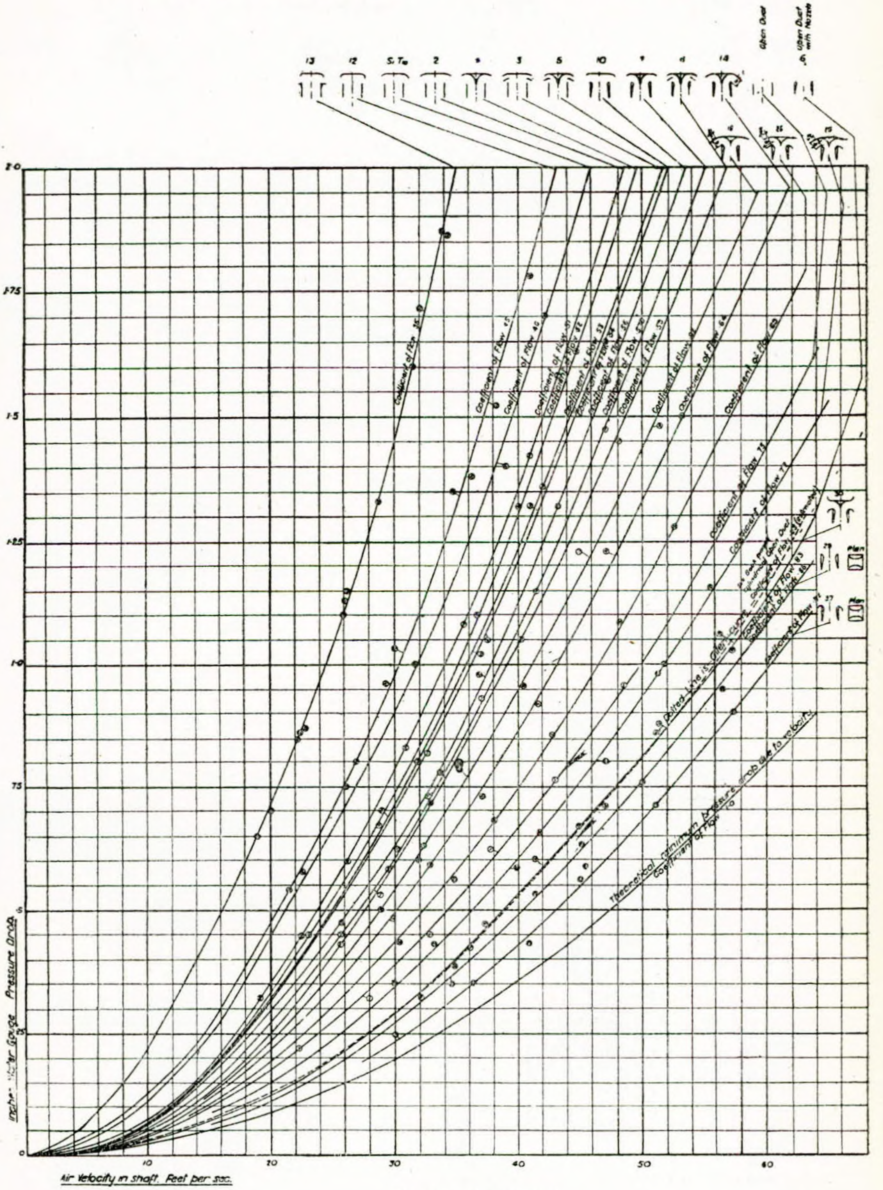
The design of the Deck Intakes, with their weather flaps, has been so greatly influenced by the requirements of protection from waves and spray in bad weather, that less attention has been given to the proper admission of air without loss or restriction. Frequently the area of admission is found to be insufficient, or part of that provided is ineffective. Also, the shape of the passage of air into the shaft makes the entry difficult. When the weather flaps come into operation to shield against rain and sea, the entrance of air practically ceases correspondingly. The difficulty of getting the air into the shaft becomes greater as the speed of the ship increases, and trouble may be encountered, particularly on fast vessels.

Many different types of deck intakes have been tried, the design depending upon the situation of the intake and its surroundings on the ship, as well as the class of vessel and the work for which it is intended.

A series of experiments has been made to establish the relative efficiency of different types of air intakes, including the designs generally in use, and also to discover the most efficient shape of entrance to conform to the natural line to flow.

The essential requirement was to provide a guide which would perform the protective duty, but at the same time induce the flow of air into the shaft, especially when partially closed against the weather.

The design proposed to replace the previous shapes offers a marked improvement in efficiency, namely, 83 per cent. against 35 per cent. The comparative tests are contrasted in Fig. 2. The theoretical curve of pressure drop due to velocity with perfect flow is given on the same graph, so that a comparison may be effected.

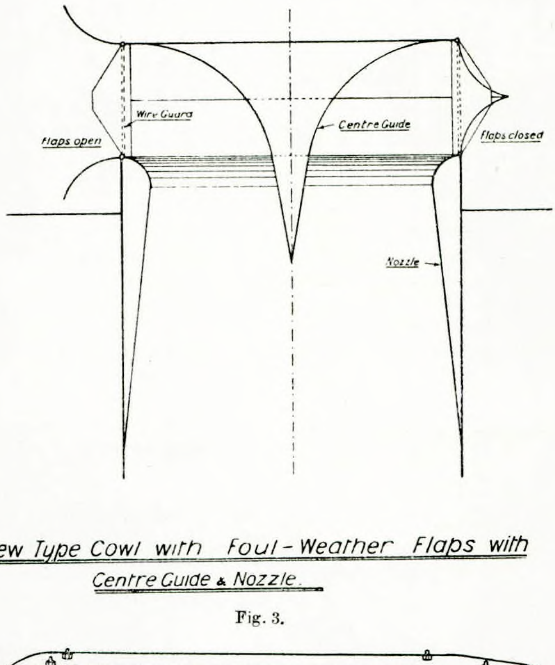


Test Results on Model
for Deck Intakes
Shaft of Square Section

Fig. 2.

The guides, which act as weather-flaps, are of stream-line form, and are hinged at the opening of the deck intake so that they can be opened any desired amount.

The improved design of cowl with the stream-line weather flaps is illustrated in Fig. 3, and is contrasted with the shape of cowl and weather-flaps fitted in the past, shewn in Fig. 4.



New Type Cowl with Foul-Weather Flaps with Centre Guide & Nozzle.

Fig. 3.

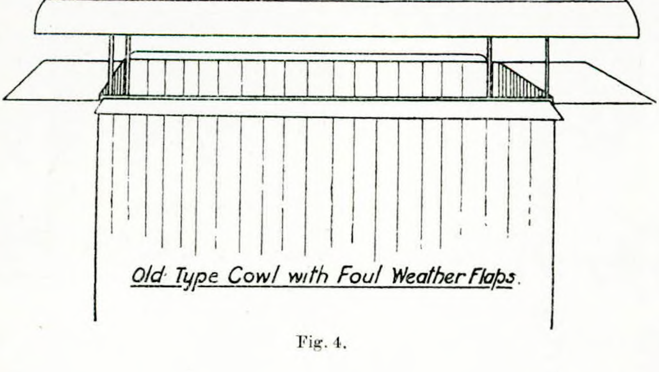


Fig. 4.

Two recent innovations, namely, the centre guide and nozzle, are embodied in the deck entry, and are also shown in Fig. 3, the centre guide in the form of a deflector or inverted pyramid attached beneath the cowl top, and the nozzle providing a *vena contracta* flow at the entrance to the intake shaft.

In explanation of the manner in which the centre guide and nozzle contribute to prevent loss of pressure, it has been proved that where these contrivances are not provided the whole of the space which they occupy is filled with eddy currents, which are continuously absorbing energy.

The reason for the formation of the eddies is partly that the direction of the air is changed on entering the shaft and owing to its velocity sweeps round the corners, and partly owing to the law of *vena contracta* for the flow of all fluids, either liquid or gaseous, at entrance or exit of a duct.

The centre guide and nozzle conform to the correct line of flow to prevent the formation of any eddies.

The ribbon tests conducted on the air intakes have been photographically recorded, and are reproduced in Figs. 5 and 6

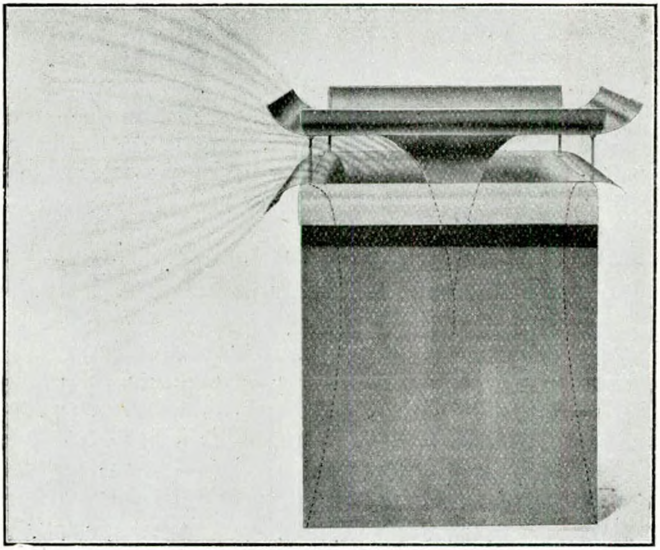


Fig. 5.

Another improvement to which importance is attached is fitting of the diaphragms, placed athwartships, sub-dividing the air intake shaft.

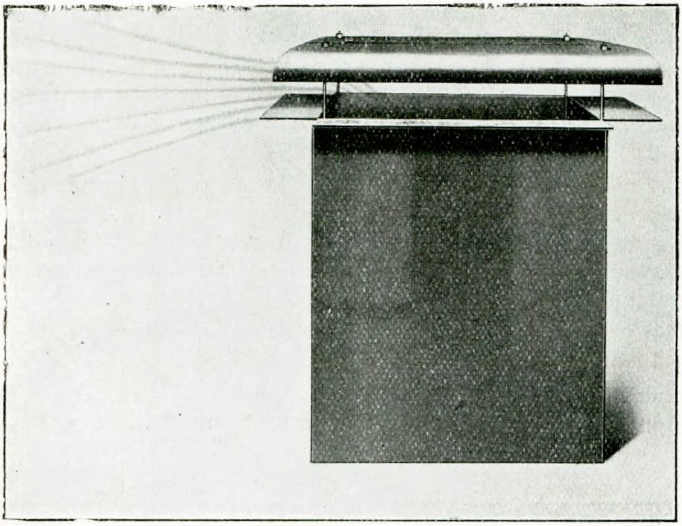


Fig. 6.

When a ship is travelling at a high speed there is a tendency for the air to rush past the intake without being drawn in, and for the air which does enter to bank up in the after side of the intake shaft, wtih a consequent tendency to starve the forward fans.

By fitting diaphragms the tendency to unequal air supply fore and aft will be efficiently counteracted, and all the fans will receive their due share of air.

(4) Stream-line Gratings.

It has been ascertained by actual trials on board ship during sea performances that considerable losses occur in the vertical air intake shafts due to the existing design of gratings, and it was decided to carry out exhaustive experiments to measure these losses. With a view to overcoming these difficulties, models to full scale were constructed whereby various shapes could be tried and a final design evolved, giving the least possible air resistance.

Previous designs of grating, which were of round section or rectangular, as shown in Fig. 7, presented a resistance to the passage of the air, inasmuch as the obstruction caused by the shape occasions the formation of eddy currents. Further, a

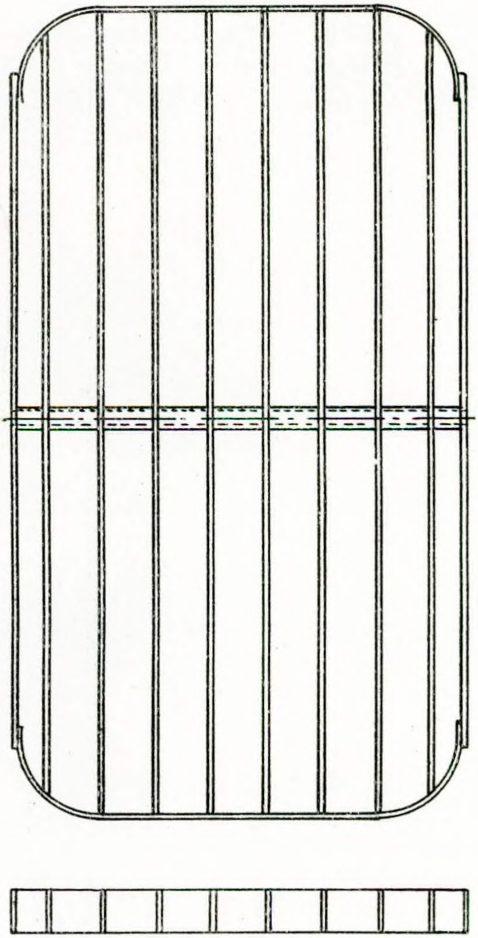


Fig. 7.

certain amount of pressure is required to produce the extra velocity of the air passing in columns through the apertures of the grating, which pressure is not regained owing to its shape.

The new design, Fig. 8, is furnished with apertures, the sides of which correctly follow the "stream-line" of the air columns, eliminating the formation of eddy currents. The separate columns of air merge into one stream again without shock.

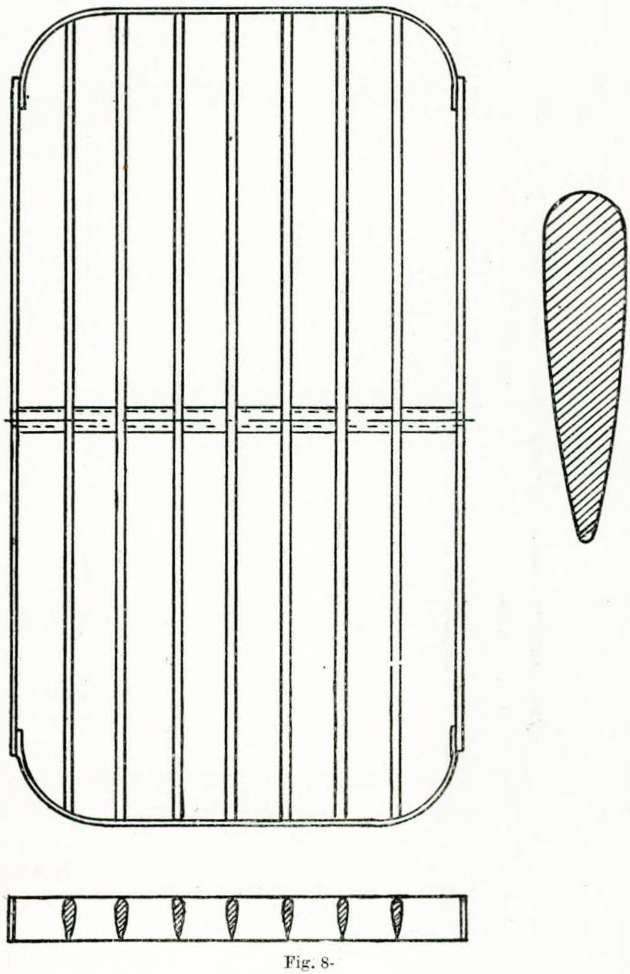


Fig. 8.

A stream or jet possesses energy, partly as static pressure, and partly as energy of velocity. A gain in velocity, due to a reduction of cross area, is made at the expense of the static pressure, since there can be no ultimate gain in the total energy. But, if there were to be no loss, it follows that for every section, a, b, c . . . . . g (Fig. 9).

Pressure + velocity energy = constant.

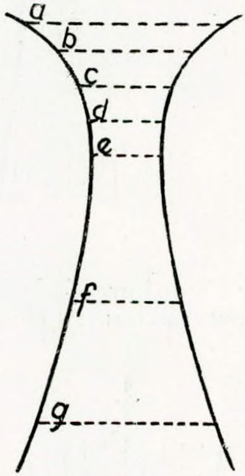


Fig. 9.

In the ideal case the pressure energy would be completely restored by a subsequent reduction of velocity by gradual increase of area.

Part of the velocity energy is, however, never actually reconverted, as it is lost in friction, shock and eddies. When wrongly shaped surfaces are presented to a stream the losses are considerable, as the current follows the natural stream-line outside the projecting surfaces, and the idle spaces are filled with eddy currents.

It would be well to emphasise that it is for this reason that the design of air passages in general presents such scope for preventing loss of energy.

The well-known form of a current of air passing through a restricted passage is shown diagrammatically in Fig. 10.

Placing two apertures adjacently, as in Fig. 11, the compound stream-line—that is, the ideal section of grating—immediately appears in relief.

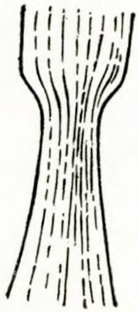


Fig. 10.

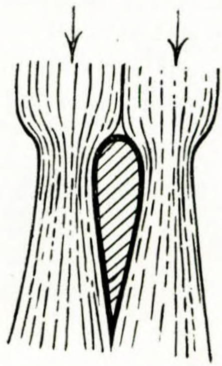


Fig. 11.

Fig. 12 shows by the shaded area L M N P the eddies which the air tends to form naturally in its effort to follow a correct

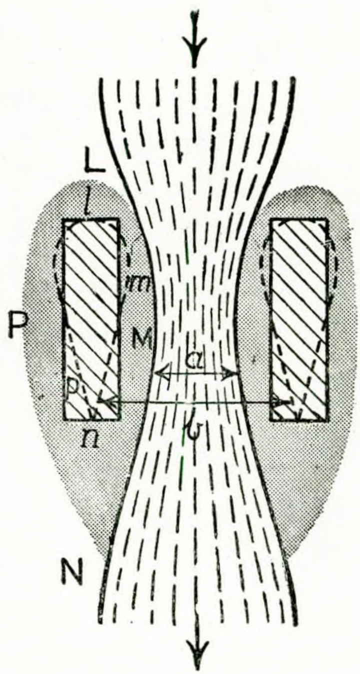
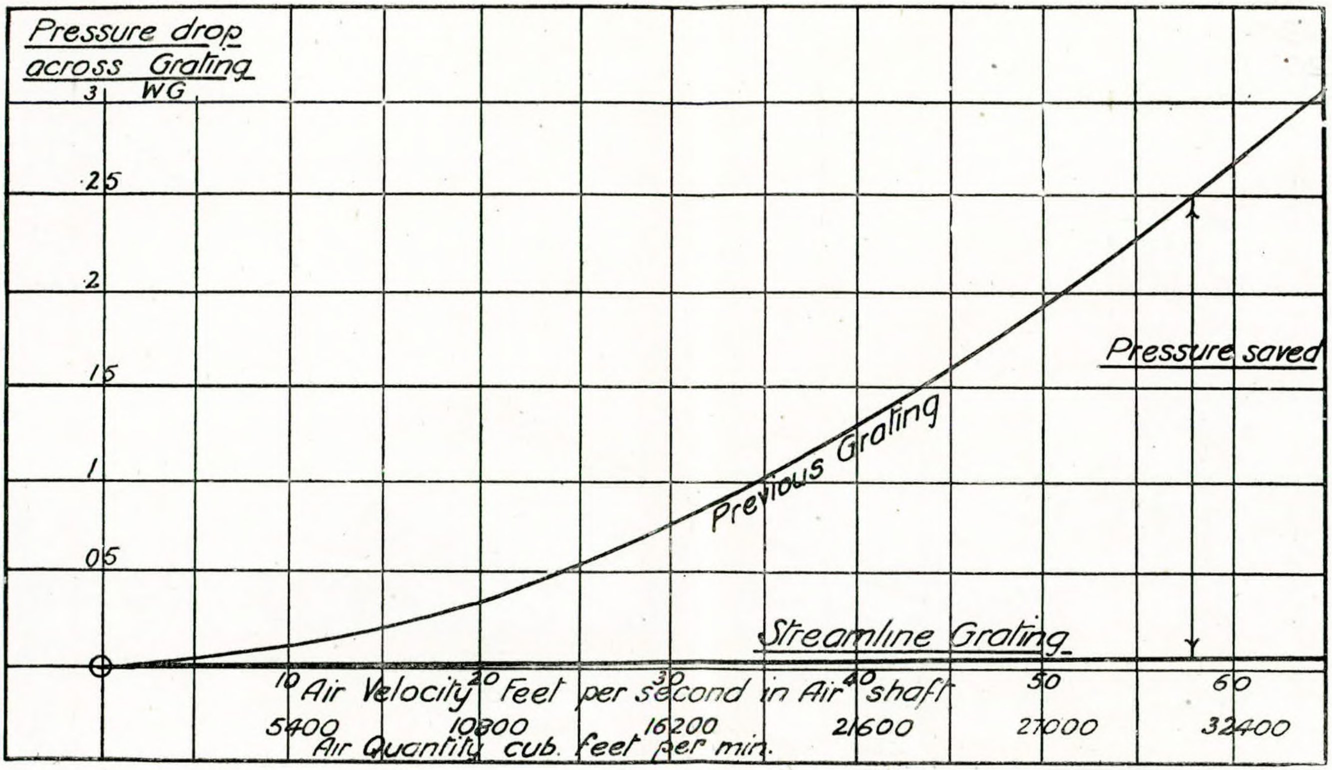
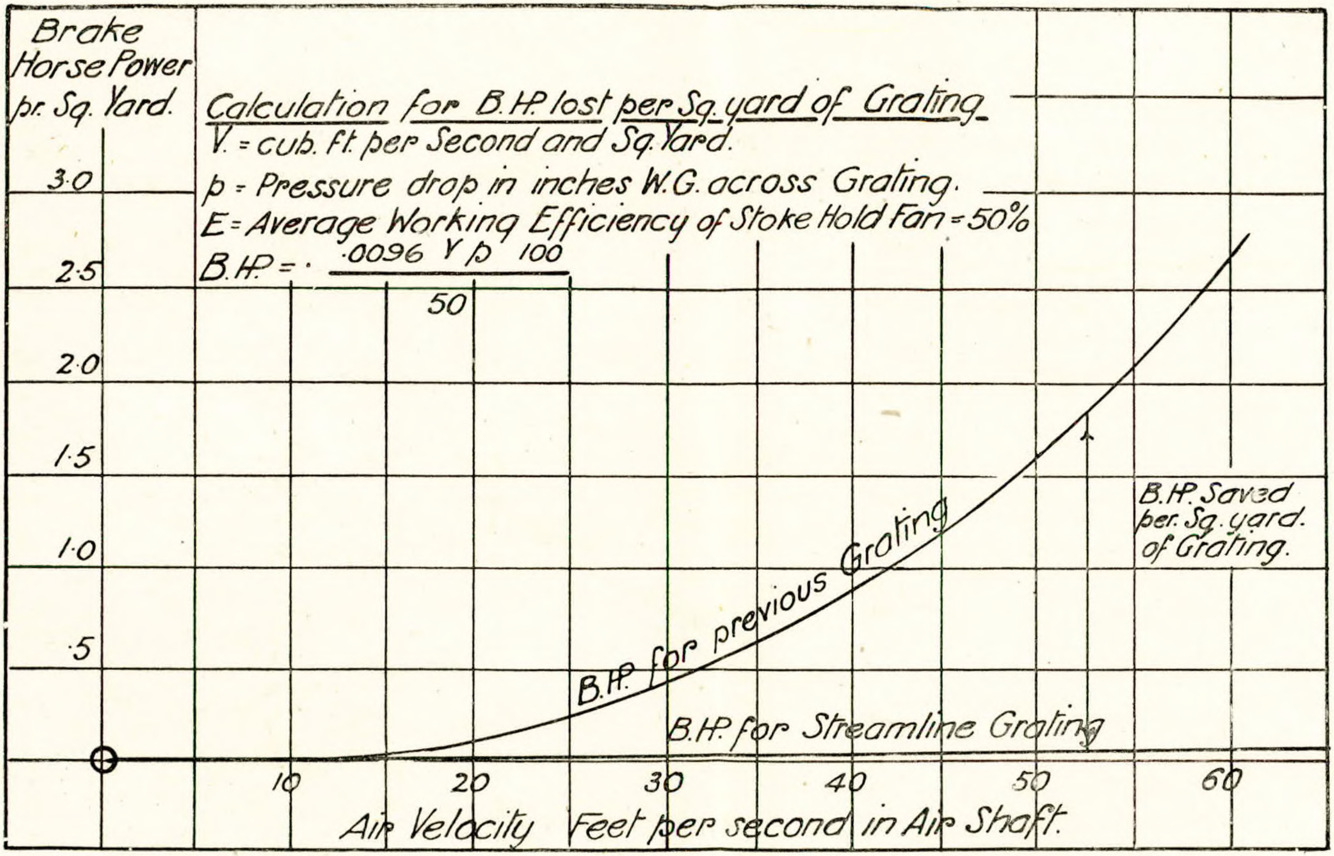


Fig. 12.



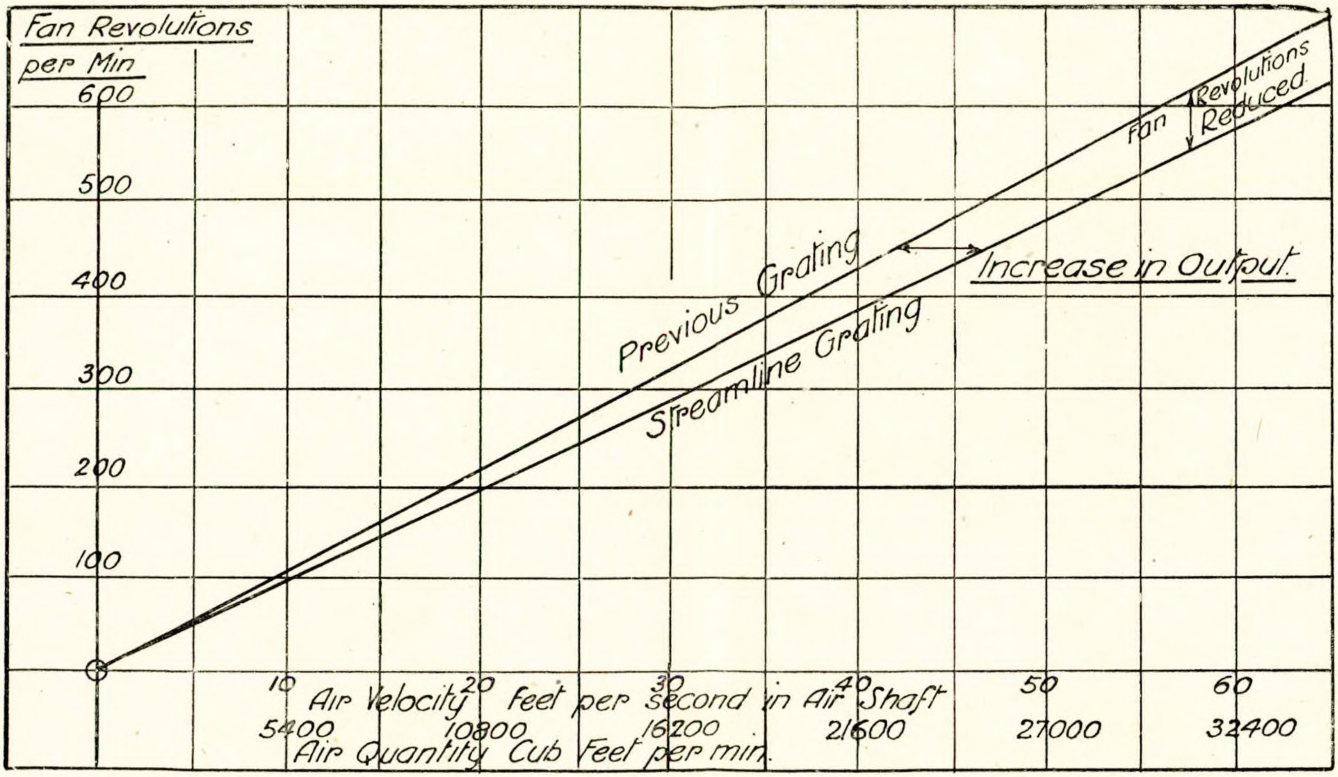
Saving in Pressure drop across Grating with Streamline Section.

Fig. 15.



Power saved with Streamline Grating on every square yard of grating.

Fig. 16.



Increase in Output with Streamline Grating.

Fig. 17.

stream-line. In setting up these eddies, however, the flow becomes unstable, being the cause of additional loss, and the flow takes a form more like that shown in Fig.13.

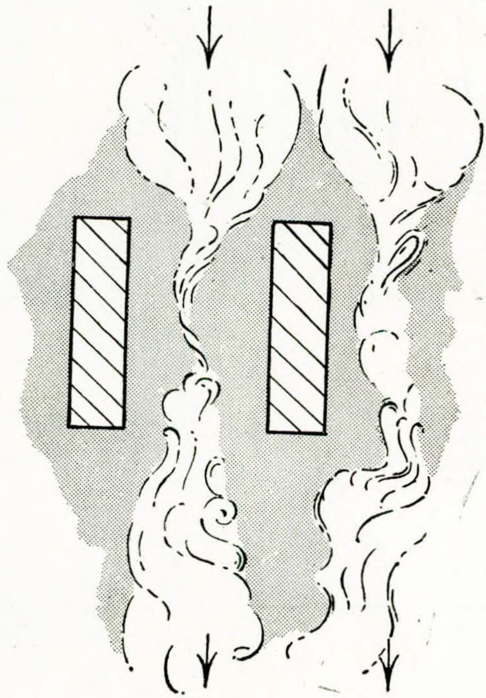


Fig. 13.

In Fig. 12 the similar area l m n p is the cross-section of the improved bar, eliminating the eddies and increasing the effective area of flow. The gain in width of stream is shown by the dimension b against the former dimension a.

The new stream is shown in Fig. 14, which illustrates the contrast between the improved flow of air and that obtaining in Fig. 13.

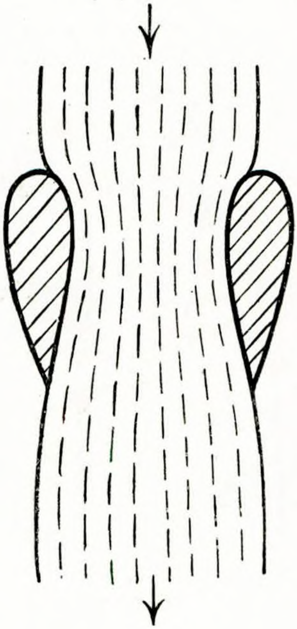


Fig. 14.

The final readings of a series of exhaustive tests are given in the following table:—

R.P.M.	Cubic ft. of air per min.	Air vel. ft. sec.	Press. loss W.G.	K.W. Input.	B.H.P.	Remarks.
			Inch.			
288	14300	26·5	·065	5·4	4·89	Previous Grating.
355	16960	31·4	·07	7·11	6·92	
400	19980	37	·13	12·0	12·5	
495	24850	46	·15	20·8	23·5	
501	25700	47·6	·17	21·9	25·0	
540	26730	49·5	·21	26·8	30·6	
560	29000	53·7	·22	29·8	34·3	
287	15450	28·6	·00	4·98	4·42	Stream-line Grating.
328	17400	32·2	·00	6·76	6·5	
402	22150	41	·00	12·2	12·97	
498	27650	51·2	·00	22·1	25·3	
560	31500	58·3	·00	31	36·68	
577	31910	59·1	·00	32·7	37·7	

These readings are also shown in the graphs, Figs. 15, 16 and 17. Each pair of curves gives the characteristics for the old and new respectively, so that the vertical ordinates between them give:—

(1) Actual saving in pressure;
(2) Saving in horse-power;
(3) Reduction in fan revolutions;

plotted to co-ordinates of various velocities of the air through the shaft.

In many classes of ships a number of gratings are installed at different deck levels, through which the air passes in succession. The total saving effected on one ship is a multiple of the amount indicated on the curves for one grating or for unit area of grating.

This in itself will have an effect upon the efficiency of the fan installation in the boiler room, either by using the additional air pressure or, if the additional pressure is not required, by securing the benefit of the consequent reduction in steam consumption of the fan engines on account of the revolutions being reduced.

(5) Stream-line Fan Inlet Shutters.

The introduction of the stream-line inlet shutter has been developed to overcome the difficulties which have been found in practice, the first being (a) losses due to eddies and pulsations which are ever present with the existing arrangements of a fan inlet with its wire guard and folding doors, and, secondly (b) to provide a simple method for closing down a fan when two or more fans are fitted to a stokehold.

Owing to the elastic nature of air a current is generally accompanied by a series of undulations and pulsations.

In the case of air approaching the suction inlet of the fan this action has a marked influence. In centrifugal fans of high efficiency the vanes are so designed as to coincide with the direction of the vectors of the compounded velocities of the air.

Therefore, since the vanes are fixed, in order that they may operate most efficiently, it has been found desirable to guide the air at the entrance to the fan-eye in parallel streams, normal to the fan inlet, and also to correct or dim the pulsations.

A series of tests was carried out on a comparative basis, and a fan equipment was selected which was fitted with a wire screen over the fan inlets under conditions mentioned below.

The output of the fan was first tested with this arrangement, which was subsequently removed, and in place the stream-line shutter was fitted.

The results are given in Fig. 18, recording the increase in air pressure and quantity of air due to the stream-line shutter.

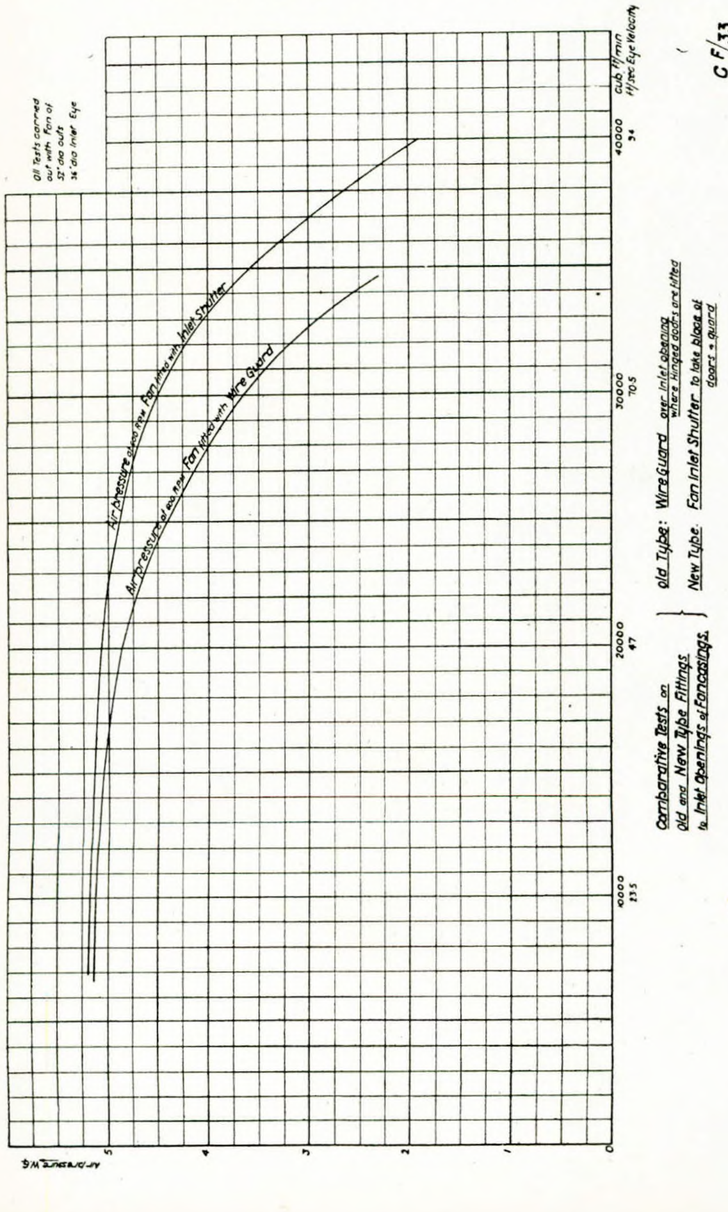


Fig. 18.

This shutter replaces the loose and hinged folding doors and the wire guard usually fitted. It can be opened or closed instantaneously by moving a handle. The shutter, illustrated in Fig. 19, consists of a number of slats operated by a connecting bar or bars. A lever is attached to the pivot of each slat, and the ends of the levers are attached to a connecting bar, at the

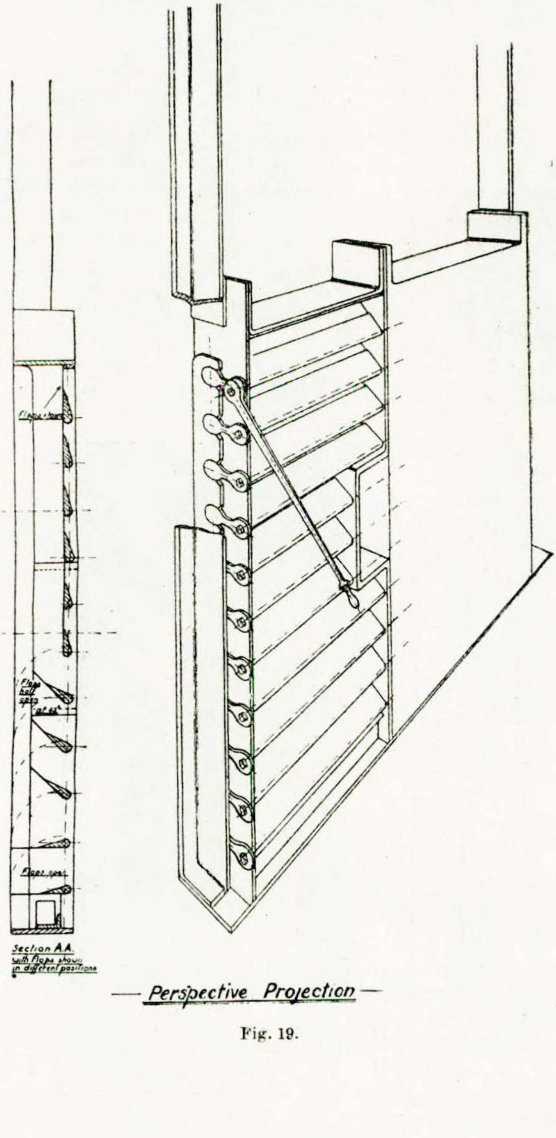


Fig. 19.

end of which is an operating lever and handle. The slats are stream-line in cross section, and each slat consists of a bar of stream-line cross section, to which is riveted a thin metal plate. When the shutter is closed the end of one slat engages with the adjacent slat, and makes an air-tight connection with it.

The fitting of the stream-line inlet shutter will also be a means of considerably reducing the steam consumption of the fans, especially when in port, as, owing to the ease with which these shutters can be closed, one fan or a reduced number of fans need only be run according to the steam required in the ship.

The relative internal directions of motion at different parts of a stream of air may be examined at any required moment by the aid of instantaneous photography, which has been successfully applied to these experiments, using silk ribbons to indicate the direction of stream.

Figs. 20 and 21 are reproduced from instantaneous photographs (exposure $\frac{1}{250}$ part of a second) of a short-ribbon test. Figs. 22 and 23 demonstrate prolonged exposures (150 seconds) of a long ribbon test.

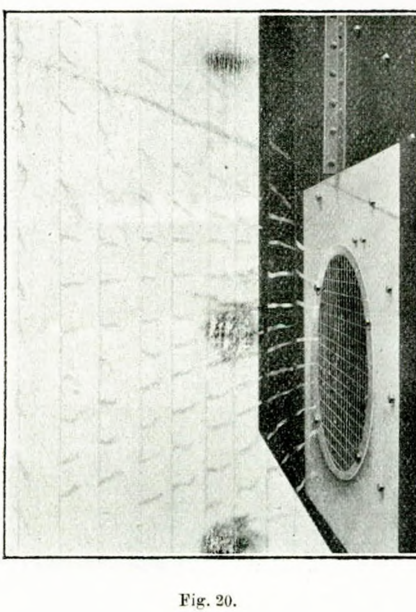


Fig. 20.

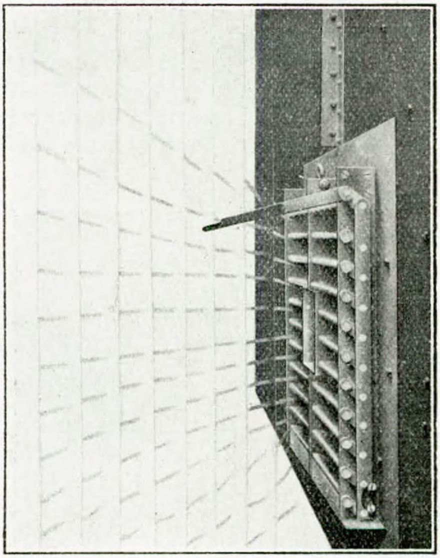


Fig. 21.

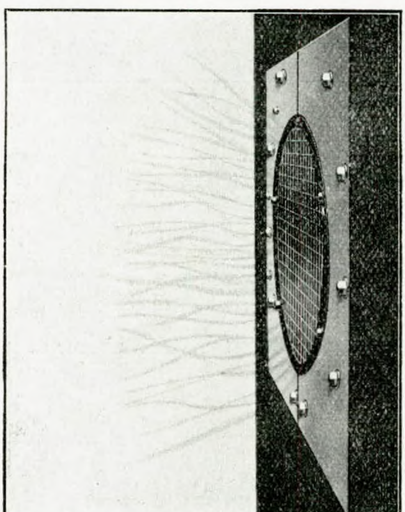


Fig. 22.

The influence on the air is far more marked after its passage through the stream-line shutter than during the approach, and, therefore, the photographs reproduced in Figs. 20 to 23 do not show the full extent of the correction. Evidence of the beneficial influence of the stream-line shutter is provided by tests, which are given in Fig. 18 and already described.

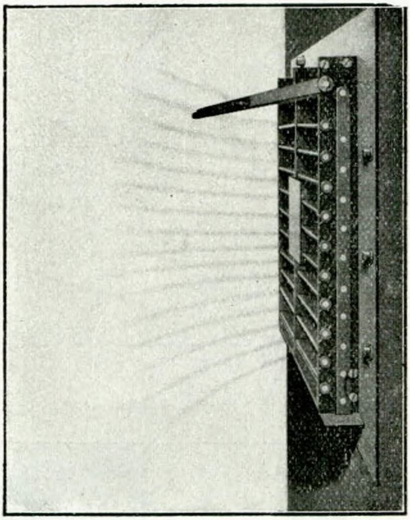


Fig. 23.

Figs. 24 and 25 illustrate stream-line shutters in open and closed positions fitted to fan inlets of double-ended steam engine driven fan sets. The end wall of the fan compartment on the ship is shown removed.

(6) Inlet Rings on Fan Entrances.

The velocity of air through the inlet ring of a fan eye depends very largely on the design of the fan and the type of the driving motor.

With a forced lubrication engine-driven fan, the inlet eye can in most cases be made large enough to keep the inlet speed low without reducing the radial length of the blades too much.

With a steam-driven turbine fan, to obtain an efficient turbine, the revolutions per minute must be kept fairly high, thereby reducing the fan diameter necessary for a given pressure. In order to keep an effectual radial length of blade the inlet eye has been reduced as compared with an engine-driven fan, and the entrance air speed accordingly increased.

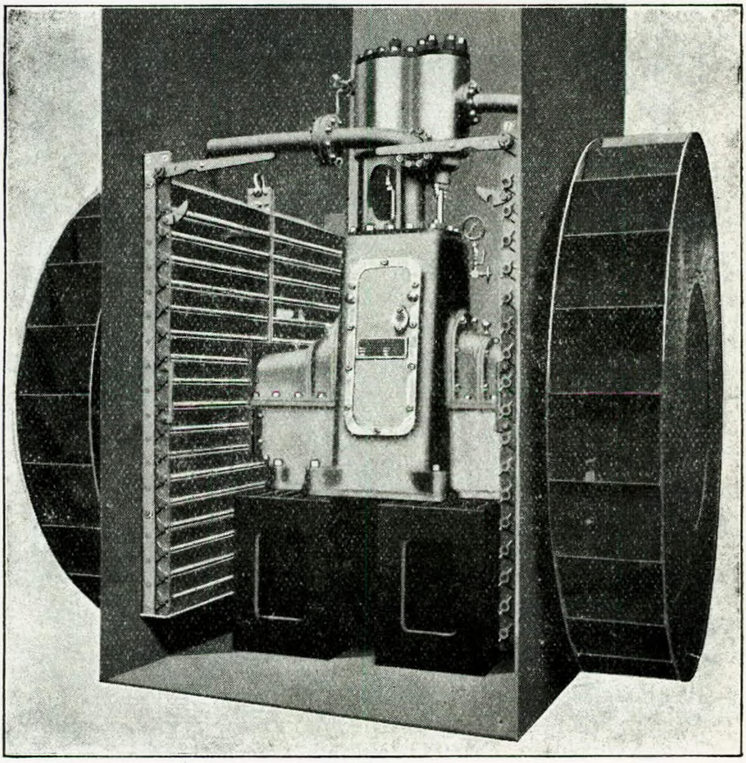


Fig 24.

Since the introduction of the improved design of fan in the year 1910 the tendency has been to reduce the diameter of the fan still further, so as to economise in space required for the fan installation. To obtain at the same time higher fan efficiencies, thereby reducing the driving power required, the velocity of the air at the eye must always be very carefully considered. It is generally desirable not to exceed a speed of 40 ft. per second.

When a fan has failed to deliver its designed output, this has on some occasions been found to be due to an inlet ring badly fitted to the fan eye or to an inlet ring of unsuitable

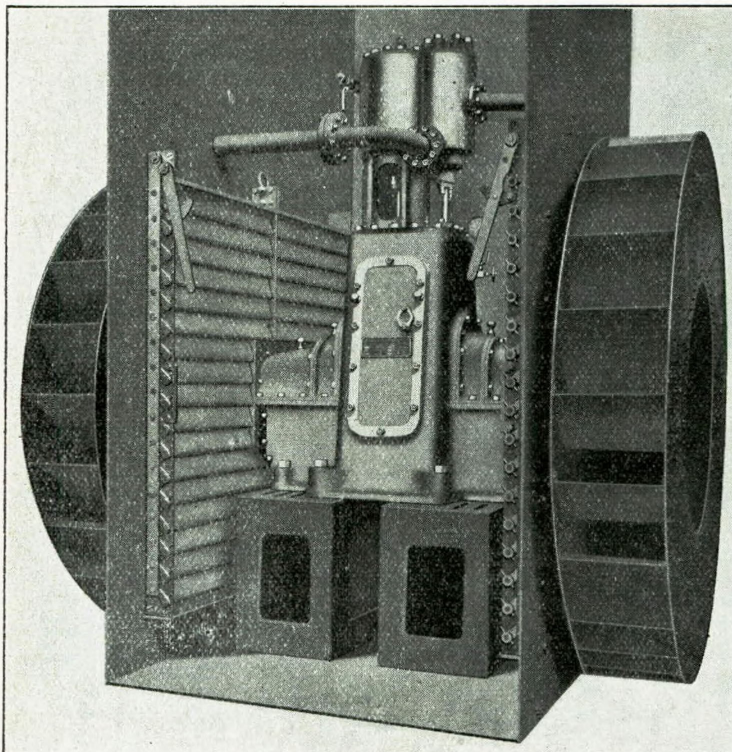


Fig. 25.

shape. It is, therefore, important to pay attention to the following points:—

(a) Correct clearance.

(b) Angle of entry.

(c) Avoidance of sharp corners.

Greater clearance has a direct influence on the amount of leakage, *i.e.*, on the slipping back of the air from the pressure side to the suction side, and a more indirect influence on the air stream entering the fan eye, inasmuch as an increased leakage restricts the area of the fan eye besides disturbing the flow of the air.

The angle of entry has an important effect on the efficiency of flow of air along the impeller vanes, as well as on the effective area of inlet to the fan eye.

Sharp corners set up eddies.

Different shapes of inlet ring are illustrated in Figs. 26 and 27, including one of recommended design with correct clearances.

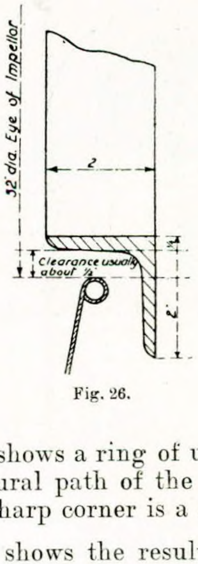


Fig. 26.

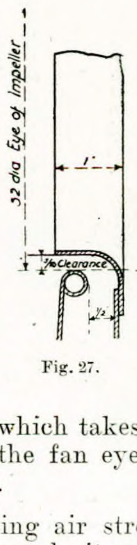


Fig. 27.

Fig. 26 shows a ring of usual section, which takes no account of the natural path of the air entering the fan eye. In addition, the sharp corner is a source of loss.

Fig. 28 shows the result on the ingoing air stream. The effective area of fan eye is reduced, the velocity of entry increased, and consequently the momentum of the air in the direction parallel to the axis of the fan.

Fig. 27 illustrates an inlet ring designed on correct principles, which may yet be simply constructed, being made of steel plate flanged.

Fig. 29 shows how the *vena contracta* is increased in area, and the velocity at entry thereby reduced. With the lower momentum and removal of the outer eddies, the radius of change of direction of the air becomes smaller.

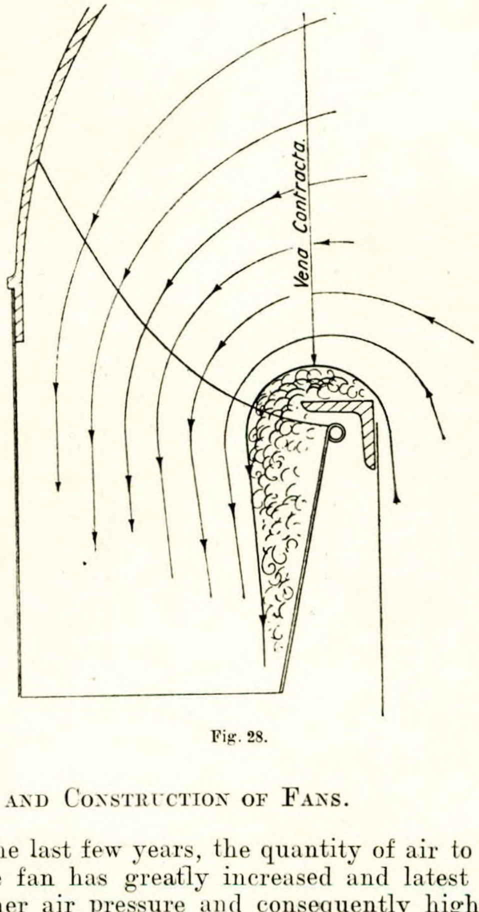


Fig. 28.

(7) Design and Construction of Fans.

During the last few years, the quantity of air to be delivered by any one fan has greatly increased and latest practice demands higher air pressure and consequently higher velocities through the fan, and in order to achieve a maximum all round efficiency closer study must be given to the design of the vanes and their number.

With this ever increasing power and output per fan the construction becomes a matter of great importance. The fan should therefore be strongly built and where riveting is employed this should be made stronger than the plate and where possible all rivets be driven home by pneumatic riveter. All holes should be drilled and reamered to ensure the rivets fitting the holes. It is recommended that washers be fitted under the head of each rivet, which gives great strength. Many experiments have been carried out to establish the correct form of

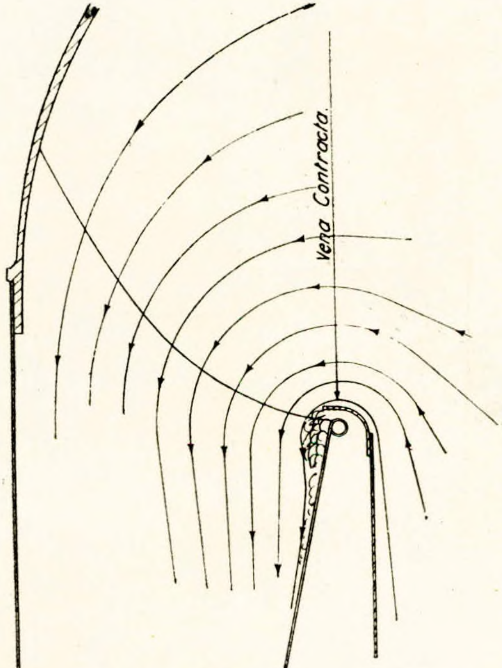


Fig. 29.

riveting according to the thickness of the plates. Double and treble riveting has been found to be necessary in the larger sized fans. Fig. 30 gives an example of riveting which has proved satisfactory in practice for fans of large diameter.

Every fan must be carefully balanced on frictionless rollers.

(8) Design of Fan Casings and Arrangement of Deflectors.

A number of tests have been made which prove that the performance of a fan is considerably improved in output as well as efficiency if attention is given to the design of the fan casing, and to the discharge of the air from the fan case.

Where fan casings are provided it is of the utmost importance that they should be constructed as a volute form, designed specially to suit the exact conditions for each ship, which are governed by the quantity of air to be delivered and the air pressure required.

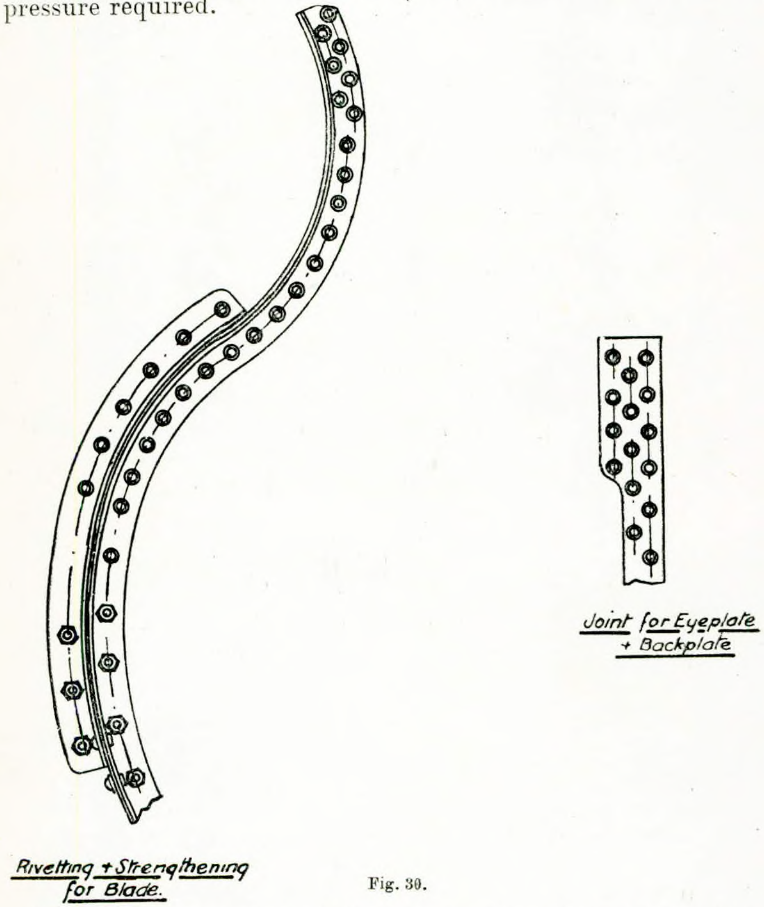


Fig. 30.

The following tests, carried out on various sizes of fans, illustrate the importance of correct design of casing.

TEST NO. 1.

The fan was tested in a volute casing of a considered design, and tests were also carried out in an ordinary volute casing which had not received the same careful study with a view to maximum output.

The results, illustrated in graphical form, Fig. 31, show that the output was approximately 10 per cent. greater at normal duty with the improved design than with the ordinary volute, when fitted to the same fan running at the same speed.

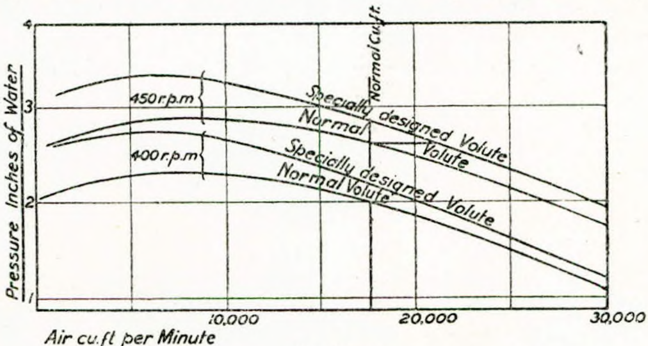


Fig. 31.

Test No. 2.

The fan was first tested in a concentric casing. Secondly the same fan was tested in a casing of volute shape. The improvement effected by the second test over the first amounted to 30 per cent. in output, and 9 per cent. in efficiency (efficiency being raised from 36·8 per cent. to 40·3 per cent.). The average readings are given from the tests.

R.P.M.	Quantity. cub. ft./min.	Pressure, inches W.G.	Fan Efficiency.	
450	10,600	2·98	36·8	Concentric casing
450	13,800	2·96	40·3	Volute casing

Test No. 3.

The fan was tested in a concentric casing without volute, and also in the same casing with a volute introduced. The superiority of the volute casing over the concentric casing amounts to approximately 70 per cent. in output, and 40 per cent. in efficiency. Average readings are given from the tests.

R.P.M.	Quantity. cub. ft./min.	Pressure. inches W.G.	Fan Efficiency.	
510	27,600	4·95	42·0	Concentric casing
515	28,700	5·00	43·0	
523	30,600	5·10	43·7	
496	42,750	5·35	64·8	Volute casing
492	31,000	6·00	66·8	
497	25,200	6·20	64·3	

Numerous comparative results have been recorded, from which the readings quoted have been selected to illustrate the importance of the fan casing.

When several fans are placed side by side, as is often the case in the fan compartment of a boiler room, it is found that some of the air delivered from one fan obstructs the delivery of air from an adjacent fan, thus diminishing the output. This objection is overcome by the employment of deflectors of special form.

When two adjacent fans are revolving in opposite directions the guide or deflector is of a form resembling a four-sided prism with concave faces.

Where fan casings are fitted, two of these faces form continuations of the curves of the two casings, the edge formed by them being situated between the two impellers at or near the point where they are nearest to each other, whilst the opposite edges of these faces are each in close proximity to its impeller. The other two faces of the prism form guides which turn the two meeting currents of air more or less through a right angle, and so cause them to flow together away from the fans, as illustrated in Fig. 32.

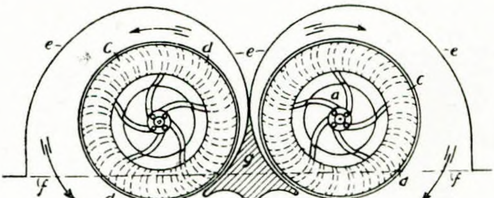


Fig. 32.

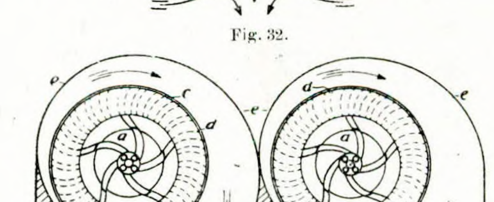


Fig. 33.

When the adjacent fans revolve in the same direction the deflector is three-sided, one edge, as before, being situated between the impellers, the two faces meeting at that edge being continuations of the curves of the casings, whilst the third face forms a guide which directs the air from one impeller into the same direction as the stream delivered from the other impeller, as shown in Fig. 33.

The result on the air streams issuing from a fan casing, with deflector fitted, is illustrated in Fig. 34.

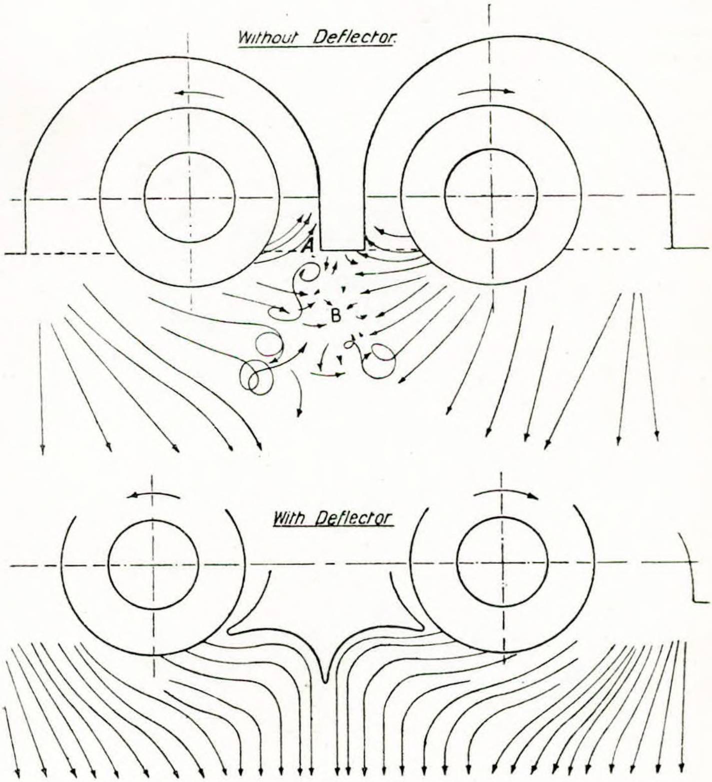


Diagram shewing Influence of Deflectors on Air Currents.

Preventing (1) Re-entrance of Air into Casing at A.

(2) Obstructing Delivery of adjacent Fan at B.

Fig. 34.

Without deflectors, after concussion of the opposite streams, the air, in its endeavour to follow a natural path, tends to form deflecting planes of moving air by the formation of eddies. The deflector saves both the shock caused by opposing streams and the energy absorbed in the eddies.

Where fan casings are not fitted the form of deflectors is more dependent upon individual circumstances. Thus, if a fan runs close to a bulkhead or discharges into a corner formed by the ship's structure, or if part of the periphery runs near some obstacle, the improvement in output and efficiency due to fitting an effective deflector is very appreciable.

Tests were also carried out on board ship where fan casings were not installed to ascertain the effect of fitting deflectors.

The arrangement of fans in the boiler room on trial was as shown in Fig. 35. It will be noticed how the direction of rotation is responsible for banking the air up into the recesses formed by the deck above and the air-lock at A A.

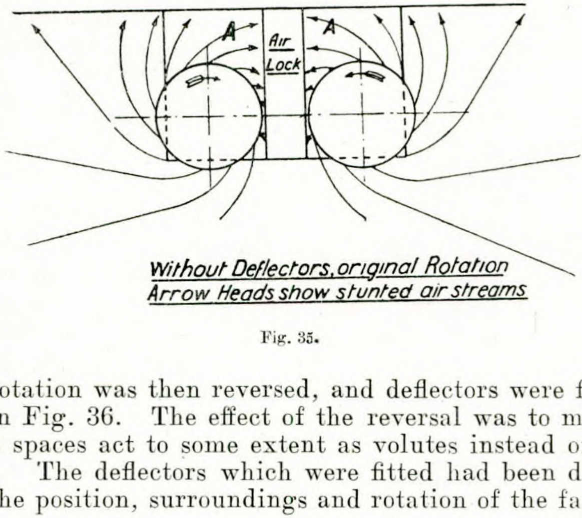
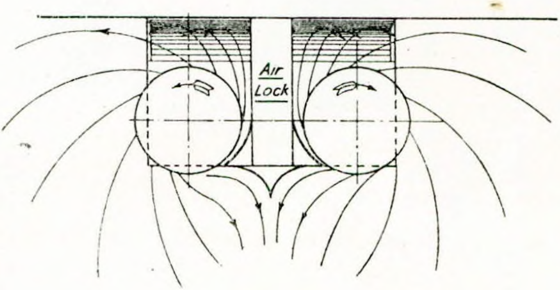


Fig. 35.

The rotation was then reversed, and deflectors were fitted as shown in Fig. 36. The effect of the reversal was to make the confined spaces act to some extent as volutes instead of as air pockets. The deflectors which were fitted had been designed to suit the position, surroundings and rotation of the fans.

Two series of readings were taken on this ship before and after fitting deflectors, which are plotted on the graph, Fig. 37. The improvement effected with the deflectors is represented by the area between curves "B" and "D."

Deflectors have been proved to be of greatest value when the output of air is large or velocity of the air is high. This necessarily follows, since both conditions are interdependent



With Deflectors, reversed Rotation
Arrow Heads show deflected air streams.

Fig. 36.

and have a tendency towards high resistance of flow, which calls for high pressure drop; thus, for any particular ship the benefit derived would be most when the demand on the fans is at a maximum. In comparing different ships, the larger the quantity of air supplied, or the higher the velocities of air currents, the greater will be the saving effected by the deflectors.

From experiments carried out on speed trials several valuable observations were recorded by means of the ribbon test. It was found that some of the air leaving the fan at high velocity went straight to the furnace doors. These streams may be of great value if guided correctly by deflectors; the losses are then the minimum possible under any conditions, as there are no losses at all incidental to the conversion of velocity to pressure energy and back again. The rest of the air leaving the fans supplies the storage of air in the boiler room—that is to say, its velocity is changed into pressure energy, which is converted as demanded by the pressure difference across the furnace into the required velocity of air passing through the furnace doors. The storage pressure in the boiler room produces low velocity streams radially to the furnace doors from all directions.

Considering the value of the high velocity streams described, much benefit may be derived from avoiding, where possible, any obstacle being placed near the periphery of the impeller.

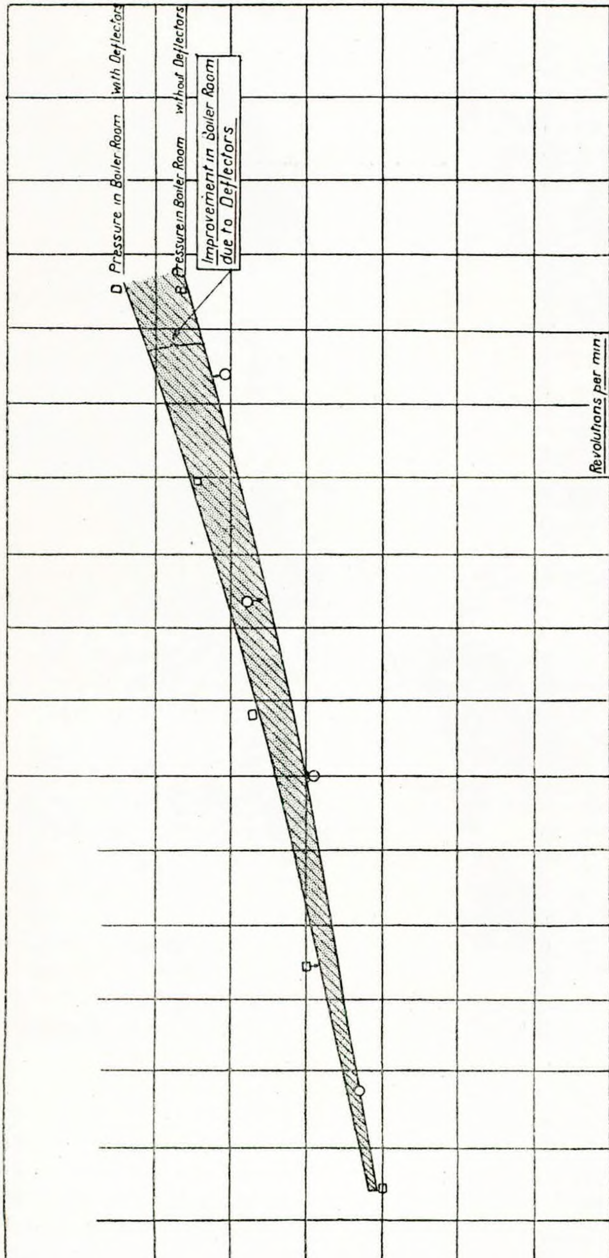

D Pressure in Boiler Room with Deflectors
E Pressure in Boiler Room without Deflectors
Improvement in Boiler Room due to Deflectors
Revolutions per min
375
400
425
450
475
500
525
550
Air Pressure in inches of Water Gauge
0
1
2
3
4
5
6
7

Fig. 37.

Deflectors should always be arranged so as to guide the streams of air in a correct and natural path.

Deflectors should be fitted as close as possible to the periphery of the fan impeller, only allowing a running clearance of about 1 inch. The guard round the fan, which has a greater clearance, should be fitted afterwards.

Since the velocity of the air streams are highest as they leave the fan, the momentum of the air streams is then at a maximum, and deflectors, which act as a guide to the streams, can be applied with the greatest effect.

Recent observations have demonstrated the value of long deflector plates as compared with short ones, and where there is room for them it is desirable to have long plates, so as to deflect the streams of air gradually, and also to act as a guide for a greater distance.

(9) Uniform Distribution of Air in Boiler Rooms.

In the disposition of a group of fans in the boiler room little or no consideration has in the past been given to the influence which direction of rotation of the fan has on the uniform distribution of air in the boiler room. It is generally assumed that the pressure which the fans create in the boiler room is sufficient and uniform enough throughout the boiler room to supply all the furnaces equally with air.

The air currents, however, caused by the discharge of air from the fan casing, and also from the periphery of the fan itself where it is open to the boiler room, are so considerable with the latest types of fans that the air is not uniformly distributed to all parts of the boiler fronts. The usual result is that while some of the furnaces are not fed with sufficient air for perfect combustion, other furnaces receive a surplus supply, causing an unnecessary lowering of the funace temperatures and a consequently higher fuel consumption.

The wings of the boiler rooms are not always adequately supplied with air, but this can often be remedied by re-grouping the fans, by rearranging the direction of rotation and by fitting suitably designed deflectors. Recent experience has shown the value of these deflectors in effecting an economy in fuel consumption and a marked reduction in the revolutions of the fans. Further, it was established that with better distribution in the boiler rooms a lower air pressure was sufficient to achieve the same results.

(10) OIL FUEL.

Most liquid fuels are derivatives of petroleum, which occurs in many different parts of the world, and varies to some extent in composition. Practically the same material is obtained by the distillation of oil-shales and some classes of coal.

Whatever its source, petroleum always consists of a mixture of different hydro-carbons, capable of being more or less completely separated from each other by fractional distillation.

The theoretical quantity of air required for complete combustion of the fuel is based on the precise amount of oxygen which that air contains, and assumes that as the air passes through the furnace the whole of this oxygen is completely extracted and combines with the gases given out by the fuel.

Such a condition, of course, is never reached in practice, as each particle of air cannot be brought into contact with the fuel at the correct temperature, and for a sufficient length of time. The amount of excess air required depends upon the type of oil burner, design of boiler and the conditions of combustion.

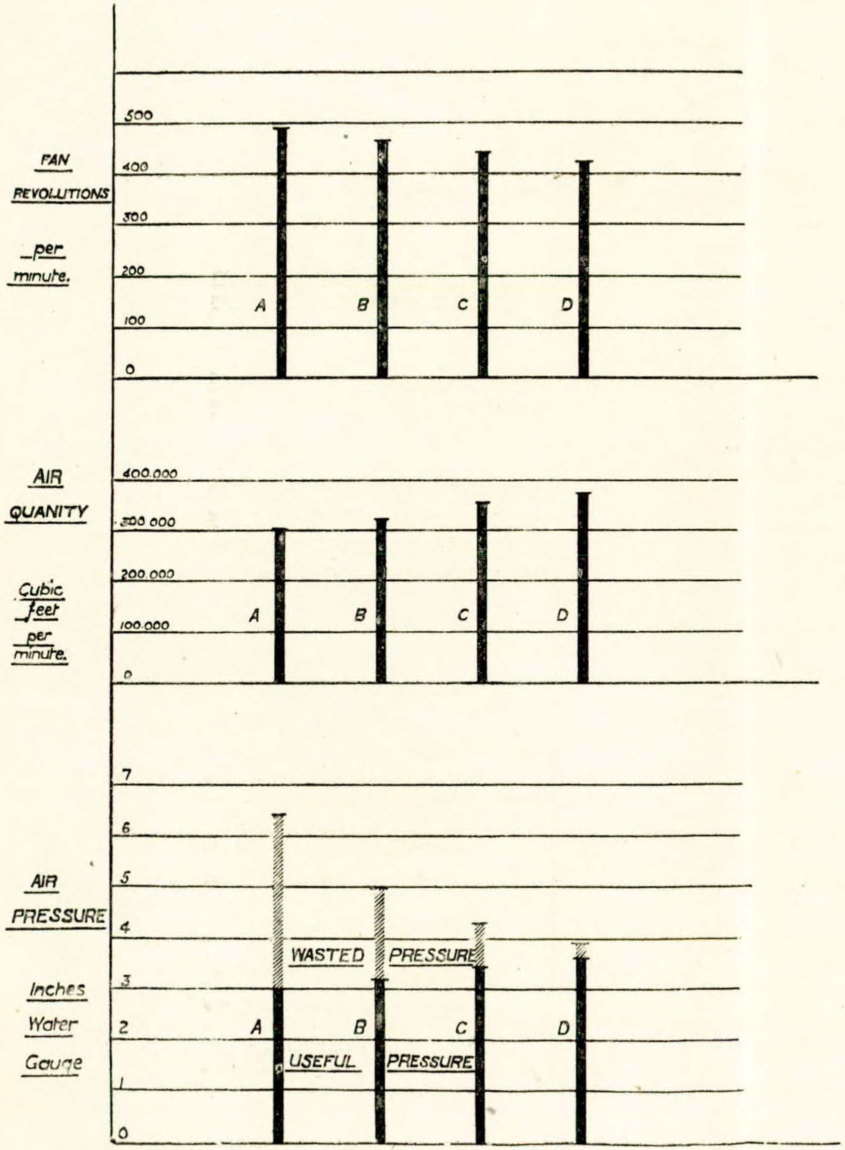
To arrive at the amount of air required in practice the theoretical amount must be multiplied by a factor which is usually found to be within the range of 1·6 to 2·5—that is to say, the volume of air as measured at normal atmospheric temperature and pressure required for the combustion of 1 lb. of oil fuel is from 250 to 450 cubic feet.

(11) STEAM TURBINE DRIVEN FANS.

There is a tendency nowadays towards the consideration of employing auxiliary machinery of the steam turbine type.

Steam turbine driven forced draught fans have been constructed in this country for many years, but they have not been universally employed on account of the fact that the present reciprocating forced lubrication engine is a very reliable machine.

The change to the steam turbine can hardly be recommended unless some great advantages be obtained in weight, space occupied and steam consumption. The reciprocating engine is to-day more favourable in these respects. On the other hand, advantages are with the steam turbine, inasmuch as there are no cylinders, piston rings, piston valves and high pressure packing to keep in order.



		Year.
A	Original Arrangement.	1915
B	Deflectors added in Boiler Rooms to Fan Discharge. & Obstacles at Deck intake & Vent removed.	1916
C	Deflectors added in Boiler Rooms to Fan Discharge & proportions of Deck Intake & Vent improved.	1917
D	Improved Intake Cowls including streamline weather Flaps, centre guide & nozzle, streamline splinter grating, streamline Fan inlet shutters installed in addition to improvements enunumerated under 'C'.	1918

Year 1918. Improvements above results in 1915 :-	
Saving of wasted pressure	3·05 inches Water Gauge
Increase in Boiler Room Pressure	·6 " " "
Increase in Air Quantity	70,000 cu.ft. per min.
Reduction in Fan Revolutions	57 revs. per min.
Reduction in Steam Consumption	25%
Smokeless Combustion.	

Fig. 38.

Experience has been gained with the steam turbine fans that they run with little or no attention reasonably quiet provided that the revolution is not too high, run continuously, and possibly the steam consumption will not increase with running, wear and tear as in the case of the reciprocating engine.

(12) CONCLUSIONS.

The author has tabulated a series of results of trials taken under the same conditions on one class of ship over a period of four years, Fig. 38.

These results clearly show the gains effected in each year as experience is accumulated. It may be interesting to record that in tabulating these results many ship trials were recorded, and in each case the machinery—namely, the steam engines and the fans—remained the same.

All the improvements as shown in the table are independent of the fans and engines themselves.

The subject of the air supply to boiler rooms where closed stokeholds are adopted is one of great interest and importance. It may be stated that in dealing with this question it has only been very briefly treated.

Many points described in this paper in connection with closed stokehold arrangements would be suitable for and apply equally well to all systems of forced draught; for instance, the air entrances, downtakes and stream-line inlet shutters are all applicable, and would very materially improve any system.

The author hopes, in conclusion, that, having drawn attention to this subject, it may be the means of stimulating an interest in the air supply by the engineers and shipbuilders of our country, resulting in the standardisation of all the air supply arrangements.

Mr. W. H. McGREGGOR: It is apparent that no consideration has been given in the past to the direction of the rotation of the fan. It should be remembered that it is not always possible to have fans placed just where they are most wanted, on account of the difficulties in apportioning space.

Mr. F. A. CORNS: I cannot venture at the moment to offer many comments on the paper itself as it has opened up quite a new field for thought. It is true that no proper consideration has been given to the position of fans. In one steamer of which I was Chief Engineer, we had two fans on deck, both delivering air, on the top of the boilers. I had them altered so that one delivered down into the forward stokehold and one into the aft stokehold. I did not work the problem out scientifically, but it was obvious that if we could get the air draught down nearer to the furnaces, we would get better results. The turbine driven forced draught is not so satisfactory, on account of the greater heat being bad for bearings. There are many ships now fitted with electrically driven fans, and where electricity is available I would be inclined to favour its use as a driving power.

The Hon. Secretary: There is no doubt that the fans ought to be placed in better positions than is usually the case. In the Merchant Service the fans have been often placed in improper positions, and this is not conducive to upkeep and overhaul. Sufficient attention has not been paid to the subject brought to our notice this evening by Mr. Allen, and we are indebted to him for pointing out several important details which have been made good as the result of careful tests, and as these have been described to us we can derive benefit from the hints given.

Mr. T. E. Owen: I can confirm from my own experience what has been said as to the faulty placing of fans, having worked on one of H.M. Auxiliaries where fan engines were perched on the tops of the boilers, and it was anything but pleasant to give attention to them.

Mr. H. J. Savage: I am afraid it is not uncommon to find that in the designing and construction of merchant ships too little thought has been given to air draught, and to the best arrangement to get the most economical results from the air supply. It is apparent from remarks already made that the position of the fan for want of thought, does not receive the attention it ought.

Mr. J. B. Harvey: I quite agree that this subject has not been dealt with as its importance deserves, and we are indebted to the author for calling our attention to it; he has opened up new ground, and offered us so much more food for thought than we can digest at one sitting, that it appears fitting that we should deliberately study the paper and then write our comments, forwarding these to be included in the transactions, subsequently.

Mr. Jack Payne: I have pleasure in being present and in expressing my appreciation of the paper. I should like, if it could be extended to deal with other parts of the vessel besides the boiler rooms. There are many other parts of the ship ventilated by means of fans. I believe electrically driven fans are being largely used for the stokeholds. Many of the forms of fans referred to in the paper are only fitted in warships, and I would like Mr. Allen to give us another paper dealing with the delivery of air to all parts of the merchant ship.

The CHAIRMAN: It is a question well fitted for discussion as to which of the two systems of air supply is the better: that in general use in the merchant service or in the Navy. Under this heading comes consideration of the problems as to weight and cost of auxilaries and efficiency. Many of the ships in the Mercantile Marine have oil firing, and all of these use the closed stokehold system. So far as the comfort of the men is concerned the Howden system of forced draught leaves little to be desired, especially with fans supplying air to the stokeholds instead of ordinary ventilators.

THE AUTHOR'S REPLY.

When asked to read a paper to the Institute I felt it my duty, as a member, to do so, and if I have given any food for thought I feel amply rewarded. Leading Engineers have devoted their attention to the boiler, the condenser, and the propeller, which latter, by the way still offers many unsolved problems, but so far as I know, no engineer has directed his attention chiefly to the most vital part of a ship—the boiler room equipment. The question has been raised as to whether the direction of rotation is very important. In small slow going vessels it may perhaps not be so very important, but it certainly is in the larger types of vessel. In the recent hurry, ships have even been fitted with fans, the rotation of which was decided in the drawing office with disregard to the best duty, and there has been nothing written on the subject of the direction of rotation best suited for distributing the air over the boilers and in the boiler room. I hope that the subject will become one of keen discussion and then progress will be made. I should like to make it clear that this paper has no reference to merchant ships, but merely gives a record of hard facts gathered during the past four years work. I do not wish to bring in any contentious matter, or to favour one system or another, but simply to lay facts before you for the benefit of engineers generally. I certainly cannot say off-hand that the Navy system is better than that of the Mercantile Navy, but will require to take a hint from Parliamentary procedure and say "that notice is required for that question." The Navy system might be applied to the merchant ships. I cannot see why in the Howden system a water pressure of $3\frac{1}{2}$ ins. is required at the fan, or why there is such a loss in pressure in transit, and I am making enquiry into this part of the question. With regard to due attention being paid to fans, it may interest you to know that now on H.M. ships all fan inlets are painted white, and they are kept white, a usage that might profitably be made general. Forced draught fans with electric motors are very satisfactory, but the steam turbines are as good for the purpose.

I may explain the experiments, which resulted in the new stream line entrance, lasting over a year, were carried out in 1916. The design then in use seems of a very curious form, and the whole apparatus seems out of shape. You will see how much the shape has been changed, in fact the top has been reversed, bringing us to the type we use to-day, and which is so much more efficient. This paper I should explain was written before the Armistice, and could not be delivered then because of the Censor, on account of it dealing so largely with Naval Service work. However, now that conditions are somewhat altered the restrictions are removed, and I can place the subject before you freely without any detriment to the Royal Navy. I may mention an extraordinary thing that happened at the trial of a fast naval ship while I was on board. A sailor was passing one of these air entrances and had his hat blown off. One would have expected the hat to have been drawn down the shaft, instead of being blown off. We discovered, however, that the air did not pass straight down the shaft, but set up an eddy, and it was this eddy which had carried off the hat and gave us an object lesson.

Referring to the ribbon test, I have found this to be the most satisfactory method. A visible test is necessary as one cannot see the air and by means of these fine ribbons, preferably red, because they are more easily photographed, it was possible to see exactly what the air is doing. Air, it must be recognised, does not flow evenly down the shaft but in pulsations, and these set up eddies which it is our task to avoid, a task in which we have been very successful.

All these experiments have been carried on throughout the war on one class of ship, the light cruiser. "C" and "D" class. When we started the experiments we had a lot of work to do. We had an immense amount of pressure loss to contend with. The fans had to be run at a great speed and we did not get a proportionate amount of air; but at last we did solve the problem before us, and secured increased pressure in the boiler rooms with 70,000 cubic feet more air, and most important of all, we obtained absolutely smokeless combustion—a very great matter from a military point of view.

The CHAIRMAN: We are doubly indebted to Mr. Allen for the paper he has placed before us, and for his presence to-night, especially when we consider the amount of work that he has done not only in shipping but also in air-work, and we must look upon it as a great compliment that he has devoted so much time on our behalf. Diagrams Nos. 2 to 38 are really curves of the test work that Mr. Allen has done.

The paper shows that the general conception of the subject of air supply to the boilers some four years ago was in a somewhat crude state. As far as the Merchant Service is concerned forced draught is usually adopted, but as Mr. Allen has pointed out, with the improvements already made in the closed stokehold system, it might be found adaptable and more economical. This reference is to the air supnly to boilers, but there is the question of air supply to other parts of the ship for ventilation, as the tendency now is to have fans in various quarters throughout the present day steamers, so that the importance of the subject introduced by the author does not end at the stokehold.

Corrections.

In the paper on Boiler Heating Surface, p. 291, giving the new rule for safety valves, where the sign $\times$ is printed in error for $+$

$$\left(\frac{1{\cdot}25}{p + 15}\right)$$

Page 292, Stefan's law should be as follows :— $\dfrac{16\ (T_1{}^4 - T_2{}^4)}{10^{10}}$

and the efficiency of the tube surface, $E = 1 - e^{\frac{-cw}{m}}$.

Correspondence.

The following announcement has been received from the Board of Trade, Marine Department, relative to the incident referred to in the December issue, p. 280 :—

15th February, 1919.

Sir,

With reference to your letter of the 19th November last, addressed to the Registrar-General of Shipping and Seamen, I am directed by the Board of Trade to inform you that His Majesty the King has been pleased, on the recommendation of the President, to award the Silver Medal for Gallantry in Saving Life at sea to Mr. William James Lapper, assistant engineer in the Marine Department of Nigeria, in recognition of his services in attempting to save life on the occasion of an explosion on board the steam barge *Gallwey*, at Forcados, on the 9th December, 1916.

The Board desire me to thank you for calling their attention to the case.

I am, Sir,

Your obedient Servant,

G. E. BAKER.

James Adamson, Esq.,
Institute of Marine Engineers,
85/88, The Minories,
Tower Hill, E. 1.

The following has been received from Mr. J. M. Buchanan (Member), who is resident at New Orleans :—

"I enclose herewith a cutting from a local newspaper, which may be of interest to you. The heading is 'Rivetless Steel Ship of future,' and announces the intention of the Emergency Fleet Corporation to build a 9,300 ton freighter without rivets; that is, to weld the plates and other parts by some system of electric welding. It appears that the cost of such a vessel would be three-fourths of that of a riveted vessel, and the time to build her would be reduced to three-fourths compared with a riveted vessel.

I may say that the electric arc welding system is largely used in this port, more particularly for boiler repairs, and to some extent for ship repairs, such as welding seams in lieu of caulking, locally corroded parts, etc., rivet holes in plates taken off for fairing where the holes may have been damaged."

RIVETLESS STEEL SHIP OF FUTURE.—The Electrical Welding Committee of the Emergency Fleet Corporation, composed of eighty-two metallurgical and electrical experts, after careful experiments, believes that large steel ships may be built without rivets. It has recommended that a 9,300-ton freighter be built by electric welding, and as a test a 42-foot midship section of a vessel of that size will be constructed by the new process. Its success would revolutionise the industry, for ships may be turned out in three-quarters of the time now required and at three-quarters of the cost.

Between 600,000 and 700,000 rivets go into a 9,300-ton ship, and only men of great strength can drive them. The draft has made it impossible to obtain the number needed, but women, even a one-armed man, can be trained as electric welders in the same time required to train a riveter. Doing away with rivets will save weight—500 tons on the hull of a 9,500-ton ship, adding that much to cargo capacity. These are the estimates announced by Prof. Comford A. Adams, Chairman of the Welding Committee and member of the faculty of Harvard University and the Massachusette Institute of Technology.

There are two methods of welding. In the arc process, largely used in England, a wire an eighth of an inch in diameter is brought in contact with the work, and then drawn far enough away to form an arc. This melts the wire and the metal with which it comes in contact. The molten metal is deposited in the joints, fusing the plates together as solidly as if cast in one piece. This was the process used in repairing, in far less time than was thought possible, the wrecked machinery of the German and Austrian ships taken over by the Government.

The other method is "spot" welding, an American process, applied to heavy plate work. The plates are brought together under a pressure of twenty-five tons, and an electric current sent through them, welding them together. The welding leaves a spot; hence the term. Fifteen seconds are required for the operation. The apparatus is much more expensive than that required for the arc process, but it saves labour and so can do the work at less cost.

Early this year a 275-ton steel barge was launched in England and announced as the first boat ever constructed by electric welding. As a matter of fact a 60 foot tug was built at Ashtabula, O., by the process several years ago, so the honour belongs to America. Both these vessels have stood the test of rough seas. Electric welding is not new. It has been in use here, particularly in railroad repair work, for a quarter of a century. The war brought about its application to shipbuilding. The Electric Welding Committee is sure that vessels so constructed will be at least as strong as riveted ships, and in addition to saving time and money, the method will make available a large class of labour not now suitable for work in shipyards.

NOTICE TO MEMBERS.

At the Annual Meeting on Friday, March 28th, at 7 p.m., the under-noted Resolutions will be submitted, and on Friday, April 11th, at 6 p.m., a General Meeting will be held to confirm the Resolutions in question, subject to the finding of the members on March 28th:—

"I. That certain alterations be made in the By-laws, Nos. 1, 2, 3, 4, and 5, relating to membership, with a view to include Allied Industries, as per the detailed recommendations of the Council, already submitted to the members for consideration, and issued with the notice calling the Annual Meeting.

"II. That certain alterations be made in By-laws Nos. 33 and 35, so that these shall read as follows:

"33. There shall be a Board of Advisers numbering three, elected annually by the Council at the first Council Meeting after the Annual Meeting.

"35. The Board of Advisors shall be elected from the Members, and, or, the Honorary Members of the Institute."

JAS. ADAMSON,

Hon. Secretary.

10th March, 1919.

Election of Members.

Members elected at a meeting of the Council held on Tuesday, 11th February, 1919:—

As Members.

Thomas Anderson, 27, Hepocott Terrace, South Shields.
Harry Neville Bonsor, 4, Mechlenburgh Square, W.C. 1.
Ralph Charles Coulthard (Engr.-Lieut.-Comdr., R.N.), H.M.S. *Raider*, c/o G.P.O., London.
Samuel Edward Cook, Stebonheath, Broadway, Bexley Heath.
William McLaren Forwell, 142, Roselea Drive, Glasgow.
Harry Routleff Hall, 4, Alliance Avenue, Hull.
Herbert Gordon Hean, Huntscliff, Sarnia, Natal.
William MacPherson Hutton, 203, Great Northern Road, Aberdeen.
Thomas Henry Hepple, 38, Ranelagh Gardens, Ilford, E.
Herbert Humbert, 12, Stamford Mansions, Oldhill St., N. 16.
William Henry Kirkaldy, "Melville," Bede Street, Sunderland.
Charles M. McArthur, B.I. Engineers' Club, Calcutta.
William Brown McCall, 33, Lothian Road, Edinburgh.
Jack Payne, Cockatoo Island, Sydney, N.S.W.
Septimus Marshall, Holniside, 8, Kew Gardens, Monkseaton.
Frederick Stephens, Tresillian, Blakehall Crescent, Wanstead, E.
James Yelland Truscott, Rosewyn Cottage, Truro, Cornwall.
Victor Edward Ward, 42, Stranmillis Road, Belfast.
Henry John Watty (Engr.-Lieut., R.N.R.), Comoro, 8, Thornbury Avenue, Southampton.
Hugh Wright, 368, Edge Lane, Liverpool.

As Associate-Members.

William Catterall, 2, Dolland Street, Blackley, Manchester.
Charles White Halfhide, Fir Villa, Warley, Essex.
Walter Taylor, 45, Pritchard Street, Burnley, Lancs.

As Associate.

Albert Edward Andrews, New Zealand Convalescent Hospital, Grays, Essex.

As Graduates.

Frank Stanley Gander, 76, Romford Road, Stratford, E. 15.
Robert Albert Peckham, 6, Brightside Terrace, Hither Green, Lewisham.