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VOLUME XXVII.

Development in Mechanical Ventilation Hygienically, Aboveground, Underground and Underdeck.

BY MR. JAMES KEITH (Member).

READ

Tuesday, November 2, 1915.

CHAIRMAN: MR. J. H. R. KEMNAL (Vice-President).

MR. KEMNAL: I have much pleasure this evening in presenting to you Mr. James Keith, not only as the author of a paper which I am sure you will find of very great interest, but also as one of our most recently elected members. Mr. Keith is one of the most eminent of the experts in the subject on which he is writing, and with his usual thoroughness, he has brought models of an interesting, elaborate and instructive character to illustrate various points in his lecture. I have read an advance copy of his paper, and at the moment I will say nothing regarding it as I anticipate that there will be a very ample discussion. Of course, such an interesting paper as this is would have merited a very full audience, apart for the fact that Mr. Keith's position in the engineering world entitles him to it. But we all know the demands which war is making upon engineers, so that many of our members are prevented from being present.

We have received, both from Mr. Galbraith and from Mr. Currie, expressions of regret for their inability to attend. I will now call on Mr. Keith to read his paper.

———o———

The author has already dealt pretty fully with the question of mechanical ventilation in three articles published respectively in the *Lancet*, *Cassier's Magazine*, and the *Railway News*, so he cannot claim to bring before you anything absolutely new, but, having regard to the importance of the subject, he ventures to submit his view to the Members of the Institute of Marine Engineers for their careful consideration, knowing their criticisms will be most valuable.

Within recent years public opinion has been much exercised on the question of better conditions for the workers in overheated and ill-ventilated engine—and other working—rooms on land and on board ship, and the object of this paper is to place before you the most up-to-date applications in the practice of ventilation and some of the results attained.

The work of physiologists during recent years has gone to show that the chief effect of ventilation and open-air treatment depends on the movement, temperature and moisture of the air, and less upon its chemical properties than was expected; and, in order to obtain economically adequate ventilation on physiological principles, without production of uncomfortable draughts, the ventilating system employed should be designed on certain lines herein indicated, embodying appliances specially adapted to the cooling of over-heated engine-rooms and the like aboveground, underground, or underdeck, by flooding them with fresh air from outside under slight pressure.

This positive ventilation or a continuous change of air also removes all noxious gases and smells emanating from the oil and bilges.

The principle employed is exemplified by the following:—

Fig. 1 illustrates part of the large electric power-house of Saint Denis, outside Paris. It shows how the long switch-house (with switch-board about 500 feet in length) is cooled down.

At Saint Denis Power-House, the switch-board house, as erected, was wholly open along one side to the power-house from which emanated heat generated by the electrical machinery, to such an extent that the working of the switch-board was practically put out of action in summer time even though the large windows high up along both sides and ends as well as the doors at the ends of the power-house were fully open all the time.

In this case a series of ten open fans, each having 25 inches diameter air-inlet and running 700 revolutions per minute, is installed along the length of the switch-house ceiling, and delivers in all 90,000 cubic feet of fresh air per minute or 5,400,000 cubic

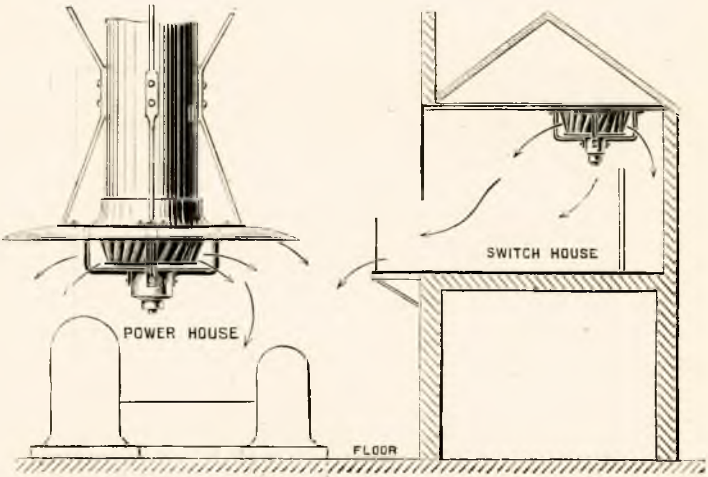

Fig 1.

Part Section Power-House and Switch-Board House, Saint Denis, Paris.

feet per hour, and distributes it in the direction shown by the arrows across and through the switch-house into the power-house; in other words, the whole cubical air contents of the switch-house are changed once every 40 seconds or 90 times an hour, and the inside temperature of the switch-house reduced from say 120° Fahrenheit in summer to that of nearly the normal outside atmosphere, without production of unpleasant currents, for a total expenditure in electrical power of 14,000 watts. In the main building or power-house proper there may be, as shown, similar fans of larger size arranged along its length of six hundred feet.

Fig. 2 shows a portion of the underground engine-room of the Singer Building, Broadway, New York, in which are installed three large open fans capable of propelling pure fresh air into the engine-room under moderate water gauge to the extent of 120,000 cubic feet per minute, thus giving a change of air contents of more than 60 times an hour, and ensuring comfort and coolness without draughts, under all outside atmospheric conditions.

The fresh air in this case is taken from the side-walk of Liberty Street on the one side, and from the open area between the wings of building block, and is drawn into large chambers against and through considerable areas of moistened burlap before it passes into the inlet conduits and is delivered by the fans into the engine-room.

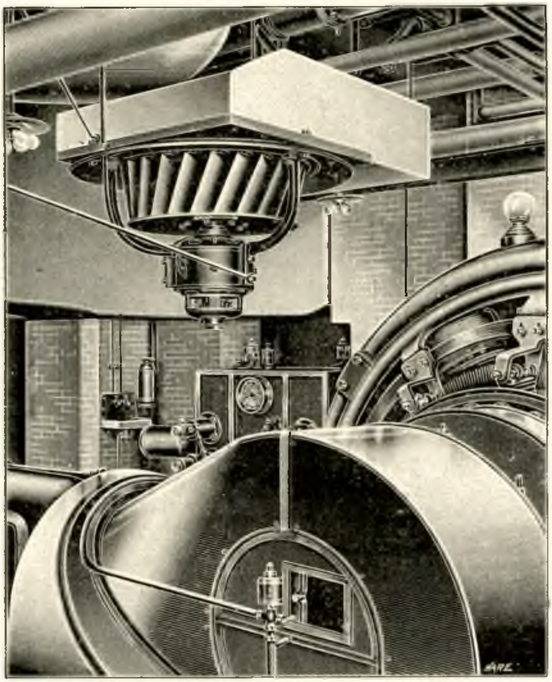

Fig. 2.
Inside View of Singer Engine-Room.

The system shown has superseded other systems hitherto in use in the engine-room of the Singer Building, and represents a satisfactory solution of the problem how to keep such engine-rooms comfortably cool and healthy.

The change of conditions from an excessively high and unhealthy temperature inside to that of a normal outside temperature is effected (in the case of the Singer engine-room) by the expenditure of no more than 22 horse-power when the fans are running at full speed. The air displaced mostly escapes towards the floor level into the boiler-house, thus benefiting the ventilation of the boiler-house and promoting the draught up the chimney.

Fig. 3 shows diagrammatically the delivery and dispersion of the fresh air into any similar underground engine-room or other chamber.

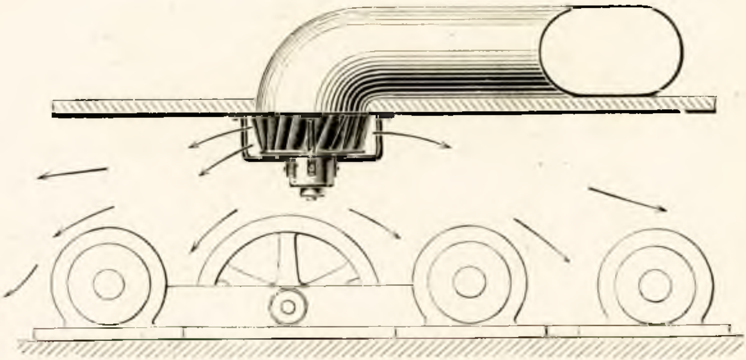

Fig. 3.
Diagram of Engine-Room Mechanically Ventilated.

Fig. 4 is a transverse sectional view of the engine-room of a trans-Atlantic liner showing the application of the recommended method for flooding the engine-room with cool fresh air, under moderate pressure.

The air is delivered into the engine-room by a large open fan placed at the junction of the lower ends of the air-shafts, so that the full volume of fresh air, equal in this instance to about 150,000 cubic feet per minute, is propelled into and properly distributed through the engine-room without loss from delivery ducts. When desirable, the air in the engine-room may be changed 120 times per hour without uncomfortable draughts.

An essential characteristic of this application is that the cool air is drawn, not forced, down from the upper deck and delivered laterally by open fans placed as low down in the engine-room as permissible, so as to flood the whole engine-room with air, the cooler incoming air falling towards the floor, displacing the heated air and expelling it up the main hatch or hatches or other exits without the necessity for extract fans.

The system shown was installed in the engine-room of the ill-fated SS. *Lusitania* in 1912, and was so successful that the engine-rooms of the later Cunard vessels, *i.e.*, SS. *Andania*, *Alaunia*, *Transylvania*, *Aquitania*, *Tuscania* and *Aurania*, were similarly equipped.

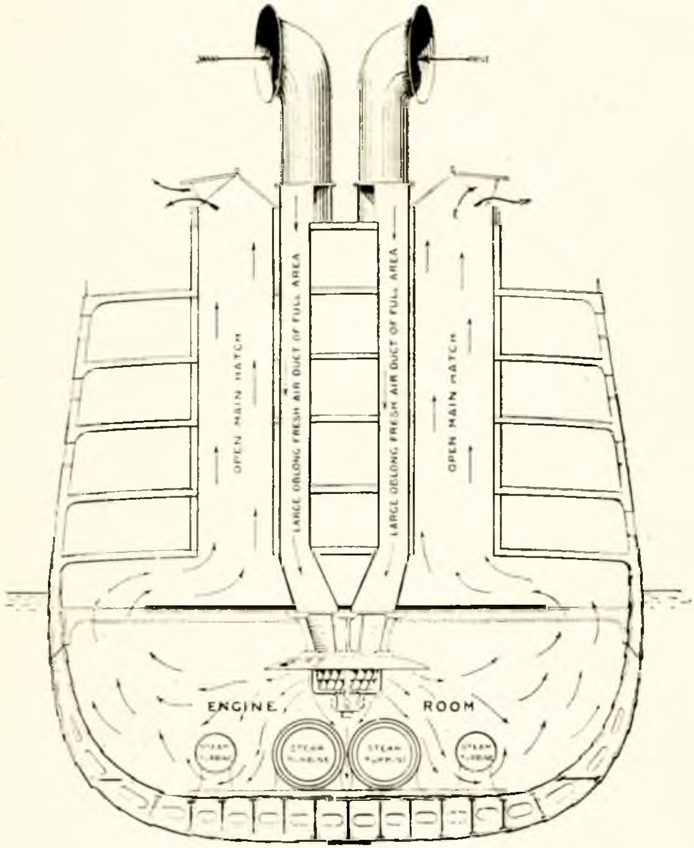

Fig. 4.

Fig. 5 is a reduced part longitudinal section through the central engine-room of the SS. *Aquitania*, showing the arrangement of inlet conduits and fans and indicating how the change and movement of air are effected at the level of the starting platform 100 feet below the upper deck from which the fresh air is drawn.

The main supply of fresh air for the central engine-room is drawn down four vertical shafts, two of which marked "A" serve one open fan marked "B," and each of the other two of which marked "C" serves a separate open fan marked "D." These three fans collectively distribute and diffuse 180,000

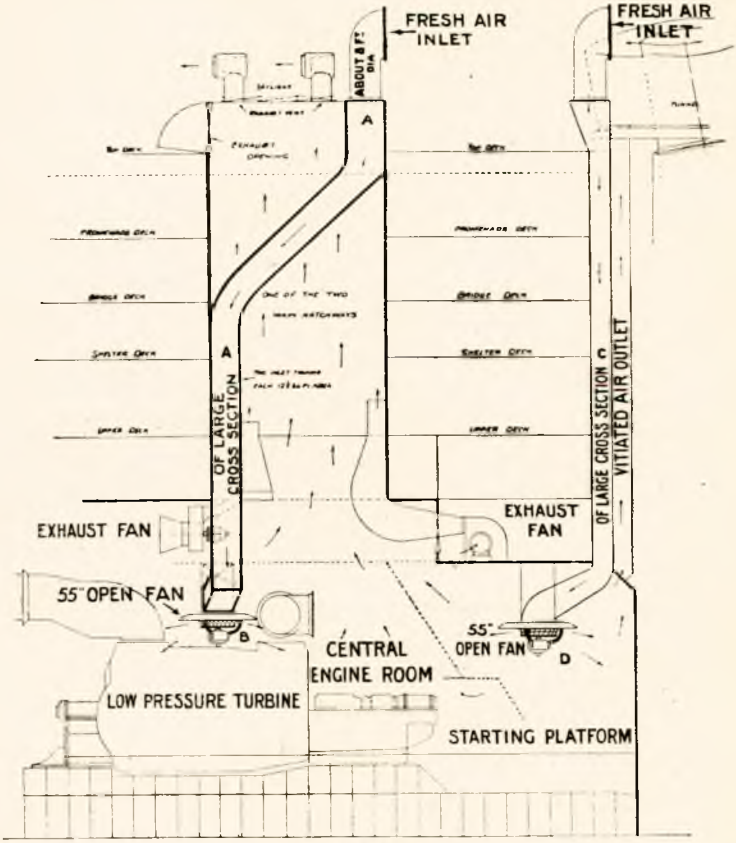

Fig. 5.

Longitudinal Section through Central Engine-Room and one of the hatches of SS. *Aquitania*.

cubic feet of fresh cool air per minute, without unpleasant draughts, into the lower part of the engine-room with an expenditure of 66 horse-power. In the two wing turbine rooms 120,000 cubic feet of air per minute are distributed by other fans requiring 68 horse-power. The condenser and turbodynamo compartments receive 120,000 cubic feet of air per minute, absorbing 66 horse-power. For circulating air in and emitting it (by separate fans) from the various compartments mentioned, 167 horse-power is required, 273,000 cubic feet of air per minute being handled in this manner.

The net result is that the atmosphere at these depths is kept fresh and wholesome at an average temperature of about 75° Fahrenheit.

A similar result could be obtained by blowing or forcing air downwards by cased fans from the top deck. With similar structural conditions, however, a much higher water-gauge pressure-difference would have to be created in order to obtain the necessary volumn below, and the expenditure of horse-power would be considerably greater.

In this connection, it may be desirable to point out some of the reasons for the advantages obtained by drawing in the air and distributing it without inside conduits as distinguished from pressing it towards a room from the point of view of the power consumption requisite for good ventilation.

A fan fitted to the lower end of an air duct may be so arranged that it serves not only to handle the air but also to diffuse it in a favourable manner over the room to be ventilated. If the air be forced to the room, however, distribution pipes and nozzles are necessary to effect an even ventilation all over the room.

While, therefore, in the former case there is only at one place, namely in the fan, a transformation of energy and change of velocity of the air, in the latter case a second transformation takes place where the air passes through the nozzles into the room. In the former case the absolute velocity of the air, where it leaves the fan, is used to distribute the air in a favourable manner; in the second case such velocity is lost to a large extent in eddies.

It may also be pointed out that on board ship, when the principle of sucking the air to the room is adopted, it is usually easier to have the smallest number of bends and therefore a more efficient passage for the air till it enters the room.

Again, the fan and motor are not so much exposed to atmospheric conditions and are more easily watched and controlled when fitted in the engine and boiler room, than when arranged on deck.

The only way to prevent draught currents from the nozzles below when forcing the air downwards would be to use large distributing diffusers in the engine-rooms in order to deliver the full volume desired at a lower velocity.

In actual practice these points are well exemplified in the case of the SS. *Aquitania*, in which, because of machinery difficulties, the two wing engine-rooms are served by the plenum method at a cost of one-third more power than is required for the ventilation of the central engine-room in which the system illustrated and recommended is installed, the proportions of downward air-ducts and air volumes delivered being identical.

When it is considered that many modern underdeck (as well as underground) engine-rooms have a uniform or an unvarying overheated "*windless atmosphere*" of from at least 100° Fahrenheit in winter to 150° Fahrenheit in summer, notwithstanding the presence of old fashioned apparatus expected to secure so-called mechanical ventilation, the urgent necessity for a practical remedy will be appreciated.

Until about four years ago it was unusual to employ open fans for ventilating engine-rooms, etc., and it was difficult to obtain open fans capable of creating efficiently an underpressure in a duct or air-inlet sufficient to induce an air-current of fairly high velocity.

To meet this demand, a fan as shown in Fig. 6 has been specially developed.

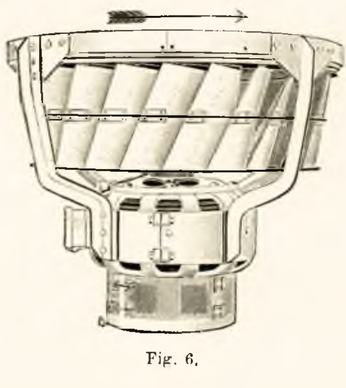

Fig. 6.

It will be seen that the impeller vanes are scooped on the inlet side and are of such shape that they slice into the incoming air and divert it gently from the axial into the radial direction, as shown conventionally in Fig. 7. The outer longitudinal edges of the blades are inclined backwards with reference to the direction of rotation, as shown in Fig. 8. Experience has shown that impellers so bladed do not tend to race when employed as open fans running in parallel, and that there is little tendency for the air to re-enter the space between the blades and cause eddies when the fan is running against a comparatively high pressure. This design ensures strength and rigidity without internal stays.

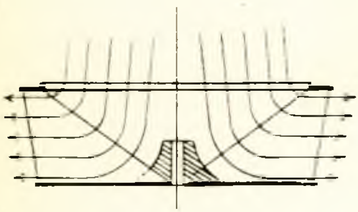

Fig. 7.

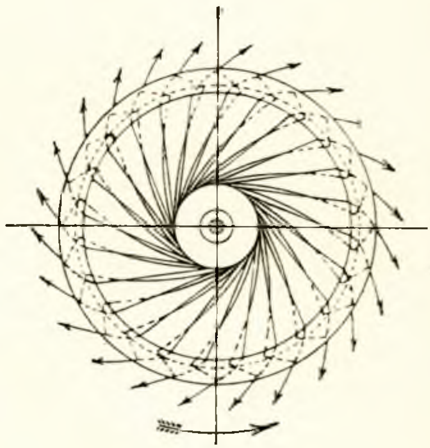

Fig. 8.

There have been published elsewhere diagrams indicating by stream lines the approximate course followed by the air when passing through the impeller. As might be expected, the stream lines show a continuous course with no sudden changes in direction, so that also the actual course of the particles of air may be regarded as steady, a result which is corroborated by characteristic and efficiency curves already published.

Strengthened forms of this impeller as shown in Figs. 9 and 9A driven respectively at high speed by steam turbines have now been adopted for use on board the latest forms of torpedo-boat destroyers of British, Italian and other foreign navies for giving forced draught at a static water gauge of 6 inches, and obtaining coolness in the stokeholds.

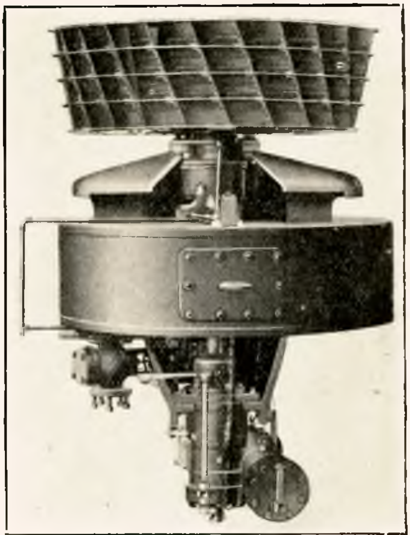

Fig. 9.

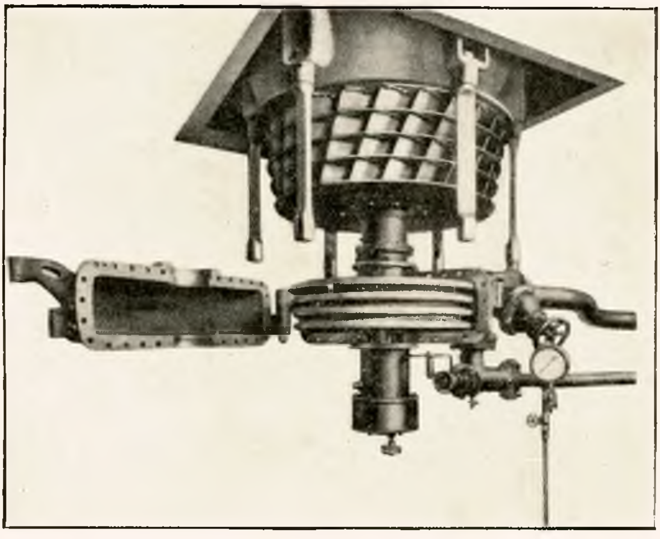

Fig. 9A.

By virtue of the vertical arrangement, air is distributed high up in the stokehold where the pressure equalises itself, thus avoiding unequal air distribution to the burners and formation of eddies which would set up draughts and cause discomfort to the occupants of the stokehold. Tests of fans such as shown in Fig. 9 have been published in the Journal of the American Society of Naval Engineers of November, 1912.

Up to this point there have been discussed only means of freshening the atmosphere in overheated engine-rooms; but in certain circumstances it is often necessary to furnish fresh air in volume, either artificially cooled or warmed.

Fig. 10 represents a part vertical section and a part elevation of an open fan installation capable of furnishing fresh air,

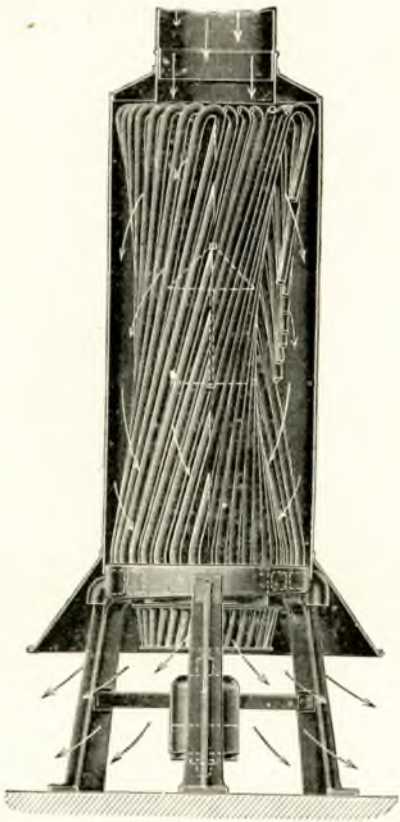

Fig. 10.

either heated or cooled, to a working room on land or on board ship. As shown, the apparatus is designed to rest on the floor, but naturally it may also be constructed for erection at a higher level. In either case the apparatus may be connected to a fresh air duct coming down through the roof or from the upper portion of a building.

For furnishing an abundant supply of fresh air from the upper deck of an ocean liner and delivering it under moderate pressure, either cooled or warmed, into state-rooms, saloons, etc., below, a different construction of apparatus is called for.

Fig. 11 represents a transverse section of what is commercially known as a "Rhigothermo" Plenum ventilating cased fan installation, for performing the work described. By way of indicating the mechanical efficiency of the installation represented, it may be stated that with a difference of temperature of

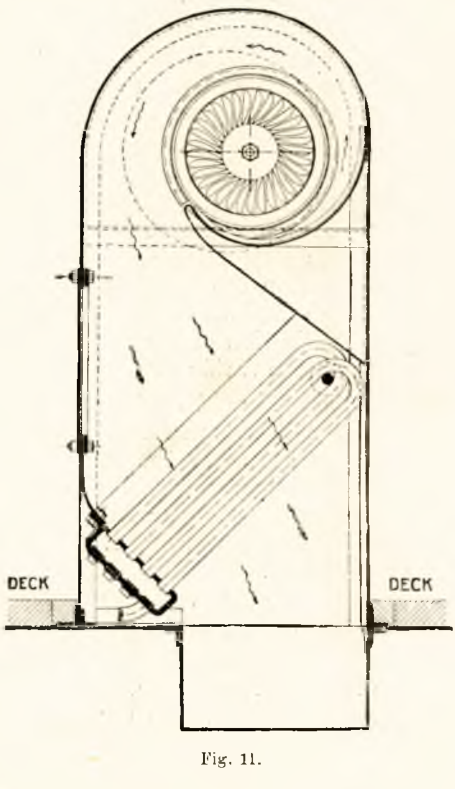

Fig. 11.

40° Fahrenheit between the temperature of the outside air in cold weather and that of the air delivered into the deck main ducts, every 1,000 cubic feet of air so delivered, at a constant water-gauge pressure of two inches, requires for electrical current the expenditure of only half horse-power.

It will be understood that the fan draws in fresh air, compresses it to a pressure sufficient to ensure its delivery to the main duct, the flow being only slightly impeded by the heated or cooled surfaces around which it passes; while the air delivered, being in no way initially overheated, remains in fresh condition. The installation shown is to be distinguished from constructions which require air to be forced through narrow tubes in a cylinder.

The "Rhigothermo" apparatus has already been successfully installed on the latest Canadian Pacific liners as well as on the latest Cunarder, the *Aurania*.

In connection with the ventilation of underground railways and "tubes" or "sub-ways," it is interesting and instructive to consider the advance that has been made within the past fifty years, and even during the past twenty or even ten years.

The first underground railway in London (the Metropolitan and District Railway) was opened from Paddington to Farringdon in 1863, and, as the original intention was to use *Hot Water Locomotives* therein, no special provision was made for ventilation at all. As is well known, however, no hot-water locomotives were ever run on the Underground Railway, and, from the first, coal or coke fired steam locomotives were used for traction. Hence the ventilation of the tunnel sections was bad from the start, even when the traffic was comparatively small.

Within the past ten years the old Underground (Metropolitan and District) Railway has been transformed into an electrically worked line, and, is now probably the best ventilated underground railway of its kind in existence. As this comfortable state of affairs has been secured under English climatic conditions, without mechanical ventilation, it is naturally of interest to seek the explanation.

Like the Paris and New York "Undergrounds" or "Subways," but unlike the London deep "Tubes," the tunnels of the London Metropolitan main underground railway are only a few feet under the level of the streets.

The stations are on an average about half a mile apart; most of them have now been opened up to the outside air with large open spaces on each side, the tunnels also being of large dimensions. It has been found that under these conditions and with electrical traction the movement of the double-track trains travelling in opposite directions keeps the air of the tunnels in sufficient motion to prevent stagnation or the existence of the deleterious uniform or "*windless*" atmosphere so much complained of by hygienic authorities, and, so gives good ventilation and a feeling of freshness all the year round.

On the contrary, unlike the main London Underground Railway but like the London "Tube" Railways, the "Undergrounds" or "Sub-ways" of Paris and New York are generally unprovided with open stations or with spaces or areas throughout the lines open to the outside air, and, although electrically worked and otherwise well equipped, cannot by any stretch of imagination be said to be well ventilated. As regards ventilation, these Paris and New York lines were designed to work on practically the same principle as that originally applicable to the London "Tube" lines *i.e.*, the "*piston action*" of the trains when running was fallaciously expected to be sufficient for the perfect ventilation of the tunnels.

Satisfactory ventilation can be secured either by largely opening up these underground conduits at short intervals completely to the open-air and depending upon the working of the traffic electrically each way to give the necessary movement to the atmosphere therein (as exemplified in the case of the London Metropolitan), or by flooding these underground roadways, when practically closed to the open-air above, with fresh-air in sufficient volume, from a central position in each section towards exits at each end, by mechanical means, substantially in the manner illustrated diagrammatically in Figs. 12, 13 and 14.

These figures represent respectively a longitudinal elevation and part section, a plan, and a transverse section of a working model of a two-track "Underground" electric railway or "Subway."

This working model is 12 feet long (representing in full size 144 feet in length) but, otherwise it is constructed to the scale of one inch to the foot, or one-twelfth of the actual size of the real tunnel or "Sub-way." The diagrams are drawn to a scale of nearly 1-26th of the size of the working model and to a scale of nearly 1-307th of the full size or actual "Sub-way," the cross-sectional measurements internally of the actual "Sub-way" represented being 16 feet in height by 25 feet in width.

As represented, a specially constructed open type of fan, having double air-inlets, each $7\frac{1}{2}$ inches in diameter (representing $7\frac{1}{2}$ feet diameter air-inlets in actual or full size) is placed in

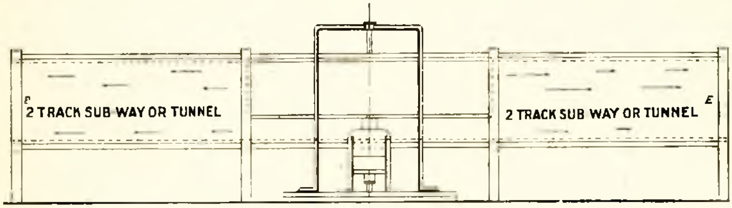

Fig. 12.

Longitudinal Elevation and part section of Working Model of Underground Electric Railway.

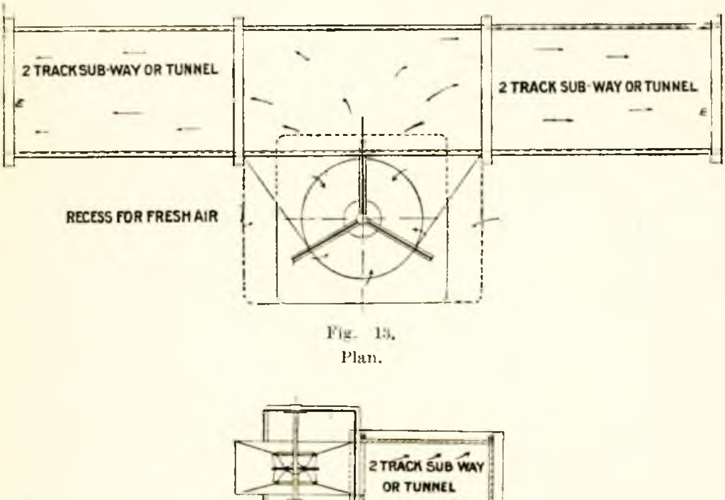

Fig. 13.

Plan.

Fig. 14.

Transverse Section through Fan and Sub-way.

a recess formed on the side of the "Sub-way" so as to draw fresh air down the recess (from above or the outside) and propel the air in volume into the side and towards the upper part of the "Sub-way" or tunnel.

With this model working as a guide, the motor and fan running at 4,000 revolutions per minute, the motor absorbing 1·6 horse-power, 1,004 cubic feet of fresh air per minute are propelled along the tunnel towards each end of the section (or towards each station) as shown by the arrows; the air-current being rated at an approximate air-speed of 4·6 miles per hour towards each extremity "E."

These figures indicate (giving the same rate of air-speed or current in an actual tunnel) for a fan of full size a running speed of 330 revolutions per minute, and the delivery of 150,000 cubic feet of air per minute towards each end of the tunnel, or for both ends "E" a total of 300,000 cubic feet of air per minute, with an absorption of from 90 to 170 horse-power according to the form of fan used*, effecting a change of the whole of the cubical air contents of the tunnel section every three to three-and-a-half minutes between two stations half a mile apart.

Indifferent though the ventilation of the London deep "Tubes" may be, it is perfect in comparison with that of the New York "Sub-ways," which during summer time have an atmosphere that is quite intolerable.

Notwithstanding the usually over-crowded conditions of these "Sub-ways" unprovided with sufficient ventilation, and the consequent unpleasant and unhealthy state of the atmosphere, aggravated by the effluvia or odour and heat generated from the running of hundreds of electric motors, there is no reason why the air should not be as fresh and healthful as that of the open wide streets immediately above, provided a proper system of mechanical ventilation be installed.

The author has come to the conclusion that for "Sub-way" ventilation there is no necessity to do more than bring the fresh air from a point outside to where it is needed. No reasonable person expects better atmospheric conditions in these underground highways than are to be found in wide, healthy streets or roadways above ground—conditions which can undoubtedly be obtained by the proper application of the methods suggested.

It may be noted that one great advantage of the Plenum Ventilation system described, is that, given a pure source from which to obtain the fresh air supply, all local or surrounding smells are effectively kept out of the apartments or places

*In actual practice, these full-size fans will develop considerably more capacity for the horse-power stated, or will absorb much less power while giving the volumes of air mentioned.

treated, while the vitiated air is thoroughly displaced through the proper exits. It is understood, of course, that where the external source is either impure or not free from suspicion, or is dust-laden or smoke-contaminated, it may require to be screened or cleansed (as in the case of the Singer engine-room) before it is drawn or propelled into buildings containing valuable and delicate machinery and where there are workers.

By no other methods than those on the lines described and known to present-day ventilating science can we obtain what has been called a "sufficient draught of cool and relatively dry air (conducive to good health)," free from unpleasant currents, in crowded places and especially in over-heated engine-rooms, sub-ways, etc.; but the results obtained by the author, would some years ago, probably have been considered almost impossible; and, with our present-day facilities for the economical adoption and distribution of mechanical power by electricity, there is no excuse for lack of good ventilation anywhere.

Before closing, the author would like to impress upon you that there is no royal road to success in this or in any other branch of technical science: but this much is certain, viz.: that good ventilation cannot be secured without the aid of experience and of mechanical energy in some form or other under what may sometimes be thought unnatural conditions.

Some lantern slides will now be shown on the screen giving views from photographs of the buildings and ships dealt with in the paper, also of photographs of some of the principal engineers and men connected with one or two of the ships mentioned.

Afterwards members can see a few prepared models (as illustrated, page 291) at this end of the hall, one or two of these being shown working, which may perhaps give a better idea of what the author had been endeavouring so imperfectly to lay before you.

Fig. 17

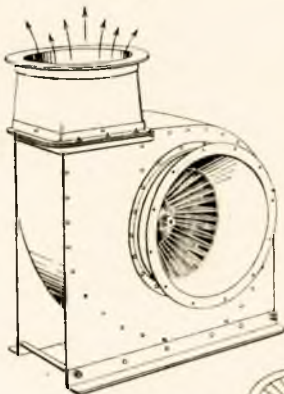

Fig. 15.

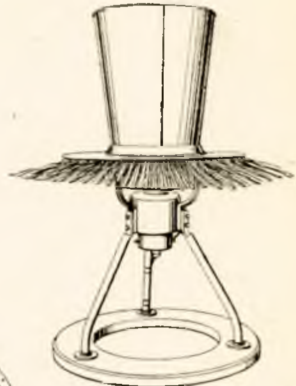

Fig. 16.

Fig. 18.

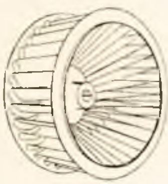

Fig. 20.

Fig. 21.

Fig. 19.

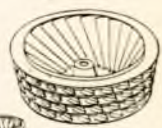

Fig. 22.

Fig. 23.

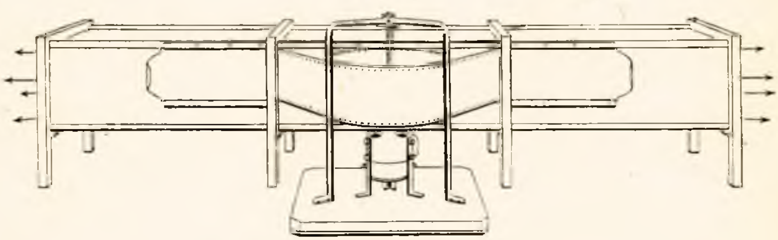

Fig. 15. Open Fan Model at rest.
Fig. 16. Open Fan Model shown working.
Fig. 17. Cased Volume Fan at work.
Fig. 18. Cased Fan Wheel.
Fig. 19. Open Fan strengthened for high speed.
Fig. 20. Open Fan with double air inlet for pressure.
Fig. 21. Ditto ditto for volume.
Fig. 22. Open Fan Paper-weight Model.
Fig. 23. Working Model demonstrating Sub-way Ventilation.

DISCUSSION.

The Chairman: I think we all agree that this has been a most interesting paper, but before we proceed to convey a vote of thanks to Mr. Keith in sufficiently warm terms, I invite you to discuss the paper.

Mr. W. H. Massey: I heartily agree with the proposal to formally vote our thanks to Mr. Keith, and hope we shall be unanimous in offering him our congratulations on the success which has attended his efforts to add to the comforts, to minister to the health, and, therefore, to increase the efficiency of the engine-room staffs, by permitting them to labour under what may be described as more natural conditions than those caused by the design, or rather want of design, on the part of those who were responsible for the general arrangement of machinery in ships. For more than 30 years I have been thrown more or less in contact with various works of the author, and I have always found him full of energy and go; difficulties with him were only things to be overcome, and I envy and admire his tireless energy. No matter what he has to do, he will do it in the best manner in the shortest possible time and at a reasonable cost. But there is another side to the question, and that is the side which touches us as Marine Engineers. While praising Mr. Keith, I cannot help thinking that it is sinful that a man of his abilities should prostitute his talents in remedying defects which ought not to exist; and if we, as Marine Engineers, would only call the attention of the authorities to the fact that they are wasting money, we may induce them to do away with the present state of things. There is the question of horse-power—actual figures do not matter—but on a certain occasion it took, according to Mr. Keith, nearly 200 H.P. to drive the fans alone! If the ventilating arrangements were properly designed, the movement of the ship, driven at nearly 30 miles an hour, ought to be sufficient to renew the air without this extra work. We do not know the exact temperature of the air, nor whether it is at normal pressure, but even without exact data it is apparent to all that there is an abnormal waste of power through *radiation* losses, as there is no such thing as heat; and I venture to say that if proper calculations were made we should be astonished at the waste resulting from heating the air itself. It amounts to hundreds of horse-power, and such waste is wicked; but, of course, in England we are wasteful. A paper on combustion was read at the British Association some time back, when some startling figures were quoted as bearing on the great waste in fuel going on constantly. You will remember that it has for years been suggested that some sort of economy ought to be practised at collieries where coke is made, and a certain well-known iron company now finds it possible to make rails with no further consumption of coal than is required for the production of coke. An enormous saving can thus be effected in the cost of manufacture; and we, as Marine Engineers, ought to try and save some of the energy wasted in the overheating of engine-rooms. If radiation cannot be prevented the energy should be used in improving the draught of boilers or some other practical use should be made of it. I should like to ask Mr. Keith one question: Whether he has any idea of the difference in power required to ventilate an engine-room when the ship is standing still or going 25 knots an hour, the cowls being properly set so as to get the advantage of the speed of the ship in one direction and the wind in another? On one occasion in my experience, the inlet cowl was put on the wrong way and the air went down the outlet cowl, with the result that the fan did not draw the air up and down at all; but I know that the amount of air coming down these cowls is very great, and ought to be enough to ventilate any ship that is properly arranged. I was at sea long before any mechanical ventilation was attempted. My first experience of fans on board ship was in 1873 during the months of September and October, in H.M.S. *Devastation*, where we had about 32 fans; but, after three days' battened down in a heavy sea on the S.W. coast of Ireland, the result was a worse stench than anything I ever struck before or since. I do not want to do away with Mr. Keith's bread and butter, and of course ventilation must be carried out on other parts of the ship, but I do contend that there is an unnecessary amount of waste going on in the engine-rooms of these ships, and I submit that this waste ought to be prevented.

Mr. W. J. Dibb: I congratulate Mr. Keith upon his excellent paper, and feel quite sure it will be read with great interest by the members, as ventilation plays a very important part in their lives, whether ashore or afloat. As the author rightly says, there is no royal road to learning; this is proved in the case of the *Lusitania*. This ship at the time of launching was supposed to represent the last word in naval architecture; yet, from Mr. Keith's evidence, it was six years before the temperature in the engine-room was reduced from 140° to 75°, the ship being engaged in the Atlantic trade where the average temperature would be about 50° to 60°, and the steamer travelling at 30 miles per hour. This I should call ideal conditions, and I would like the members present to imagine what it would be like in the Red Sea with air and sea-water between 80° to 90°. It is to the interest of shipowners to have the engine-rooms as cool as possible; all excessive heat radiating from uncovered pipes, boilers, cylinders, etc., is a waste of fuel. These units of heat should be conserved inside their respective places and made to do useful work. I think it is unreasonable to expect the average shipowner to instal expensive fans after the ships are built. But I venture to suggest that if this matter received more attention at the time of building, the ventilation could be greatly improved, with only small additional cost.

The laws of air convection tell us that heated air will always rise to the top. Therefore, if upcast ventilators were fitted as well as downcast, it would greatly assist the circulation of air. Personally, I am not in favour of fans, steam or electric, if they can be avoided. From my experience, they require a lot of attention, occupying a large amount of space, and in the end are very expensive. For instance, it required 480 I.H.P. running night and day to ventilate the engine and boiler rooms of the *Lusitania;* it would be interesting to know what this cost per year, for oil, coal, and attention. Regarding one item, I should like to ask a question; it is stated that 6in. air pressure in the stokehold was used. I suppose this is a mistake?

Mr. Keith: This is correct if it was in a torpedo boat destroyer.

Mr. Dibb: I have had experience in torpedo destroyers with water tube boilers burning oil, also coal, but I have never noted such high air pressure, and I am quite sure it would ruin the ordinary boiler. With reference to the ventilation of power houses, etc., I have never had any experience, but from the facts given by Mr. Keith, I should say very efficient results have been obtained from the various fans he has so kindly exhibited for the benefit of the members this evening.

Mr. Battle: I also join in offering congratulations to Mr. Keith on dealing with this subject. On a former occasion when ships' ventilation occupied our attention, I had the honour to introduce it. I have therefore a double interest in offering my congratulations, namely, as a Marine Engineer and as a co-advocate of hygienic improvements. The offences against the ordinary laws of hygiene on board ship are appallingly numerous and glaring, and to my mind the matter of improved ventilation in the engine-room, although important and desirable, sinks into insignificance in comparison with other conditions, due to breaches of hygienic laws. I refer to bathing accommodation, lavatory and bath arrangements, and also to the carriage of drinking water on board ship. Notwithstanding this, however, we Marine Engineers are grateful to Mr. Keith for his efforts to improve the condition of life at sea. I am strongly of opinion that the average engine-room in small cargo vessels could be efficiently ventilated without any additional expenditure if at first the steam and exhaust pipes were satisfactorily arranged to assist ventilation. Marine Engineers are not thin skinned, and provided the air is fresh and pure, a moderately high temperature is not entirely objectionable, but it is when an engineer on watch has to breathe foul hot air that the trouble arises, and such a condition is a source of public danger. Can we wholly blame the young junior engineer for being overcome with drowsiness under such conditions? A system of ventilation to be efficient, should provide an adequate ventilation under the platform, and any system which merely introduces air into the engine-room, however efficiently, seems to me to be wanting in completeness owing to the fact that the engineering staff is always in the lower strata of air, or nearly so. For health and efficiency on board ship, pure air is essential, and therefore to anyone who endeavours to improve the conditions under which "they who go down to the sea in ships" have to operate, deserves the hearty thanks and approval of the whole of the Marine Engineering profession.

Mr. Wm. McLaren: I have only a few remarks to make. No matter what state the engine-room is in, no matter what the speed of the vessel, if the air of the engine-room is above 90° it is bad for the health. It sometimes causes sea sickness, and the excessive heat is injurious, no matter how pure the air may be. Mr. Keith has designed an apparatus to purify the air, and to put fresh air in. One thing is certain, the pipes and various auxiliary machinery always stop the free circulation of air in an engine-room. Mr. Keith has provided us with a system, notwithstanding this difficulty, of making a cool fresh engine-room out of an engine-room with an atmosphere of 110°F., so hot in fact, that the hand rails burn the hand if you touch them. The author of the paper to-night has put before us a system which—we express the hope—rings the death-kneel to such undesirable and unhealthy conditions.

Mr. B. P. Fielden: The only point in the paper read by Mr. Keith I have to criticise is in regard to Fig. 4. If you refer to the sketch you will see arrows showing the circulation of the air round the turbines, and it appears to me that what is good for the engineer is bad for the engine, especially in the case of turbine machinery, where condensation should be avoided.

Mr. J. Thom: With regard to Fig. 4, I presume the air ducts shown are not to scale, or I fear the shipowner would say that having got the coal and engineers with these appliances on board, there would be very little space for cargo and passengers. I also notice in this same figure the exit from the ventilating shaft is very near the ship's side in the engine-room, this also is a very valuable and necessary part for other purposes than ventilation. I do not see any reason why the ventilating shafts should not be placed in the usual positions, provided the air is afterwards guided towards the ship's side or any other part difficult of ventilating. The great difficulty in getting ventilators to work automatically in warm places is that the air on its way down the ventilator gets warmed up so much that it becomes lighter than the air above it, and naturally wants to rise instead of fall, especially so in deep engine rooms. If ventilators were made one inside the other, the inner one leading down, the outer one leading up, it would be possible to overcome this reversal of direction, as the outer ventilator would insulate the down-going air from the greater heat of the steam cylinders in passing.

The Chairman: I only wish to submit a few remarks respecting Mr. Keith's paper, and some of the matters that have arisen out of the discussion of it. As far as the St. Denis Power House is concerned, when this plant was designed, no one realised beforehand the heated air that would be produced by the rotors of these immense turbines. Although the engine-room is very high and very large, and full of windows and ventilators, it was not possible to get rid of the heat, which backed up mainly, and was most oppressive, in the switch house and the annex running a portion of the length of the engine-room. After consulting a number of experts, we called in Mr. Keith, and his contention was that if we forced a considerable amount of fresh air into the switch room, passing therefrom into the engine-room, we should drive the heated air out with the fresh air under pressure. This plan was adopted, and the result was entirely satisfactory.

In engine-rooms of steamships, the conditions are different. If you can prevent any heat being radiated, there is less need for considering the ventilation question, but radiated heat from boilers and engines and steam pipes cannot be sufficiently prevented, as matters stand at the present time. It is foolish to suppose that with oridnary cowls you can produce satisfactory ventilation, and keep a sufficient quantity of fresh air available when the engine-room is 100ft. below the top deck. Artificial ventilation, under such conditions, is a great advantage.

The question has been raised of the correctness of the air pressure stated as being that in use in the stokeholds of torpedo boats. The figure is quite correct for the rate of combustion required at full speed on torpedo boats and torpedo boat destroyers. I may mention, incidentally, a feature of interest that happens on torpedo boats, when working at a high air pressure in the stokeholds. The "Express" type of water-tube boilers used on such boats is cut down to the lowest limits in weight, and the tubes are small and thin. It occasionally happens that one of these bursts, and if the fire doors are shut at the time, the pressure in the furnaces forces the escaping steam up the funnel, and nothing happens further.

Mr. Keith: I will first endeavour to reply to Mr. Massey. Of course I am already acquainted with Mr. Massey's ideas—they are invariably good ones, but I am afraid my friend would like to live in an ideal world, but we have to live amongst things earthly. He does not believe in waste of any kind. But sometimes waste is beneficial. If a man walks along the street he wastes so much energy, but perhaps feels all the better for the waste. Taking the engine-room as an illustration: I have sailed in the *Lusitania* over and over again 100ft. down. Well, there were all kinds of fans and all kinds of shafts and ventilation cowls, and the coolest temperature was 150°. This lasted six years. Then the arrangement was altered as described in the paper, and the temperature went down to 75°. If we want heat we have got to pay for it, and if we want cold we have also got to pay for it. I think that settles that part—we cannot get anything for nothing in this world. If we could shut up the engine-room and bring the temperature of the air inside to the temperature of the steam, there would be very little waste and very little loss—except the loss of life. Nobody could live in such an atmosphere unless there were some kind of ventilation. The engine-rooms of these great vessels are not like those of ordinary boats, they are contracted (engine-rooms) out of all proportion to the size of the ships. The Chairman mentioned the St. Denis Power House, where, notwithstanding all attempts to reduce the temperature it kept constantly at 140°F., and they could never get anything less; this state of affairs continued until the whole system was altered as has been described. Why, from each of the great electrical turbo-transformers alone there was and is a constant blast or volume of air at 180°F. The air ducts again of the *Lusitania* were 3ft. in diameter; when the ship was going at the rate of 30 miles an hour, one would imagine that the air would go down through these ducts—all prevailing conditions were calculated to make it do that—but it did not and would not, it preferred naturally to get down through the main hatches. Fans were put on the down end of the air ducts, and the result convinced everybody.

Mr. Mather: I should like to propose a very hearty vote of thanks to Mr. Keith for his paper, and for bringing the models to show us. We have had a number of different systems of ventilation explained to us, it adds to the value of a discussion when we have as wide a range of the subject as possible, it gives us an opportunity of knowing what has been done over a wide experience, and comparing our own difficulties with those of others. Mr. Keith's remarks are of great assistance, following on his instructive paper. The value of the kind of apparatus he has described depends largely on whether the cost incurred is worth the result obtained, and the main point is, does it make the engine-room more efficient and thus induce the shipowner to invest his capital in its installation. I have very great pleasure in proposing this vote of thanks.

Mr. Elmslie: I have very much pleasure in seconding this vote of thanks, and have listened with great interest to this valuable paper, for which we are all greatly indebted to Mr. Keith.

Mr. Keith: I am very much obliged to you for this vote of thanks. It has been a pleasure to me to come here this evening, and I can only add that if any member wishes for further light on this subject he has only to write to me and I will afford him any assistance in my power. I now invite anybody who is interested to examine the models and judge for himself. I shall be glad to answer any further questions.

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The subject was illustrated by means of lantern views, as well as by working models which were inspected by members at the close of the discussion, and described in detail by Mr. Keith.

Note.

The Organisation of Scientific and Industrial Research.

The authorship of the report referred to on page 262—December issue—was inadvertently attributed to the Advisory Council appointed by the Board of Education. Sir Wm. McCormack has pointed out that the report in question may represent an approximation of the views expressed by the deputation at the Conference on October 18th, but is not an official paper of the Advisory Council.

Awards for Session 1915-6.

The only subjects on which essays were received were those set for the Associate and Graduate Sections. The awards have been adjudicated as follows:—

Associate Section.—Nominal, indicated, brake, and shaft horse-power; how ascertained, and their relation to one another.

"Tea-kettle," Mr. Jas. Watt, awarded £2 value.

Graduate Section.—The thrust shaft. Its relation to the work and the power transmitted. Design of an ideal thrust block, with description of details.

"Helix," Mr. C. P. Tanner, awarded £2 value.

"Alexander Giwain," Mr. D. L. Thornton, awarded £1 value.

ELECTION OF MEMBERS.

Members elected at Council Meeting held on Tuesday, December 14th, 1915:—

As Members.

John Graham, 37, Baring Street, South Shields.

James Kelt, *c/o* Reid Newfoundland Co., St. John's, Newfoundland.

Sydney Morris, Cawnpore Cotton Mills, Cawnpore, India.

Dudley E. J. Offord, H.M.S. *Conqueror*, G.P.O., London.

Wm. Steel Parsons, "Lymedale," Grove Park, Kent.

Frank John Pickthall, Bartolomé Mitre 250, Buenos Aires.

John Alexander Wilson, Bartolomé Mitre 250, Buenos Aires.

Frederick Percival Jones, 9, John Street, High Street, Merthyr Tydvil.

Walter Macgregor Yorke, 16, Ryder Street, Cardiff.

As Associate Member.

Lyndon Jackson, "Brocton," Cavendish Road, Kersal, Manchester.

As Graduate.

F. H. Hawthorn, "Toledo," Blakehall Crescent, Wanstead.

Transferred from Associate to Member.

James Alfred Seabrook, H.M. Naval Base, Kingstown, Ireland.

Transferred from Associate to Associate Member

C. V. Lewis, 72, Westow Hill, Norwood, London, S.E.