CHAIRMAN'S OPENING REMARKS

(Mr JAMES ADAMSON).

The paper for discussion to-night is a very long one, but I think we shall have fully an hour for discussion after it has been read. I will merely introduce Mr Williams, and without loss of time ask him to read the paper he has prepared, and, I may add, has come direct from Birmingham to read.

FORCED DRAUGHT.

THE advantages which may be derived from the use of a fan or other mechanical means to supply the necessary amount of air requisite for the combustion of ordinary fuel in steam boilers was long ago recognised by some of the highest scientific authorities; but only within a comparatively recent period has it received much attention on the part of practical engineers.

This is perhaps owing to the fact that foreign competition has only recently made itself felt among the users of steam power at home, and economy in every department has to be studied to enable them to compete successfully with their foreign rivals; and as the successive improvements which have been introduced in connection with the steam engine continually lessen the margin of progress in that direction, there has of late been more attention given to the boiler than it has hitherto received, and it is probable that the intelligent application of forced draught to steam boilers generally, and marine boilers particularly, is likely to mark an important advance in the direction of economy.

All boilers whose furnaces are supplied with air by mechanical means, or by means additional to the "natural draught" induced by the current of hot gas in the chimney, are usually spoken of as working with forced draught, and it is in this popular sense that the term will be used in this paper; but, strictly speaking, I think that the term "Forced Draught" should only apply to those instances in which the rapidity of combustion is in excess of that usually obtained with natural draught.

There are several methods by which the principle of forced combustion may be carried out, and among the principal, or hitherto most commonly adopted, are :—

First, Heating the air supply before its introduction to the fuel by utilising the heat remaining in the hot gases after their passage through the tubes of the boiler. This idea has been carried out in great perfection of detail by Mr James Howden, to whom has descended the mantle worn by the late Mr Wye Williams, who preached the "gospel of combustion" with untiring assiduity about half-a-century ago.

A modification specially adapted to the conversion of boilers originally designed for natural draught, or to new boilers where the space is too limited to permit an air-heating chamber, is the introduction of air to the fires direct from the fan through an air casing on the front of the boiler.

This plan, with various adaptations seems to be growing in favour in the North of England, and though other claimants exist, I believe it is generally conceded that Mr Howden originated the use of the casing on the front of the boiler for conducting the air to the fires and utilising the heat radiated from the front portion of the shell. In this arrangement the admission of air to the fuel is through valves, a system which permits the attendant to regulate the rate of combustion by controlling the quantity of air admitted separately above and below the firebars.

Another method of forced draught is by supplying the air under pressure to the ashpits of the furnaces: this is a very old way of applying the principle, and I believe was first used, other than experimentally, in America, where it may still be found in operation on board some of the river boats.

This system does not appear to have been very successful on this side of the water until taken in hand by Ferrand, and under the style or title of the Ferrando system seems to have met with a certain measure of success in burning small and inferior classes of coal; but so far as I can learn there is very little reliable information accessible to the public in connection with it, and from what I could gather during an inspection on board one of the ships fitted with it, and a talk with the engineer in charge, its success seemed to be largely due to the very practical manner in which all the details for working have been arranged. A noteworthy feature was the insertion of a glass in the ashpit door. I felt sure on seeing it that this peephole had been the salvation of many firebars.

A *third* way of increasing the boiler power by rapid combustion is that known as the closed stokehold system, which has been so extensively adopted in our own and other Government ships. To practical sea-going engineers it is difficult to account for the preference shown by the authorities to this over some of the other methods.

The evil results likely to follow cleaning fires with moderately dirty boilers must be apparent to most practical men, and I think it is difficult to imagine worse treatment to a boiler than to permit a volume of cold air under pressure whose area equals that of the fire-door to rush into the back end of a hot boiler. It is doubtful if any boiler could be constructed to remain tight under such treatment very long, and it is not probable that high rates of combustion (for lengthened periods such as obtain in foreign-going merchant steamers), and the full advantages derivable from a reduction in the size of the boilers which this renders possible, will ever be satisfactorily realised with a closed stokehold, unless means are adopted to prevent the inrush of cold air when cleaning fires.

I noticed on board the City of Paris, before that ship left Glasgow, that some provision had been made for this, and it would be very interesting to know the result. I have little doubt that it is a step in the right direction to enable boilers to work for lengthened periods in a closed stokehold at high rates of combustion. As far as I am aware, the City of Paris was the first ship with a closed stokehold whose smoke-boxes are separated and fitted with dampers in the uptake to regulate the emission from, and consequently the air admission to, each furnace when cleaning a fire.

From the manner in which the working of these dampers was arranged, I felt that possibly the engineer on watch would have to look after the firemen when cleaning a fire, to see that they made use of the appliance, as it would be difficult for them to resist the temptation of leaving the damper open if, when cleaning a fire, such a course would add to the comfortable performance of that always trying operation.

The *last*, but by no means the least, I shall mention will be the system of induced draught by causing a partial vacuum in the uptake by the use of a steam jet or fan, or its equivalent. The steam jet under various forms is probably the simplest, most widely adopted, and best known method of increasing the activity of the fires by quickening the draught; but its use is out of the question in marine boilers, where economy is a primary consideration.

On the other hand, I think that exhausting the uptake by mechanical means has much to recommend it, and perhaps I may say that the most painstaking, scientific, and extended series of observations relative to the combustion of fuel under steam boilers ever undertaken under practical working conditions, and placed at the disposal of the public generally, has been in connection with this system in America; and the substantial lesson taught to the observer seems to have been the utility of heating the air supply before it enters the furnace; and after trying various more or less well-known means to obtain economy by the employment of air jets above the fuel, he (J. C. Hoadley, Esq., author of "Warm Blast Steam Boiler Furnaces,") sums up thus:—"Aside from the one conspicuous saving by returning to the furnace in a warm blast a part of the heat of the gases of combustion after they leave the smokebox, no gain of so much as 5 per cent. over reasonably good ordinary practice can be so much as fairly hoped for."

Again, in another place, speaking of a warm blast apparatus (not Mr Howden's, I may remark, but similar in principle), he says:—"This warm blast apparatus seems to afford a means of securing a nett saving of 10 to 18 per cent. over the best obtainable practice with natural chimney draught and with air supplied to the furnace at usual external air temperatures."

But apart from the experience of others, inducing the draught is to me decidedly preferable to closing the stokehold, though one of its most objectionable features is common to both—that is, the absence in any of the present arrangements to efficiently provide against the strong current of cold air rushing through the furnaces and tubes when cleaning a fire; but I do not regard the provision of a remedy for this as offering insurmountable difficulties.

The advocates of induced draught *re* its application to marine boilers point to the results obtained with this system in locomotive boilers ashore; but they do not point out that the working conditions of the two types of boilers are very different, as the locomotive boiler fire is never cleaned when going full speed, because the runs are made short enough to permit this operation to be done during the intervals when the engine stops at a station.

A fan for inducing the draught would probably require to be much larger, or run faster, than one forcing it, as the products of combustion would be more bulky than the volume of air entering the furnaces, and the temperature of the gases dealt with would place the working conditions of the fan at a disadvantage; but an open stokehold is a much more comfortable place for men to work in than a close one, and in discussing the relative merits of any system I don't think that what an eminent North Country engineer calls the "human factor" should be entirely eliminated from our consideration. The dangerous conditions which men work under in close stokeholds have furnished some startling illustrations recently; the details of some of them may be learned from the newspapers.

I have had opportunities in various parts of the world of seeing many of the systems of forced draught which have been fitted in steamers for the purpose of increasing the boiler power, or of economising fuel. Some of these displayed a considerable amount of perverted ingenuity.

One which came under my notice enabled the ship to burn 18 per cent. more coal on a knot less speed; in another one elaborate and expensive apparatus was employed to quicken the draught by sending a jet of cold air into the funnel somewhat in the form of a gigantic steam jet about 9 in. in diameter. Perhaps it is needless to add that this unique method of cooling the funnel failed to produce the effect intended by its sanguine inventor. I have been in some very dissimilar ships which were fitted with forced draught on Mr Howden's system to effect the same objects as the foregoing. Some of these ships were of the type usually described as ocean tramps, others were passenger ships; and my experience leads me to believe that it is well adapted to all classes of ships.

The arithmetical proof which I have seen and heard so often of the small gain derivable from moderately heating the air supply would be more convincing to me if I had never observed the effect which this heating produces in quickening the combustion, or if I had never seen equally satisfactory proof given (with figures) to show that steam could be as economically expanded in one cylinder as in two or more, but some shipowners had the temerity to adopt multiple cylinder engines in spite of the figures, and the result has been the same as it has been in the majority of those ships where Mr Howden's system has been adopted and placed in fair comparison with other ships doing the same work.

My first acquaintance with draught produced by mechanical means was with two large boilers constructed to work at 100 lbs. pressure with natural draught, and after working under these conditions about four years were subsequently among the first of those which have been fitted with apparatus to work with forced draught on Mr Howden's system. Each boiler was 16 ft. diameter and 10 ft. 6 in. long over all, containing 284 tubes $3\frac{1}{2}$ in. diameter and 7 ft. $4\frac{1}{2}$ in. long, or 71 tubes to each of the four furnaces. The heating surface was about 2400 sq. ft., and grate surface about 80 sq. ft. to each boiler. These proportions enabled the boilers to maintain steam steadily for ordinary compound engines indicating 1300 horse-power on a consumption of 26 tons fairly good Welsh coal, so that there was not such a large margin of possible improvement to work upon as would be the case in a less economical boiler. When the alteration was made the grate surface was reduced one-third by substituting shorter firebars.

The exceptional nature of the coal (received at Birkenhead) made the result obtained on the first outward voyage to India less favourable than was expected; but as this ship had never burned North Wales coal before, any estimate of the efficiency of the alterations would be questionable if based on this in the absence of more comparative data. Not so with South Wales coal, which was the principal fuel burnt in this ship before the alterations, and my estimate of the utility of these is based on comparisons drawn by observing the consumption of South Wales coal under the different conditions. The Vauxhall coal taken at Birkenhead, and burned as far as Port Said, contained the very large proportion of $36\frac{1}{2}$ per cent. of volatile matter, or about 30 per cent. more than South Wales coal; and as the area for admitting air above and below the fuel was proportioned for the latter coal, it may go some way to account for the disappointing nature of the results obtained with the Vauxhall coal, though the consumption of 1·9 lbs. per indicated horse-power per hour is less, I think, than could be obtained in the same ship at full speed with natural draught.

However, with the South Wales coal taken at Port Said, the consumption was 1·75 lbs. per indicated horse-power, and I was enabled to report a saving of 8 per cent. in favour of the forced draught; but the numerous air leaks in the casing and around the air-heating tubes led me to expect a better result after they were stopped. This belief was justified during the homeward voyage after we had straightened things up a bit in Bombay and Kurrachee. On leaving the latter place for home we received orders to go at 9 knots, and the consumption of South Wales coal taken on board at Perim, and therefore not very fresh, was at the rate of 1·64 lbs. coal per indicated horse-power at this reduced speed when indicating 925 horse-power. On arrival at Port Said we received orders to go full speed to Malta. We could easily have maintained more, but I kept the power down to 1300 for the purpose of comparing the consumption under the conditions which usually obtained with natural draught. I measured and weighed every pound of coal put on the fires during 12 hours, and the result was 26,240 lbs. burned in that time. The power indicated was 1306, giving 1·67 lbs. coal per indicated horse-power per hour, and a rate of combustion of 20 lbs. per sq. ft. of grate area. The boilers had been under steam 20 days at this time, and with the same coal would burn 1·9 lbs. per indicated horse-power with natural draught when maintaining the same power.

This 12 per cent. gain, I thought, was a very encouraging result, especially in face of the fact that a large number of the air-heating tubes were still leaking, which we had neither time nor tools to repair in Kurrachee. During the voyage we had some trouble with the firebars, owing to the very limited area for admitting air between them, and the small air pressure available to make up for the deficiency. The bars were $\frac{7}{16}$ in. thick with $\frac{1}{16}$ in. air spaces between them, and this after a few days' steaming was found insufficient to allow the air to pass freely to the fuel on the bars, especially for fuel containing such a large proportion of volatile matter as the Vauxhall; and after carrying out the orders I received to space them an $\frac{1}{8}$ in. further apart, they bent sideways owing to the lack of lateral support against each other at the middle of their length.

There is little doubt that thin bars are the best for high rates of combustion, as they will remain uninjured where thicker bars would surely burn. This is because the receptive area bears such a small proportion to the dissipating area in thin compared to thick bars. By "receptive area" I mean the area of the top of the bars on which the glowing fuel rests, and through which the heat is principally conducted to the rest of the bar, and dissipated by radiation and conduction from the sides of the bars to the air passing between them. This dissipating surface is practically the same in bars of equal depth, while the receptive area varies in direct ratio as the thickness of the bar.

The principal objection I have heard urged against thin bars is the impossibility of using a pricker without breaking them; but with a closed ashpit a pricker does more harm than good, and I have burned 50 lbs. per sq. ft.per hour without using it. The success which has been obtained with similar bars to those mentioned but with wider air spaces, under exactly similar conditions, shows that this was the right sort of firebar to use if more air space had been allowed—say a space of a $\frac{1}{4}$ in.

For the preservation of the bars with a closed ashpit it is important to pay attention to the manipulation of the valves for admitting the air above and below the fuel, and while the air pressure is on it is necessary to see that one of the bottom valves is always more or less open at the same time as the top one, otherwise the air blowing on top of the fires with no draught underneath will cause injury to the firebars by overheating them. Care should be taken to rake out the ashpit immediately after cleaning a fire, so as to keep the ashes well away from the bars. The firebars should be fitted tight sideways, and after putting in a set of bars, say $\frac{3}{4}$ in. thick at ends, it will be frequently found that after getting in as many bars as possible, a space will be left perhaps $\frac{3}{4}$ in. wide.

Instead of adopting the usual plan of distributing this space between all the bars, it will be found better to fill this space with a couple of thin bars, which will prevent the other bars bending. For this purpose it will be found useful to carry a set of wrought iron bars $\frac{1}{4}$ in. thick. The number required averages about $1\frac{1}{2}$ for each furnace, or 9 for 6 furnaces, and if a little attention is paid in fitting the bars in this manner, their durability will be largely extended and water ashpits be found an unnecessary refinement at rates of combustion certainly up to 50 lbs. per sq. ft., and probably much higher rates could be continuously maintained if the difficulty of removing the clinkers could be overcome.

In working the fires I have found that a thick fire gives better results in ordinary work than a thin one, probably owing to the necessity for opening the fire door occurring less frequently, and the fire not burning in holes and admitting an excessive quantity of air. In large furnaces a fire about 10 in. deep, with a slight slope from fire door to bridge (and, contrary to the usual practice with natural draught, thickest at the bridge end), will give good results. Care should be taken to prevent any opening between the wing bars and the sides of the furnace, as the fires will always burn in holes sooner in the wings than elsewhere.

The great obstacle to the lengthened maintenance of high rates of combustion with ordinary coal, say rates exceeding 35 lbs. per square foot per hour, is the rapid accumulation of clinker. All the movable bars with which I am acquainted offer no solution to this difficulty, as they are quite unsuitable for high rates of combustion owing to the receptive area I have before mentioned bearing a larger proportion in these than in ordinary bars, causing them to get over-heated, and burn or stick in their work. With decent coal an average rate of 30 lbs. per sq. ft. can be maintained, with the fires cleaned at intervals of 12 hours. Some of the inferior coal, however, burned in steamers of the merchant service will not run six hours at this rate. In view of this any contrivance which can get rid of clinker as soon as it is formed will be a great step in advance, and will enable boilers to be made much smaller than they are at present to continuously develop a given power; and bearing in mind the ease with which I have seen $1\frac{1}{2}$ cubic foot of boiler shell develop an indicated horse-power in some of the Clan Line ships fitted with forced draught, I confidently anticipate the time when this proportional capacity of boiler will be accounted a usual standard applicable to large marine boilers of the ordinary cylindrical type, and that this great saving in space will not be at the expense of the durability of the boilers or economy of fuel.

With regard to the durability of boilers working with forced draught, I mnst say that I have seen nothing to lead me to infer that high rates of combustion are harmful to the boiler, when provision is made, as in Howden's system, for avoiding sudden and violent changes of temperature in opening the fire door; in fact, my own experience points the other way, and riveted seams in the combustion chamber, which could never be kept tight with natural draught, gave no trouble after the forced draught apparatus was fitted. The explanation which occurred to me was that with natural draught a strong current of air passed through the furnace when cleaning a fire and impinged on the seams in question, which were in line with the centre of the low furnaces. With forced draught this current was much less, owing to the obstructions offered by the air-heating chamber in the uptake and the spiral retarders in the tubes, and this reduced current of air did not chill the seams so much as the stronger current.

I think it is very undesirable for one who professes to believe in the utility of forced draught to attempt to discuss the subject publicly without taking notice of a leading article which appeared in the *Engineer* some time ago, in which the statement occurs that "all reason, and analogy, and experience go to show that forced draught cannot be so economical as natural draught." It is much to be regretted that such an extraordinary and misleading assertion should remain so long uncontradicted by one of the many engineers who could have dealt with it in a much superior and weighty manner than I can hope to do. Certainly my own experience, and also that of other sea-going engineers I could name, does not offer any support to such an assertion, as we have seen economical results produced with forced draught on Mr Howden's system which we know could not be approached under similar circumstances with natural draught and the usual rates of combustion.

But it would be unfortunate if we were in the predicament of ghost-seers, who can only relate their experiences without being able to affórd a reason to account for the phenomenon they believe they have witnessed, and after endeavouring to show that "everyone's" experience does not point in the direction indicated by the *Engineer*, I will make an effort to prove that the statement that "all reason and analogy" is antagonistic to the economical use of forced draught rests on a similarly slender basis. I take it that the real point at issue is not that more heat or power can be got from 1 lb. of coal by forced than by natural draught under any circumstances, such, for instance, as the very slow rates of combustion which formerly obtained in some of the old Cornish boilers, but that with forced draught a given quantity of fuel can be made to impart a greater percentage of its heat to the boiler, and this in less time than can be imparted by it when burned with natural draught *at the usual rates of combustion such as obtain in marine boilers at present.* I will take for an illustration the representative rates quoted in the article in question, viz., 15 lbs per square foot with natural draught, and twice that quantity with forced draught, which, fortunately for my purpose, happens to be about the mean rate of combustion obtaining in the boilers of the Inman and International Co.'s s.s. Ohio. The lower rate mentioned first is that usually obtained with South Wales coal in ordinary sea work at full power with natural draught, and can only be maintained for lengthened periods under these circumstances, with boilers having tubes less than 30 diameters long, and the products of combustion enterirg the base of the funnel at 700° after a few days steaming.

Now, is it not quite reasonable to conceive that by increasing the heating surface by lengthening the tubes or otherwise, and using a fan to promote the draught, that the temperature of the escaping gases would be reduced by having to remain longer in contact with the metal surfaces, and that this reduction in the funnel losses would augment the efficiency of the boiler? But a similar result can be obtained in other ways, without employing tubes of excessive length, by placing various impedimenta in the path of the gases between the furnace and the funnel.

This idea has been carried out in several ways, and among them Mr Howden seeks to attain this object by inserting twisted strips of steel in the tubes, which practically rifles each one, and causes the issuing gases to traverse a spiral path, tending to bring every portion into intimate contact with the interior surface of the tube before leaving it. After this its temperature is further reduced by passing through a number of short tubes in the uptake on its way to the funnel. It is around the outside of these short tubes that the air from the fan circulates and becomes heated on its way to the fire. The efficiency of this process in reducing the temperature of the issuing gases may be judged from the fact that the temperature at the base of the funnel in the "Ohio" averaged 465° Fah. when burning American slack at the rate of $31\frac{1}{2}$ lbs. per square foot per hour, with an ashpit pressure of $1\frac{1}{8}$ in., and less than 400° when burning 28 lbs. Welsh coal per square foot with about $\frac{1}{2}$ in. water guage pressure in the ashpit. It never reaches 500° throughout the whole run across the Atlantic with the highest rates of combustion obtained in this ship.

The principal gain derivable from properly applied methods of forced draught is due to the greater range of temperature between the furnace and the funnel, and the smaller amount of heat carried away from the latter by the products of combustion, owing to their low temperature and the reduction in their weight consequent on the more restricted supply of air to the furnaces to consume a given weight of fuel when worked with forced compared to the quantity found to be necessary when working with natural draught at usual rates of combustion.

Assuming for our purpose that the theoretical quantity of oxygen necessary for the complete combustion of 1 lb. of coal is contained in 12 lbs. of air, it is generally admitted that twice this quantity is usually required for furnaces working with natural draught under favourable conditions, and an eminent authority, who has recently investigated the matter, states that "it is under-stating rather than over-stating the matter to say that the average of good practice would show a double supply of air." Again he says, "Doubts may be entertained as to so large an excess of air as 150 per cent. occurring in practice. In fact, it is very common. It is not easy to carry on complete combustion by means of natural draught with less than 100 per cent. in excess." Now, with forced draught it has been abundantly proved that, to say the least, equally perfect combustion can be attained with 18 lbs. of air, and if the products of combustion be discharged into the chimney with the same temperature in each case, the loss due to the heat carried away by the escaping gases is reduced in ratio from 25 to 19. In practical work this ratio is greater, owing to the chimney temperature being lower with forced than with natural draught at similar rates of combustion.

Taking the approximate figures given in the *Engineer* for the specific heat of the escaping gases, the loss per lb. of fuel with natural draught and 700°, assuming that of the air to be 80° before entering the stokehold, will be $(700 - 80) \cdot 23 \times 25 = 3565$ units, or about 25 per cent. of the total heat of the fuel. Comparing this with an actual case of forced draught, with the air entering the fan at the same temperature, or 80°, and the products of combustion entering the funnel at 400°, the loss would be $(400 - 80) \cdot 23 \times 19 = 1398$ units, or only about 9 per cent. from this cause for coal of the same calorific value. This low funnel temperature, with the high furnace temperature consequent on high rates of combustion, is one of the distinguishing characteristics of Howden's system, and no other system of forced draught is likely to be economical where these objects are not attained.

Of course, in estimating the net saving effected, the power for driving the fan or other appliance used for promoting the draught should be taken into account. In the "Ohio" it takes 10 indicated horse-power to drive the fan when burning 3300 lbs. per hour, assuming each indicated horse-power at the fan engine to cost 30 lbs. steam or 300 lbs. steam per hour, equal to, say, 300,000 heat units, or 91 heat units per lb. of coal, or less than 1 per cent. of the heat given off by it, leaving a net reduction in the funnel losses of over 40 per cent., and enhancing the value of the fuel about 15 per cent., a result which would be improved if the fan was driven by the main engines, as the power driving it would be produced more economically. This question of fan driving is beginning to attract some of the attention which its importance deserves, and the barbarous practice of putting high-speed engines in the stokehold is being abandoned after some unfortunate experiences. In some ships fitted with forced draught it is probable that a considerable portion of the benefit arising from the application of the principle is sacrificed by using wasteful engines to drive the fans. The most perfect installation of fan-driving gear I ever saw was on board the Italian steamer I have before referred to as being fitted with the Ferrando system.

From the foregoing it will be seen that it is important to limit the supply of air as much as possible, consistent with the proper combustion of the fuel and maintenance of steam. As a rule this limitation of the quantity of air only applies to that portion admitted above the fuel, and a practical method of determining its amount is to close the upper air valves until a small quantity of smoke is perceptible issuing at the top of the funnel. It will generally be found more economical to show a little smoke than none at all; but some good Welsh coal will not show smoke with forced draught with the upper air valves closed altogether, but it is always advisable to keep them a little open when under way to prevent the furnace fronts becoming overheated. I am not acquainted with any simple method of practically determining the quantity of air passing into marine boiler furnaces—an anemometer placed in the fan discharge pipe is not always reliable, as the velocity of the air is not always uniform throughout the area of the same section of the pipe, and in a square vertical pipe leading from a fan I have observed a difference of pressure, shown by a water gauge, of 20 per cent. simply by changing its position on the same horizontal plane; on the other hand, the quantity of gas discharged from the funnel will always contain more or less air, which has leaked through smoke-box doors and uptake joints.

In computing the amount of air passing into the furnace, I have tried to avoid errors due to leakage out of air casings or into uptakes, by estimating the velocity at which the air passed through the valves immediately at the front of each furnace. I am aware that such a method can only be approximate, but I think the errors arising from such a method of calculation will not tend to under-estimate the quantity of air passing into the furnace, and the result arrived at will be the maximum quantity that could possibly pass in under the observed conditions.

For illustration I will take an actual case where the air pressure at the fan was $2\frac{7}{8}$ in. in a water gauge on the casing in the front of the boiler it was $1\frac{1}{4}$ in., the mean pressure in the ashpits was $\frac{9}{16}$ in., and in the air boxes above the fire-bars it was $\frac{7}{16}$ in. with the top valves half shut. This makes the mean difference of pressure between sides of valve orifice above the bars $\frac{13}{16}$ths, and below the bars $\frac{11}{16}$ths; the temperature of the air in the casing and entering the valves was 206° Fah., or 667° absolute. The volume of 1 lb. of air at any temperature within probable limits of observation may be simply calculated with sufficient accuracy if we assume it to occupy 1 cubic foot for every 40° absolute temperature; therefore, each lb. of air at 667° will occupy $\frac{667}{40} = 16·7$ cubic feet. The pressure per square foot represented by every $\frac{1}{16}$th difference in the levels of a water gauge equals 0·325 lbs.; for $\frac{13}{16}$ths the pressure will therefore be 0·325 × 13 = 4·225 lbs., and for $\frac{11}{16}$ths will equal 3·575 lbs. per square foot. Multiplying these pressures by 16·7 gives the height of a column of air at 206° Fah. and one square foot in section, whose weight would balance a column of water same section and as high as the difference in levels shown by the water gauge.

And in calculating the velocity of the air passing the valves, I have used the approximate formula for calculating the velocity of falling bodies, viz., Velocity = 8 $\sqrt{\text{height}}$. When the height is that of the column of air in question, the velocity in the present case will be 67 feet per second above the bars, and 61·6 feet per second into the ash-pit. As the area for admission through the valves was 0·117 and 0·372 square feet respectively, top and bottom the quantity of air passing will be 0·117 × 67 = 7·839 cubic feet over, and 0·372 × 61·6 = 22·915 cubic feet under bars, making a total of 30¾ cubic feet, or 1·84 lbs. of air passing into each furnace per second. The coal burned in nine furnaces was 3089½ lbs. per hour, giving 19·3 lbs. of air per lb. of coal. If we assume $\frac{9}{10}$ths as the co-efficient of efflux (perhaps the high ratio of perimeter to area of openings warrant more, being 1¼ inch of perimeter per square inch of area), the quantity of air will be less than 18 lbs. per lb. of coal burned at the rate of 27·8 lbs. per square foot of grate per hour. The temperature of the air entering the fan was 77°, and the temperature at which the products of combustion entered the base of the funnel averaged 435° during the twelve hours in which every lb. of coal put on the fires was carefully weighed. The coal burned was a mixture of Welsh of fair quality, with American slack of an inferior description, the latter being in proportion of about 25 per cent.

As these observations were made when the ship was eight days out from port, they will very fairly indicate what may be expected under average conditions, and will tend to show that the calculation I have made elsewhere of the possible saving derivable from the use of forced draught was not an exaggerated estimate, but a fair representation of what has already been accomplished under everyday working conditions. Under suitable conditions these results can be always attained in any ship. Among the necessary conditions, and perhaps ranking first in importance, is the diameter of the furnace. In designing boilers destined to work with forced draught at high rates of combustion, the advantages of a large furnace should not be lost sight of.

I have often heard expressions of surprise from engineers concerning the want of uniformity in the results obtained in terms of indicated horse-power per square foot of grate on board different ships whose boilers contained essential differences in this as in other particulars. A boiler with corrugated furnaces cannot be worked as comfortably and economically at high rates of combustion as one whose furnaces are plain and of the same mean diameter. The effective diameter of a corrugated furnace for firing purposes is not its *mean* but its ***smallest*** internal diameter, and it is surprising to note the difference which a few inches in the diameter of the furnace makes to the quantity of coal which can be put on the grate at each firing, and when there are many fires fronting each other, as in a fore and aft stokehold, an interval of twenty minutes is the least time in which this operation can be performed to enable the men to work properly and without undue interference one with another, as the fires require "raking," and, when getting dirty, "slicing," during this interval, the firemen will have to be pretty constantly at work to keep the fires in good order.

When the average rate of combustion is 30 lbs. per square foot per hour, the actual rate in individual furnaces will vary about 25 per cent. each side of the mean, the clean fire burning about 38 lbs. per square foot for a few hours, the length of time depending on the quality of the coal. Taking the density of the coal when loosely thrown on the fire at 45 lbs. per cubic foot, each fire will burn on an average a layer of fuel 8 in. deep, the clean fires burning a layer about 10 in. deep per square foot per hour. To obtain the best results, the fresh coal should not be thrown much past the middle of the furnace, so as not to cover more than two-thirds the grate area, which makes the thickness of the layer of coal put on this part of a clean fire at twenty minute intervals about $4\frac{1}{2}$ in., and as the fire should not be less than 6 in. deep before charging (to keep steady steam), the depth of fuel on the bars will be $10\frac{1}{2}$ in. after putting on the coal, and this will swell to above 12 in. on becoming heated. If the top of the grate bars is 3 in.

below centre line, a space of 11 in. will be left between the fuel and the crown of a 40 in. furnace, and my observation leads me to infer that this is the least diameter which may be expected to properly and economically maintain with coal of average quality for long voyages a mean rate of combustion of 30 lbs. per square foot per hour, or 23 indicated horse-power per square foot of grate (when the grate does not exceed 1½ diameter long) with fairly economical triple engines.

I am quite persuaded that superior results can be got from larger furnaces, as the distance from bottom of furnace to bottom of bars need not exceed 12 in., and if possible should not be much less, so that any increase in diameter after 40 in. may be wholly utilised in increasing the distance from the fire bars to the crown of the furnace, and only those whose experience has been similar to that possessed by the members of this Institute can be fully alive to the great difference which an inch or two here makes to the fireman. To supply 18 lbs. of air per lb. of fuel when burned at the rate of 30 lbs. per sq. ft., the theoretical delivery at the fan at the temperature of 80° would be 121½ cubic ft. per sq. ft. of grate per minute, but it is always advisable to provide a reserve of 50 per cent. in the capacity of the fan in view of contingencies arising from air leaks, increased temperature, different qualities of coal, etc., so that a provision of 180 cubic ft. per minute per sq. ft. of grate will be found amply sufficient to secure good results. The pressure at which this quantity of air should be delivered from the fan depends on the size and shape of the air passages leading from the fan into the furnace ; these should lead as straight as possible and be of ample area. When heated air is supplied to the fires, as in Howden's system, the ashpit pressure for this mean rate of combustion may vary from ⅜ in. to 1 in., according to the quality and structure of the coal used. Small caking coal, such as that burned in the American mail steamers on the return voyage, requires about twice the ashpit pressure that suffices for good Welsh coals, and, as a rule, the air pressure at the fan may be estimated at three to five times the ashpit pressure, to overcome resistances due to friction and bends in air passages, heating chambers, etc.

Throughout this paper I have mentioned cleaning fires so often that I fear its repetition may appear tiresome, but I entertain a strong opinion that the primary difficulty to be overcome in the continued maintenance of higher rates of combustion than any I have yet mentioned—such, for instance, as obtains for limited periods in locomotive and torpedo boat boilers—is not to be looked for in the tubes and tube plates (as Mr

Howden has already shown how these may be kept tight), but in the frequency of the necessity arising for removing the incombustible constituents of the fuel from the grate bars to prevent the furnace choking up, and to provide free access for the air to the fuel. This operation at present is performed in the great majority of cases in the same primitive manner as it was in the days when men first began to "go down to the sea" in steamships.

The application of forced draught marked the first important change which has affected the operations of the stokehold since steam was first introduced, and I have little doubt that the genius of the engineers who have affected such great and important changes in the engine-room will not be baffled by the mechanical difficulty of getting the refuse out of the furnace without practically placing the latter *hors de combat* while it is being done.

There is another point which I think I ought to refer to, as it may tend to correct an impression which may be generally prevalent, since so eminent an engineer as Mr Parker, of Lloyd's, gave utterance to it some time ago. I allude to the idea that the forced draught apparatus, as fitted by Mr Howden, was not successful until improved upon by and at the expense of those owners who adopted it. Mr Parker cited the case of the "Ohio" as illustrative of his statement, but I can respectfully assure him that he was mistaken in this matter, and that no alteration was made in any part of the forced draught apparatus except the fan engine, and that no expense was incurred by the owners in altering a single detail which may have influenced the difference which was observable between the first and subsequent voyages of this steamer.

The difference was caused partly by the substitution of more efficient fan-driving gear, but principally by Mr Howden taking steps to ensure that his system was worked in accord with his instructions. When this was done, the result placed the "Ohio" in the position she now occupies as the most speedy, powerful, and economical passenger ship of her size crossing the Atlantic. The owners were so well pleased that they contracted with Mr Howden to refit a sister ship in a similar manner; but before finally deciding on this step, they satisfied themselves by a trial on board the "Ohio," under circumstances similar to those which obtained during ordinary work. This trial took place almost exactly two years ago, and will be better described in Mr Howden's own published words, as follows:—

"As is well known by those experienced in the Atlantic passenger service, it is difficult to arrive at a correct estimate of the actual consumption of the propelling engines when steam is being supplied from the main boilers at the same time to a large number of auxiliary engines, and also for cooking and heating purposes throughout the ship, if the total consumption is expressed in terms of the indicated horse-power of the main engines only. Being conscious that the more accurately the tests were made the more clearly would my undertaking of $1\frac{1}{4}$ lbs. per indicated horse-power be found about the actual consumption of the main engines at sea, I have been always most desirous of having the actual consumption in the 'Ohio' tested by careful weighing over a considerable period. The owners of the steamer have kindly favoured me in doing this by their superintending engineer, Mr Doran, and assistants, using all precautions possible to ensure accuracy, and they have furnished me with tabular particulars of the trial from which I give the results.

"The trial took place on 26th Oct. last, under the following circumstances and conditions:—It was made on the outward passage between Holyhead and Queenstown, and lasted two watches, or eight hours. The sea at the beginning of the trial was comparatively smooth, but gradually got rougher, ending in a gale with the ship running against a head wind and sea. The firemen on first watch had never before worked with forced draught, and consequently had something to learn. On the second watch two of the three firemen had been in the ship on a previous voyage. Three fires were cleaned each watch. Diagrams were taken every half hour, and record of steam pressure on gauge made every quarter of an hour. The mean revolutions were taken from the engine counter divided by the minutes of the trial. The mean indicated horse-power was calculated from sixteen sets of diagrams taken, each of which was calculated and recorded separately. The indicated horse-power taken is that of the main engines only, no allowance being made for the auxiliaries or heating of the ship or steam cooking purposes. The auxiliary engines working during the trial were the following:—The fan engine, the centrifugal pump engine, two Weir's feed engines—all these with full pressure steam; and with reduced steam pressure, the steering engines, double cylinder Worthington pump, electric light engine, also steam cooking and heating stoves throughout the ship. By an accidental occurrence the metallic packing of the low pressure piston rod got out of contact with the rod before starting consumption trial, and was not put in order until after the trial was finished, causing a blow-off of steam every revolution and an inrush of air whenever the pressure in the cylinder got below the atmosphere. The consequence was, that to maintain the vacuum at 26 in. the centrifugal pump engine had to be run at 196 revolutions per minute, or about 20 per cent. above its usual speed for a 27 in. vacuum. Besides the reduced vacuum, the feed-water was necessarily colder than usual. During the first four and a half hours of trial all the auxiliary engines, the steam cooking and steam heating throughout the ship, were supplied with steam from the main boilers only. For the last three and a half hours of the trial, after steam had been got up in the donkey boiler, only the auxiliary engines worked with full pressure were supplied from the main boilers. During the first four and a half hours, though the water in the exhaust steam was for the most part returned to the condenser, the waste water from the steam throughout the ship was such as to require the feed of the main boilers to be supplemented all the time by water from the sea. Under above conditions, the mean of the sixteen sets of diagrams of the main engines was 2144 indicated horse-power, and the mean pressures of steam on pressure gauge at the half hours when the diagrams were taken was 147·3 lbs. The mean pressure of the steam during the trial on the quarter hour records was 148·4 lbs., showing that the times at which the diagrams were taken synchronised with periods when the steam pressure was under the average, and consequently they give a power somewhat under the true mean. The total coal consumed for all purposes in the main boilers as explained above during the eight hours was 23,856 lbs., or 2982 lbs. per hour, which, divided by the mean of 2144 indicated horse-power of main engines, gives 1·39 lbs. per indicated horse-power per hour. I do not here attempt to make any calculation of the reduction to be made on this item to arrive at the actual consumption per indicated horse-power of the main engines alone, and leave this to be done by your readers in the light of the facts stated; but I do believe that few of those qualified to judge will put it at much, if anything, above the 1·25 lbs. of my guarantee; and I will say further that probably no sea-going steamer, on her ordinary voyage, was ever before so carefully and accurately tested as to consumption."

This trial provided the owners with conclusive proof that the 18 per cent. reduction in the machinery and boiler and bunker spaces was also accompanied by a gain of more than 16 per cent. in the power obtained from just half the number of furnaces. The "Illinois" provided Mr Howden with a better opportunity of showing the advantages derivable from the adoption of his system, and he contracted to develop the same power as in the "Ohio" with only two boilers and six furnaces, the machinery and bunkers to occupy 25 per cent. less space than they do at present. A sister ship to these, the Indiana, is to be converted into a cargo ship, and the 1200 horse-power for propelling her is to be generated from one boiler only; but as she is to ply in the North Atlantic, this power will probably be exceeded. I understand that the first Clan Liner fitted with forced draught, which has completed a long voyage in a warm climate, averaged 1050 horse-power from one single-ended boiler; but the testimony of the owners with reference to this voyage will be more interesting on this point, and I will now conclude this paper by giving it, with a tabular statement appended, showing the saving in space effected in some of the best known steamers which have been or are now being fitted by Mr Howden on his system:—

Glasgow, 17th June 1889.

Messrs James Howden & Co., 8 Scotland Street.

Dear Sirs,—In reply to your inquiry for particulars of the results of the first round voyage of the s.s. "Clan Gordon" since her engines were tripled by you and fitted with your forced draught, also comparative results of similar voyages made before refitting, we have pleasure in appending the particulars you request:—

Mean time under steam of three voyages before refitting,	2568	hours.
Time on similar voyage after refitting, - -	2052	,,
Time saved per voyage by refit, $21\frac{1}{2}$ days, or - -	516	,,
Mean total consumption on three voyages before refitting,	1844	tons.
Total consumption on voyage after refit. - -	1440	,,
Saving in coal per voyage by refit, - - -	404	,,

It is fair also to mention that the engines before refitting were highly economical and in first-class order, the last voyages being performed quite equal in regard to time and economy with the first voyages of the steamer.

The engineers and firemen on board had no previous experience of working forced draught before sailing, so that we expect that the high results already obtained will even be surpassed on the present voyage with the further experience gained in working forced draught. The voyages made are from Glasgow, *via* Liverpool, to Cape Town and South African ports, thence to Coconada on the Madras coast, returning to London *via* the Suez Canal, a distance averaging fully 20,000 miles.

We must congratulate you upon the remarkable results which have been obtained.—Yours faithfully,

(Signed) CAYZER, IRVINE, & CO.

Steamers	Dimensions.	Machinery & bunker space before refit, lengthways of vessel.	Machinery & bunker space after refit.	Reduction in space lengthways in ship.	Percentage of reduction boiler room.	I.H.P. before refit.	I.H.P. after refit.
		Feet	Feet				
City of Venice, -	379 × 38 × 29	80	68	12	28*	1350	1700
Ohio, - - -	343 × 43 × 34·6	86	70	16	26	1850	2150
Austrian, - -	319 × 38·5 × 32·5	73·6	45	28·6	54	1150	1400
City of Canterbury	379 × 38 × 29	80	64	16	37	1350	1700
Illinois, - -	343 × 43 × 34·6	86	64	22	38	1850	2200
Sarmatian, - -	370 × 42 × 35·6	124·3	49	75·3	63	2000	2200
Indiana, - -	343 × 43 × 34·6	86	44	44	67	1850	1200
Clan Gordon, -	305·6 × 34·9 × 24				28	750	1050

*Boiler Room 4 ft. longer, or 20 per cent. larger than necessary for boilers, to allow deduction for tonnage.

CHAIRMAN'S REMARKS.

(Mr JAS. ADAMSON).

It is with great pleasure and satisfaction that I have listened to the paper prepared by Mr Williams. We are all indebted to him, I think, for coming such a distance, and also for the careful way in which he has prepared his paper and put it before us. I wrote to Mr Howden and invited him to be with us, but received a reply saying he regretted very much that his engagements otherwise would not allow him to be present. I regret that Mr Manuel also has been prevented from attending. The "New York City" has been mentioned, and I hope Mr Nicholson will be here and give us the benefit of his experience. One or two points upon which Mr Williams has remarked in his paper will readily provoke discussion. I think it will be well if we can rise as quickly as possible to the occasion and save time. We have an hour and a half to-night which I think we can spend very profitably on this subject. Mr Williams has referred to the steam jet and induced draft, hot and cold blast, and closed stokeholds. Many of us have had a painful experience of leaky backs in the combustion chambers due to the cold air getting into the furnaces when cleaning fires, or opening the doors with a full head of steam. Mr Williams has referred several times to the cleaning of fires, and I think most of us can endorse the opinion as to the importance of having as little of it as possible. The whole subject of forced draught will probably come before us again on some future occasion, and I will now ask members to rise and speak upon the subject-matter of the paper.

Mr GRAY—I do not intend to speak so much to-night as I have been doing at previous meetings. I was not here at the beginning of the paper, but I will try and read over the early portion of it; meantime, I think Mr Richardson has something to say which will show that forced draught is not altogether the greatest improvement of the day for boilers.

Mr WILLIAMS—I would like to know if Mr Gray refers to a certain ship being a failure. I happen to know about most, if not all, the ships which have been fitted, and shall be glad if anyone can point out how forced draught has been a failure, and I will discuss the matter with them.

Mr GRAY—I did not mean my remarks to apply to any system or ship in particular, but to what I understand Mr Richardson may have to say

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Mr RICHARDSON'S REMARKS.

It was not my intention to speak at this meeting to-night, for I am sorry to say I labour under the same disability as a large percentage of the members of this Institute, namely, the inability to express my thoughts when speaking in public.

However, as I have risen, I may be allowed to say a few words. Mr Williams has stated in his paper:—"One of the greatest disad-

"vantages under which forced draught of any kind laboured was the "great influx of cold air into the furnace, combustion box, and tubes, "when a fire was being cleaned;" also that "he was not acquainted "with a movable bar which could remove the clinker and other refuse "of combustion in a way to get over the difficulty of cleaning fires."

I may state that there are several firebars in the market which are supposed to overcome this evil, but in the most of cases these have to be manipulated by the firemen; and we, as engineers, know that any patent which requires the attention and regulating by firemen on watch, would also require an engineer to ensure its efficiency. A firebar has come under my notice on several occasions which entirely does away with cleaning fires, and is perfectly automatic in its action. In proof of this, a few days ago, the superintending engineer of a very large shipowning firm in London showed me a letter he had just received from the chief engineer of one of their steamers; in this letter he stated that these bars had given him the greatest satisfaction, and that during a voyage to Australia, Japan, &c. (using North Country, Welsh, and Japanese coal), —extending over six months—they had not once cleaned a fire, and would require no new bars, as not *one* bar (out of six furnaces) had gone wrong. He also stated that the revolutions previous to the bars being fitted were 54, and speed 9·7 knots, while the revolutions were now 57, and speed 10·25 knots, that the firemen have much easier work now than formerly, and there was no trouble in keeping the steam at a steady pressure even in the Red Sea and the Tropics.

Mr Williams states that "with Howden's forced draught 23 indi-"cated horse-power per sq. ft. of grate surface can be got." I take it this is the maximum, and not the average indicated horse-power. Well, with these bars the patentee will guarantee as a minimum average all through with natural draught to get 15 indicated horse-power per sq. ft. of grate surface. Looking at these facts, combined with the very much greater wear and tear and general deterioration in boilers where forced draught is used than is the case with natural draught under any circumstances, I am of opinion that a firebar of this description is very much better than forced draught.

Mr Williams says:—"In his experience" (which doubtless has been very great) "he has not found the boilers in any worse condition, with "respect to deterioration and corrosion, than he had found in other "boilers under natural draught." I have had some experience of forced draught, both in the closed stokehold and other systems, fitted by some of the best engineers in the country, and I am sorry to say my experience has been the very opposite to that of Mr Williams.

Mr J. MACFARLANE GRAY'S REMARKS.

I have been much pleased with Mr Richardson's description of the automatic firebars. With that system, and a closed stokehold, and forced draught, the difficulty about cleaning fires would be got rid of entirely, and the stokers would have a comfortable job. Unfortunately, however, the 25 per cent. of waste heat which has been mentioned by one of the speakers would still be passing away. It is much to be regretted that shipowners could not afford to neglect that loss of heat, because there seems to be no other way of recovering any portion of it except by the plan described in the paper—heating the air for the furnaces by that waste heat. Wherever boilers are worked to produce the maximum amount of steam, as for example in the Atlantic mail steamers, it appears to me that heated forced draught must involve a great increase of stokehold temperature, and must intensify the hardship of life to the firemen. I understand from the paper that the "human nature" element has been well considered in the designs particularly described by the author, but I cannot see how the increase of discomfort could be wholly avoided in any case where the full steaming capability is enforced.

It is sometimes asked, why is the heating surface of the boiler not increased, and in that way the temperature of the gases reduced, and the draught maintained by a fan? The efficiency of heating surface depends upon the differences of temperature between the gases and the water in the boiler. Very little steam is produced from the last foot of length of the tubes now, and an enormous increase of heating surface would be required to make any considerable reduction of funnel temperature. The increase of steam pressure in the last 25 years has increased the temperature of the boiler water 100°, and by so much reduced the effective head of temperature at the heating surfaces, and added to the difficulty of abstracting the heat from the gases. In the system described in the paper the in-coming air, at a temperature initially nearly 300° lower than the boiler water, is substituted for the boiler water, and the heating surface is thereby rendered more efficient, and the temperature of the gases can be therefore greatly reduced, the heat abstracted being utilised. The reasoning is clear enough that there must be a proportionate economy realised wherever the system of heated forced draught is properly applied.

I have sometimes heard remarks made by engineers about forced draught practice with which I could not altogether agree Probably what the speakers meant was right, but the idea conveyed by the words seemed to me to be incorrect. Some engineers with forced draught keep the funnel damper only about one-eighth open, "to take as much of the velocity out of the gases as possible." I cannot understand how that may be; I fancy it is meant to keep the gases a longer time in the boiler spaces acting on the heating surface. The time of action of the gas in seconds is found by dividing the weight of gas in the boiler spaces from front smokebox to firebars by the weight of gas passing per second. The pressure of the gas in the boiler spaces varies only an almost infinitesimal amount by partially closing the damper, and the only means of increasing the weight of gas in the space is therefore the reduction of the temperature. If closing the damper a little causes a marked difference in the abstraction of heat, there must be an explanation for it unknown to me. I think that the explanation of the damper closing is that, in the case referred to, the forced draught was unnecessary, and the closing of the damper merely counteracted the action of the fan. The "retarders" mentioned in the paper, the spirals placed in the tubes, seem to me to have been named improperly. If retarders are necessary the head of pressure producing the draught must be too great. I think that there might be a beneficial effect from the spirals acting as radiators, for a heated gas does not radiate as well as a heated solid body does. In comparing different pressures of forced draught it is important that the total effective pressure should be considered, and not merely the pressure in the ashpit above that in the stokehold. The effective head is the difference between the pressure in the smokebox, say 0·3, and the pressure in the ashpit, say 0·4; or 0·7 inches of water column. The weight of a column of air 70 ft. in height at 77° Fahr., and atmospheric pressure, is the same as that of a column of water of the same section 1 in. in height. If the column of air is heated to 615° its absolute temperature is doubled, and its weight is then equal to that of a column of water only half-an-inch in height. The over-pressure of the external air is then $= \frac{1}{2}$ in. of water column. The best temperature for draught is a little less than this double temperature, and at a higher temperature the volume of the gases increases in a higher ratio than the velocity due to the increased difference of pressures. Efficient natural draught may therefore be taken to be never more than one-sixteenth of an inch of water column for every 10 ft. of height from smokebox to funnel top. It is with this that the forced draught pressures ought to be compared. A year ago a patentee of forced draught laid before me his plans, according to which he proposed to apply = 10 inches of water column, believing that the natural draught was usually not more than 7 in. of water column. He had largely advertised and claimed to have been very successful in effecting economy, and yet that was what he thought, *i.e.*, natural draught was about 7 in. of water column. The paper which has been read to us is not open to any such criticism; it appears to be full of reliable information, and if the increased stokehold temperature could be avoided, I would wish the system great success.

Mr F. W. SHOREY'S REMARKS.

I did not intend to speak upon this subject this evening, as my knowledge of forced draught is very limited, and what little I do know has been obtained from books.

Some of the remarks that fell from Mr M'Farlane Gray's lips have led me to rise and ask a question or two. Mr Gray has said that the heating surfaces in a boiler were the furnaces, the combustion chambers, and the tubes; and that although the tubes had the greatest amount of surface they did not impart the greatest amount of heat to the water. He further said that Mr Wye Williams states that the most heat was derived from the furnaces next the combustion chambers, and least from the tubes.

Now if I understood Mr Williams' paper correctly, I gather from it that Mr Howden had arrived at the same conclusion as Mr Wye Williams; and to prevent the heated gases passing too rapidly through the tubes, he had inserted in them strips of steel twisted into spiral forms so as to somewhat retard the speed of these gases through the tubes, and also to bring them in contact with the whole of the tube surface by causing the gases to follow the retarder, thus causing the tubes to impart more heat.

If such is the object of these retarders or spiral strips, which may doubtless be beneficial, I should like to ask Mr Williams if these retarders would not cause the tubes to become choked, and also how he would manage to keep them clean; as it appears to me they must become quickly choked, owing to the obstruction in the tubes.

Mr SAGE'S REMARKS.

I believe Mr Williams referred to my having some slight knowledge of this subject. The two ships fitted under my superintendence (I am speaking now of tramp ships) were not a success, although both of the ships had boilers built on purpose. They had the usual size of boilers. I had a letter from the chief engineer of one of them saying that the forced draught had not effected any saving. They could steam well with Welsh coal, but they give as good steam with the same quantity of North Country coal. I do not say that it is owing to any fault in the system, because I am inclined to think that Howden's is one of the best systems of forced draught. The ships did not get very far before the fan engines broke down, and the voyage was completed with natural draught, which played havoc with the thin forced draught firebars. These steamers were fitted under Mr Howden's own superintendence, and had one of his own engineers out of the "New York City," who did worse during the voyage he was in charge than the engineer of the other ship who had no sea experience of the system. We had a great deal of trouble with the boilers. Considering the extra expense and cost of repairing, I for one would not venture another vessel to be fitted with forced draught, although I would give Mr Howden's system the credit of being the best I have seen. My experience has been very small, but such as it is you have the benefit of it.

Mr RUTHVEN'S REMARKS.

There is one thing I wish to speak about in connection with the blast generator—that is multiplicity of fans. My father tried this many years ago, and it answered well. It was a system of one fan taking the air from another. He used as many as three fans; the first discharged into the second, and the second into the third. I think this might be tried with advantage with a much reduced speed of engine.

Mr BRUCE'S REMARKS.

I have been desired by an engineer in Glasgow (a namesake of the author of this paper) to bring before you an improved method of applying heated air under pressure for the combustion of fuel. However, I beg to leave this for some other occasion, as time is too short to-night, and explanation would be more interesting when accompanied by the result of actual experience. It may be mentioned, however, that several engineers, expert in this subject, have expressed favourable anticipations for Mr Henry Williams' arrangement.

This paper is of importance inasmuch as it comes from a practical man, and one who understands what it means to work in a stokehole, and I can freely state that so far as the paper has reference to the general working of Howden's method of applying heated air under pressure to furnaces in an open stokehole, what the author has stated is confirmed by my own observations of its operation in some of the steamers he has mentioned.

In regard to the fan engines, and complaints as to the working of these engines, as you all know this is a mere matter of detail. I lately saw a fan and engine at work at Messrs Hawthorn, Leslie & Co.'s, Newcastle-on-Tyne; the engine has three cylinders working compound and coupled direct on to the fan shaft; the engine running 600 revolutions per minute, steady, and quite cool; the whole arrangement taking up very little space, and very light.

The "Rotary" type of engine is being revived, and we may shortly hear some interesting accounts of an improved form of this oldest of all types of steam engine, with reference to its application to fans and dynamos.

In reference to the saving of space and weight by the use of forced draught in ordinary merchant steamships, such as the author has alluded to, I venture to think that he claims too much, for any saving of space or weight by using forced draught can only be effected in the *boiler* compartment. As in the "Ohio," single-ended boilers may take the place of double-ended ones, thus saving the space of one stokehole; and in other steamers one boiler may replace two, or by other arrangements space may be saved. In the case of the "Ohio" the space and weight saved and claimed to be saved by the application of forced draught is not fairly stated. The old compound engines, having cylinders 57 in. and 90 in. diameter by 48 in. stroke, and indicating 2100 horse-power, took up large space, and the boilers were double-ended. When these compound engines and boilers came to be replaced by modern propelling machinery of equal power, her owners determined that they would endeavour to augment the economy of fuel derivable by adopting triple-expansion engines, by applying an approved arrangement of forced draught; therefore the original three double-ended boilers were replaced by three single-ended ones—thus dispensing with *one* stokehole and throwing the space of that stokehole into the cargo-carrying space of the ship.

The owners also determined to further augment the cargo capacity of the ship by using as short an engine as it was possible to get, using three cranks and ample bearing surface. To realise this they decided to adopt what in their opinion was the best form of radial valve-gear recommended by the engine builders, Messrs James Howden & Co., and which appeared to their superintending engineer to have merits possessed by none other. Therefore they refitted the "Ohio" with modern machinery, and gained thereby an increase of cargo-carrying space due to such a length as sixteen feet.

I think it proper that these facts should be clearly stated in order that the credit of these economies should be fairly distributed.

Mr SMITH'S REMARKS.

The paper we have heard to-night from Mr Williams has been a very instructive one. I have had some little experience of forced draught, although never having sailed with it myself, my knowledge has only been gained from the experience of others, added to what I have witnessed of the results. I have watched the system carefully ever since it came out, and have seen no resulting benefit to compensate for the injury done to the boilers.

I know one steamer which has now been running with natural draught for about five years. The engines are triple-expansion, built by Messrs T. Richardson & Son, and fitted with Wyllie's valve-gear, where the consumption has been as low as 1·2 per indicated horse-power, and sometimes under that when burning *Takasima dust coal.* I mention this as an instance of what can be done with *natural draught* in the way of economy.

On the other hand, I know of steamers sailing in the East with *forced draught*, and having been invited on board of several of them by the engineers in order to see the condition of the boilers and the results of the system, in every case I found some injury done to the portions exposed to the action of the flame, either landings cracked, combustion chambers buckled, or furnace crowns fallen down.

One steamer I may refer to specially was almost disabled for three days in the Indian Ocean on account of the furnaces leaking; after being refitted—the forced draught being taken away—no more trouble was experienced.

Mr COUBRO'S REMARKS.

It appears to me that nearly everything that has been said this evening has been against the system Mr Williams is advocating. I don't mean any particular gear, but forced draught in general, and I should like to hear some one speak on the other side of the question. There surely must be some one here who has seen the advantages of it. I am sorry that my experience has been the same as those who have spoken before me. The only ship I can speak about with any absolute knowledge is one which came up the Thames, and one which I got orders to set to work at once and take out the gear so soon as she arrived at the docks. A great deal of trouble was caused by the fan engine, which was a high-speed engine. The brasses were simply reduced to a molten state, and were working out with the oil. I should like to hear some one who has sailed with the forced draught.

Mr HAWTHORN'S REMARKS.

I have had no personal experience of forced draught, but having listened to the remarks of the previous speakers, several of them, I observe, have thought that the giving out of the boilers has in some measure been due to the great heat created by the draught being forced. As to the cleaning of the fires; does not climatic difference affect the furnaces? There is no doubt that this cleaning of fires does to some extent contribute towards the leakage at joints and the buckling of the plates, but to understand the application of forced draught properly we should look into, I think, the theory of combustion a little more:—to maintain an efficient natural draught, 25 per cent. of the heat generated in the furnace is absorbed in giving that velocity to the products of combustion so that they shall ascend the chimney, and in order that we shall thoroughly decompose the coal in the furnace we find in practice that double the theoretical quantity of air is necessary, and in this air supply, oxygen only is wanted, and not only is there 25 per cent. of the heat lost in bringing about natural draught, but the enormous loss of having to heat up practically $3\frac{1}{2}$ times the weight of oxygen as nitrogen from the temperature of the air of the stokehold to that of the furnace. Again I think that economy in burning coal must be looked for from boilermakers, and until we have a furnace that can conduct the heat better through it, and the sooner that we are free from the deposition of scale on the heating surface, the sooner will the economical burning of coal be apparent in marine boilers. Now, if we can burn our coal more consistently with theoretical reasoning, and bring about perfect combustion with a less air supply than at present, and if Howden's system of forced draught does this for us, then I think it is a step in the right direction.

If my memory serves me rightly it was M. Bidard, an eminent French chemist, that proved for every $\frac{1}{16}$ of an inch of scale that was deposited on the furnace crown it necessitated the temperature of the furnace being raised 15 per cent., and it is no doubt this extreme heat, say an increase of 400° on 2500°, that has had more to do with the joints leaking than anything else. Probably some one ere long will bring out an improved patent on Howden's system as Morton has done for the radial valve-gear, and by that means bring forced draught nearer perfection. I hope we may live to see it.

Mr DIMMOCK—Will Mr Williams please give us the number of pounds of water evaporated per pound of coal as deduced from the trials he has mentioned with forced draught?

Mr WILLIAMS—A record was kept of the number of strokes made by Weir's feed-engine during the trial. the result indicated $13\frac{1}{4}$

pounds per pound of coal, assuming the efficiency of the pump to be 100 per cent. I had no opportunity of testing the actual efficiency, but I believe the maker places the efficiency of these very slow working pumps at not less than 90 per cent.

Mr DIMMOCK'S REMARKS.

Under ordinary circumstances with a natural draught, one pound of coal will evaporate about 10 pounds of water in marine boilers, while in locomotive type torpedo boilers seven pounds only would be evaporated; and in these last, if forced, it would be reduced to six pounds of water per pound of coal per hour.

Now, with the best fuel (Warlich's patent) there is a sufficient number of units of heat (16,495) in one pound to evaporate nearly 17 pounds of water. This shows engineers very clearly they are not using anything like the full mechanical power of their coal. In going over a considerable amount of data on locomotive boilers, I find as the pressure of the forced draught increases, the evaporative power of the fuel decreases; this I think shows waste. Mr Williams tells us 15 per cent. coal per indicated horse-power was saved by forced draught. I prefer to give this credit to the feed-water heating apparatus which was fitted, because we know of similar economy in fuel being effected by the use of feed-heaters where there was no forced draught whatever.

I am glad this subject is to be further discussed later on in the session; this will enable us to go more thoroughly into the matter, and find out if possible the value, if any, of forced draught, simply of itself in relation to the marine boiler. It seems to me now that it has been experimentally adopted, because it has done good service in locomotive and torpedo boat practice, and without other adequate reason; but we should remember the conditions of use are entirely different—in the one case space and weight are greater considerations than economy of fuel, and with a reduced fire grate it is absolutely necessary to acquire more rapid combustion although wasteful; in the other case fire-grate area has more scope, and economy in fuel is of the greatest consideration; therefore, what applies to the one will not well apply to the other.

One redeeming feature presents itself in the use of forced draught, viz., that the 25 per cent. of the total heat of the furnaces, which under ordinary circumstances goes to create the funnel draught necessary to supply air to the fires, can be used in heating the feed-water, while the supply of air can be effected more economically by a blast fan or other means.

Mr BRUCE—In reply to Mr Coubro', I was on board the "Ohio" about six months ago. She had been at work about two years—July 1887. I saw the boiler furnace end, top plates, and tubes, and I don't think any engineer would want to see a boiler more free from damage. There is no doubt the whole system was in a very good condition, and I was under the impression the superintendent is satisfied with the system fitted in the "New York City."

Mr COUBRO'—I did not say anything about the furnace or boiler having anything the matter with it; all I spoke of was the bearings of the fan engine that went wrong. I think you mean Mr Smith.

Mr SMITH—I quite agree with Mr Williams so far as to say that there may be a saving with *forced draught* in some steamers on account of peculiarity in construction, but to my mind, as far as I can see, it fails to amount to a large enough percentage to compensate for the trouble and expense to boilers and machinery.

I may mention that in the steamer to which I referred in my previous remarks there was nothing done to the boilers during five years' hard running; a caulking tool had never been used on them from the time of leaving the hands of the builders.

Mr COUBRO'—I think seagoing engineers should advise Mr Howden of any little faults they see, so that the system may be made to work as perfectly as possible. They sail with the gear, and obviously have a better chance of finding out its advantages and also its faults.

CHAIRMAN'S CLOSING REMARKS.

(Mr JAS. ADAMSON).

I have been through the boiler of the "New York City" and examined every corner of it. I found it in an excellent condition after two runs. I examined it again about three or four months ago, and saw the buckled combustion chamber referred to. I think the fault lies in the design of the boiler, and probably the want of an efficient arrangement for cleaning it. The combustion chambers were very difficult to clean. I noted when I saw the boiler at first that doors ought to be fitted in the back of the shells to admit of cleaning the combustion chambers. There was, I observed when I last saw the boiler, a leakage and a few small defects at the Adamson's rings which are fitted in the furnaces. I may say that in the boilers of the "City of Venice," which I have examined, I saw no sign of weakness anywhere. I think Mr Howden is working in the right direction. He will probably add a few improvements, so that, with boilers specially constructed to meet the requirements, and care and attention given to all the details, I do not see why forced draught should not be a success in the future. I think about February or March we may have another paper on this subject. I would impress upon you that Mr Williams is in no way connected with any system of forced draught for marine or land boilers; it is the *principle* of forced draught he desires to bring forward for our consideration, and he gives us the benefit of his experience.

Mr WILLIAM'S REPLY.

Mr Richardson speaks very highly of certain movable firebars, but I cannot appreciate the delicacy he exhibits in witholding their name; I don't think we can know too much of a good thing. So far as my opinion is concerned I will endorse most of what he has said if he means "Henderson's" movable bars, which I think are well suited for natural draught, but for the reasons I have set forth elsewhere are not suitable for any system of forced draught worthy of the name; and as he has not quoted an instance where they have been used with high rates of combustion, I fail to perceive the relevancy of his remarks to the subject under discussion. Instead of saying I had not found boilers in worse condition with forced than with natural draught, I wish to repeat that where Howden's system is fitted and worked intelligently the boilers were in *better* condition than natural draught boilers would be, and I believe time will show that their durability has been extended by the adoption of the system. Mr Richardson's experience of forced draught with the "closed stokehold and other systems" only confirms what I have said about them in my paper.

With regard to Mr Sage, I regret that his experience has been so singularly unfortunate. I have had (as Mr Sage stated) the privilege of seeing the condition of the boilers to which he alludes, but I must have misunderstood him, as I can hardly believe that he is ignorant of the cause of the condition in which I found the boilers when I inspected them in Cardiff, or that he is prepared to lead this meeting to understand that he attributes the leaky joints and other defects he has described to us to the system of forced draught fitted on board?

Mr SAGE—Certainly not.

Mr WILLIAMS—Then I understand you to say that you do not think forced draught had anything to do the with boiler defects you have described?

Mr SAGE—No. Not to the forced draught.

Mr WILLIAMS—Then I think that admission disposes of Mr Sage's objections, and I respectfully submit, Mr Chairman, that he has left me nothing to answer with regard to the effects of forced draught.

The suggestion made by Mr Ruthven to multiply the fans I cannot look upon as a very good one, as in several instances which have come under my notice where such a proceeding was tried the effects were disappointing. When two fans deliver air into opposite ends of one pipe the quantity of air passing from a branch in such a pipe would be found to be very little more than it would be with only one of the fans working at the same number of revolutions. When more fans than one are used provision should be made to prevent communication with each other when they are working.

Mr RUTHVEN—You have misunderstood me. I meant one fan delivering into another so as to get a higher pressure with a lower speed.

Mr WILLIAMS—I beg your pardon. The point you have raised is a novel one to me, and I should like to consider it before expressing an opinion as to its merits.

Coming to Mr Bruce's contention that in my statement of space saved in the "Ohio" I have claimed for forced draught a saving which was due in a great measure to the arrangement and character of the engines, which are fitted with Morton's radial valve-gear. But on referring to my table he will find that I distinguished the saving of space effected in boiler rooms from the general saving, and the 16 per cent. increased power I have given as obtained from these boilers neutralises the claim as to the space saved by boilers supplying steam to triple engines, as the difference in the weight of steam used in compound and triple engines comes to about the same percentage. He also thinks I have underestimated the power of the old engines. If this be the case I have committed a far greater error in the same direction with regard to the new ones, as the difference observable in the ship's speed before and after refitting accounts for at least 25 per cent. increased power. The power I have allowed for the fan engine was deduced from actual experiments, which I carried out to find the power required to drive the fan at different velocities. In the case under consideration it ranges from 6· indicated horse-power with good Welsh coal to $27\frac{1}{2}$ indicated horse-power with American slack coal. I took diagrams from the fan engine at various speeds between these limits, and plotted the results on squared paper, which enabled me to estimate very nearly the indicated horse-power required to drive the fan at any velocity, and air pressure between those actually noted at the time.

Mr Smith has told us a woeful story of cracked tube plates which have come under his notice in ships fitted with forced draught, and he says one of the ships (out in Japan) had Howden's system on board; but I must attribute the defects he has observed to other causes than the forced draught, as it is quite impossible to crack the tube plates of a boiler properly fitted on Howden's system, except under circumstances where they would crack much quicker with natural draught.

With regard to the statement that he has observed triple engines indicating a horse-power on 1·2 lbs. of coal with natural draught, I hope I have shown that if such was the case the consumption would be less than 1 lb. if a properly designed system of forced draught was fitted to the boiler which produced the results he has given us.

Mr Coubro's testimony rather illustrates my remarks about placing fan engines in the stokehold than it bears directly on the question of forced draught. I don't think Mr Howden should receive all the blame for having indulged in this practice.

Mr COUBRO'—I was alluding to another system, not Howden's.

Mr WILLIAMS—I thought all along you were alluding to his system, and as you laid special stress on the wear of the fan engine brasses, I reserved some remarks about fan engines which would apply to what Mr Sage has said about the breakdowns he has had with them also. However, the remarks I am going to make apply to any system, and if the fan engine gives trouble owing to its position on board the ship, I don't think superintendent engineers should throw all the blame on those who placed it there. If the latter were not seagoing men, they were unable properly to realize the disadvantages under which machinery placed in the stokehold must work when the ordinary work of the stokehold is being carried on at the same time. A superintendent who does not exhaust all the means in his power to dissuade his owners from allowing the fan and engine to be placed in the stokehold is more to blame than those who put it there, from the fact of the engine builder not having had the same opportunities of observation. Speaking personally, as one who has suffered under the infliction, I cannot use words too strong to express the utter abomination with which I have always regarded the perpetration of such a mechanical atrocity as the placing of high-speed machinery in stokeholds.

Mr Hawthorn states that 600° is the usual funnel temperature with natural draught, but I have not put it at 700° without reasons for doing so. Long before I had the privilege of using accurate thermometers I used to try the funnel temperatures by introducing pieces of lead and zinc into the base of the funnel as near the centre of it as possible, and I have never been able to carry a piece of zinc without melting as far as Gibraltar at full speed with natural draught; consequently I look upon the 700° given in my paper as a somewhat low estimate, and this receives confirmation from the "Meteor's" trial with natural draught where the temperature of the funnel averaged nearly 800° during the short run from Leith to London. A comparison of the "Meteor's" trial with those carried out on board the "Ohio" will enable us to estimate the value of a properly designed system of forced draught, as the boilers and engines of these steamers are not widely different from each other; the superior results obtained in the "Ohio" cannot be ascribed to excess of heating surface, as the "Meteor" had 40 per cent. more per indicated horse-power than the "Ohio" in the trial I have described at length in my paper. There are many other points of comparison in the two trials which tell strongly in favour of forced draught as applied in the "Ohio."

I was gratified to hear such an authority as Mr M'Farlane Gray attach so much importance to the philanthropic aspect of the question to which I alluded in my paper as the "human factor," an element which ought to be considered. He has also dealt very fully with the contention of those who seek to condense the air in the furnaces by partially closing the funnel damper, but even the small amount of compression he has mentioned, viz., that represented by one inch of water pressure, is very much more than can be practically attained, as the pressure under the damper must not exceed that of the atmosphere in the stokehold, otherwise the flames will come out of the fire-door. I have tried the plan and come to the conclusion that nothing is gained by closing the funnel damper; and after reducing the temperature of the products of combustion as much as possible, we should try to facilitate rather than impede their escape. It would be a mistake to assume that the use of heated air necessarily involves a higher stokehold temperature unless the air is heated beyond the temperature of the boiler. On the contrary the air casing tends to keep the stokehold cool by intercepting and utilising a large proportion of the radiant heat from the front of the boiler shell. If the air casing is carelessly fitted and hot air allowed to pass into the stokehold instead of the furnaces (which I have known it do in ships fitted out of Glasgow), the firemen will find it out and the system gets the blame instead of those who have misapplied it.

The difficulty anticipated by Mr Shorey of cleaning the tubes fitted with spiral retarders is successfully met by using a steam jet with a split nozzle, which passes each side of the steel strip in the tube, and cleans them as easily and quickly as if no retarders were there. I have called these spirals "retarders," as this is the name they are generally known by; but after what Mr M'F. Gray has said, I think perhaps "integrators" would be a more appropriate name for them, as they undoubtedly serve in some measure to integrate the variations in the temperature of the escaping gases, and this probably accounts for the remarkable uniformity observable in the funnel temperature where they are fitted. Contrary to general expectation, they do not tend to choke the tubes with soot, but with high rates of combustion they act most effectively as tube cleaners, owing to the rotative direction given to the gases, thus preventing the deposit taking place until it comes to the smoke-box, whence it requires to be frequently cleaned out. I have seen the "Ohio" after a run across the Atlantic come into Liverpool with tubes almost as clean as they were leaving port. I am aware that the benefits arising from the use of these appliances have not been sufficiently appreciated in some quarters, and that the engineer of a certain mail steamer, who I believe poses as an "improver" or "modifier" of Howden's system, had them taken out (as Mr Sage has done, and now complains of a system he is not working properly) because in the 'thwart ship boilers under his charge they worked back into the combustion chamber with the rolling of the ship! About the same time another engineer who experienced the same difficulty—and here I may say we have an illustration of the readiness and resource shown by different engineers under similar circumstances—he did not condemn the retarders, but got over the trouble by giving them a slight bend before putting them into the tube, and he found the friction induced by this simple means sufficient to retain them in position with the heaviest rolling of the ship. I may also mention that Mr James Laing, of the City Line of steamers, caused tests to be made of the coal consumption on different voyages with and without these retarders or "integrators," and the result completely satisfied him of their economical utility.

One speaker has stated that I claim 12 per cent. by the use of forced draught, but I hope I have shewn it is easy to account for 15 per cent. saving. In the majority of cases this gain has been exceeded, and I can only attribute this excess to the use of heated air. It is true that I cannot conclusively show just now (with figures) how this additional gain is brought about, but a parallel is furnished by the triple-expansion engine. The economic facts in that case were proved before the great importance of restricting the temperature in the cylinders was fully recognised, and in the case of heated air and forced draught I have little doubt that the professors will be found equal to the occasion, and after the facts have been generally established by us, they will find figures to account for the facts.

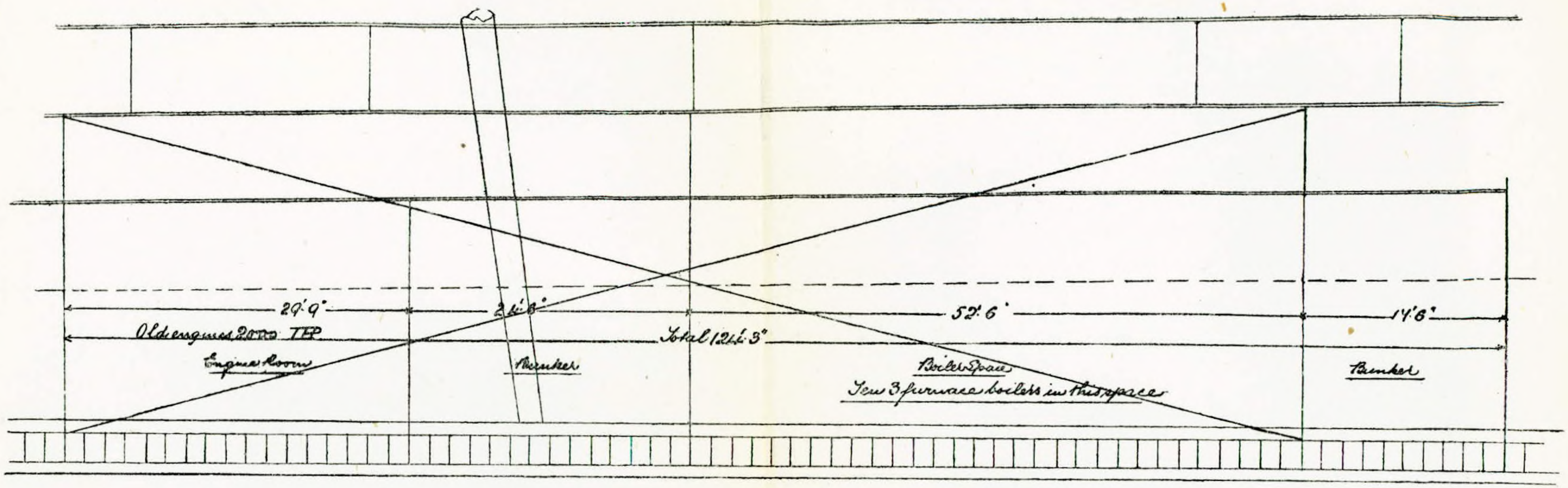
Mr Sage cannot recommend Howden's system for use in "tramp" ships, but I will compare his experience with that of another superintendent over ships of the same class as he has to do with. Two ships, the "Strathblane" and "Strathendrick," have engines by Howden & Co. precisely similar to those spoken of by Mr Sage (I can speak with some authority on this point, as the four sets of engines were erected under my direct supervision from the same drawings). The "Strathblane" was fitted with forced draught exactly similar to Mr Sage's ships; the

" Strathendrick " with larger boilers and natural draught ; both ships are now at work, but the " Strathblane " burns 19 per cent. less coal at same speed than the natural draught ship, consequently the superintendent engineer and owners have arrived at an exactly opposite conclusion to Mr Sage, and have arranged to get their next ship fitted by Mr Howden with forced draught. The Clan Line, after altering six of their steamers, are negotiating for no less than 13 others of their fleet to be fitted with forced draught on the same system.

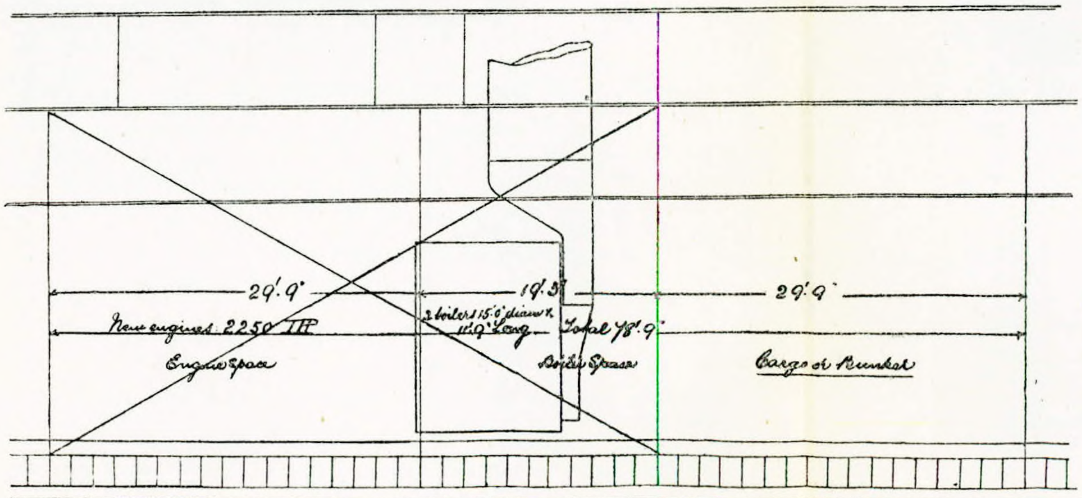
ADDENDA.

Written by Mr Williams after the discussion, and published in "Fairplay" Dec. 13th.

In reviewing the contemporary development of marine engineering, we find the principle embodied in the term "forced draught" receiving from practical engineers the attention which scientists have long pointed out as its due. Most of the attempts hitherto made to induce economy by forced draught have been failures; in some cases due to ignorance of the scientific principles involved, in others due to ignorance of the practical conditions under which these principles must be applied in actual work. Some of the inventors whose efforts have been marked by failure, are now among the most strenuous opponents of any further trial of the system, and seem disposed to regard any degree of success attending the efforts of others as an insult to their own intelligence. As the subject is one of considerable interest to shipowners, I propose to briefly review the question from a purely theoretical standpoint. The loss sustained in producing the draught in marine boilers worked with natural draught at usual rates of combustion, is considered by the most reliable authorities to be not less than one-fourth of the available heat of the fuel when of good quality, and more than this when it is of an inferior description (see "Meteor's" recent trial). We shall not be far wrong if we assume 650° Fah. above that of the external air as representative of the funnel temperature in sea-going ships at full power with moderately dirty boiler tubes. The specific heat of air at $c\,p = 0{\cdot}238$, therefore every pound of it raised 650° and discharged into the funnel carries away $650 \times 0{\cdot}238 = 174{\cdot}7$ B T units of heat, and 24 lbs. (the usual allowance of air per lb. of coal with natural draught) will contain 4192·8 units. Crediting the volatilised carbon and other constituents of the fuel which pass up the chimney in combination with the oxygen obtained from the air with the same "specific heat," we have $4192{\cdot}8 + 174{\cdot}7 = 4367{\cdot}5$ heat units passing away—per lb. of fuel—for which we receive no equivalent in the form of useful work. This loss may be minimised (and generally was so during the recent depression in the shipping trade) by reducing the rate of combustion, and consequently the power obtainable from the boilers. The possible amount of saving by this method of slow combustion was greater when low pressures were carried than can be the case with higher boiler pressures. The reason for this is not far to seek. With safety valves loaded to 160 lbs. the boiler pressure should average about 158 lbs., equivalent to a boiler temperature of 370° Fah. The heating surface of the boiler at this temperature represents the cooling surface exposed to the products of combustion. If we take Professor Dwelshauver Dery's estimate of 164° Fah. as the lowest temperature at which active transmission of heat from the products of combustion to the water in the boiler takes place, we have $370° + 160° = 534°$ Fah. as the lowest temperature at which the escaping gases can leave the boiler with the utmost extension of heating surface, or slowest rate of combustion within reasonable or payable limits. Taking the initial temperature of the external air at 60°, the loss per lb. of air supplied to the fires would be reduced to $(534\text{-}60)\ 0{\cdot}238 = 112{\cdot}8$ heat units, which represents a saving of about 9 per cent. in the coal per unit of power developed at the reduced speed with slower combustion. Now, unless we utilise the heat in the waste gases, no further reduction in the funnel temperature can take place with any system of forced draught, and the only further gain to be looked for will be due to the smaller supply of air per lb. of coal when the draught is mechanically produced; a gain which is generally, though not necessarily, neutralised by the heat units expended to work the fan engine. By utilising the heat passing away in the last example to heat the incoming air, and allowing a similar range of temperature between the air in the heating chamber and the gases surrounding it, as we have between the gas and the boiler water, we see the possibility of reducing the funnel temperature to 164° Fah. above that of the atmosphere; or, in the present case, to $164 + 60 = 224°$, equivalent to a loss of only 39 B T units per lb. of air supplied to the fires. Taking the available heat of the fuel at 15,000 H units, we have a loss of $6\frac{1}{4}$ per cent., as against 29 per cent. with the same supply of air as in the first example, showing a clear gain of over 22 per cent. That the possibility of this saving is not over-estimated has been proved by the close approximations to it in several ships where the arrangements both for driving the fan and heating the air are still susceptible of further improvement.



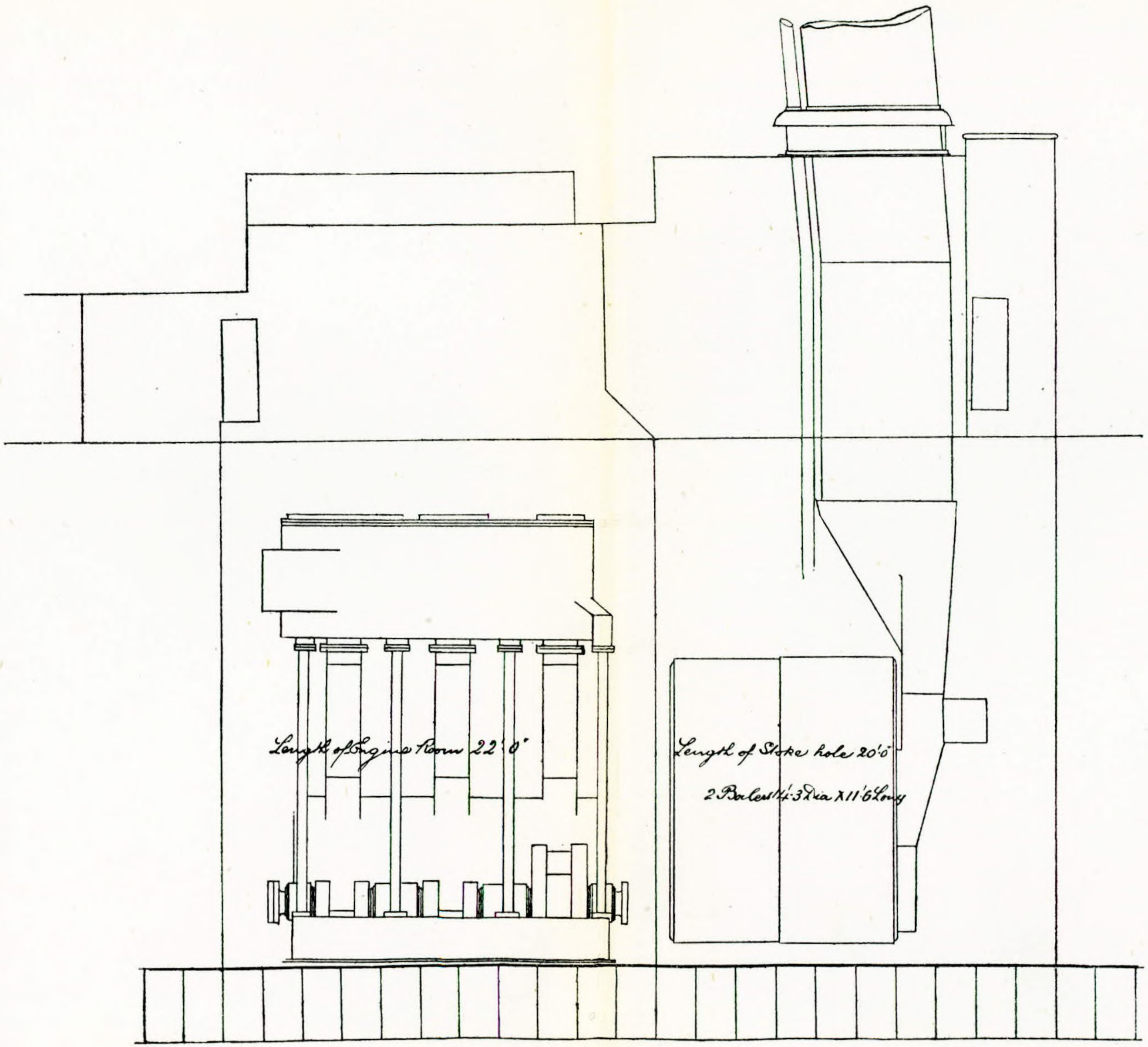
Present Arrangement S.S. "Sarmatian"



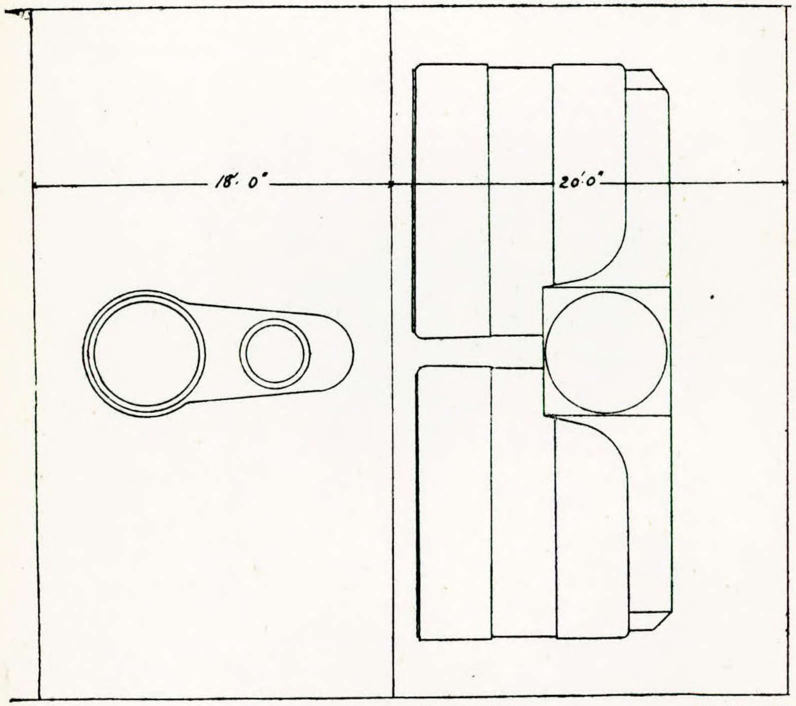
New Arrangement s.s. "Sarmatian."

This steamer will run as far with the coals contained in her bunkers in the engine and boiler spaces with new machinery as she could do with the bunkers and machinery before alterations.

The forward cross bunker in new arrangement is to enable her to run to River Plate and back with coals carried from this country.

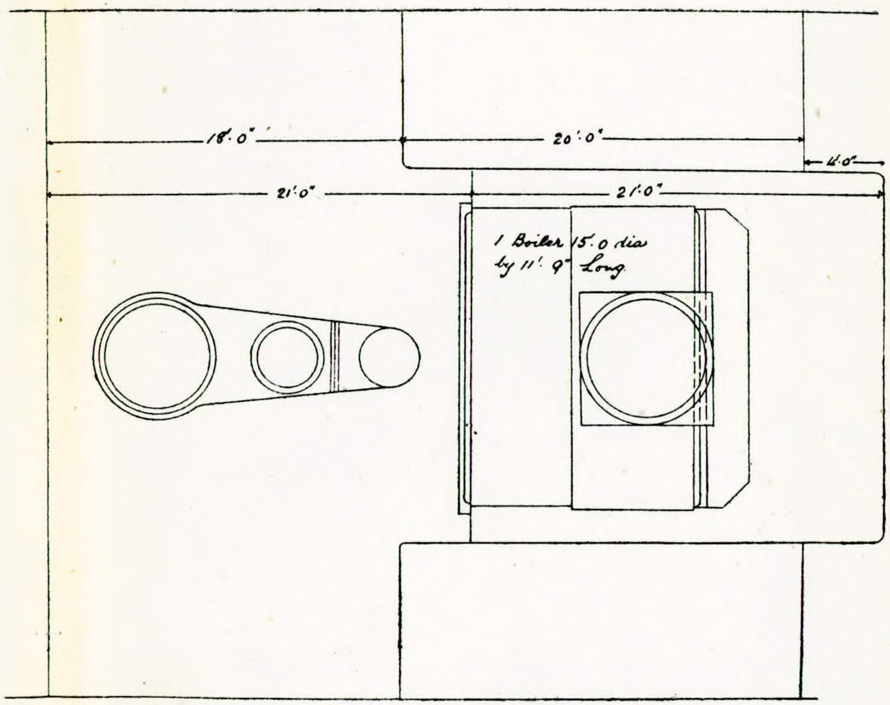


Arrangement of New City Liner.
Scale $\frac{1}{4}$ in.=1 ft
To Indicate 1700 Horse-Power.

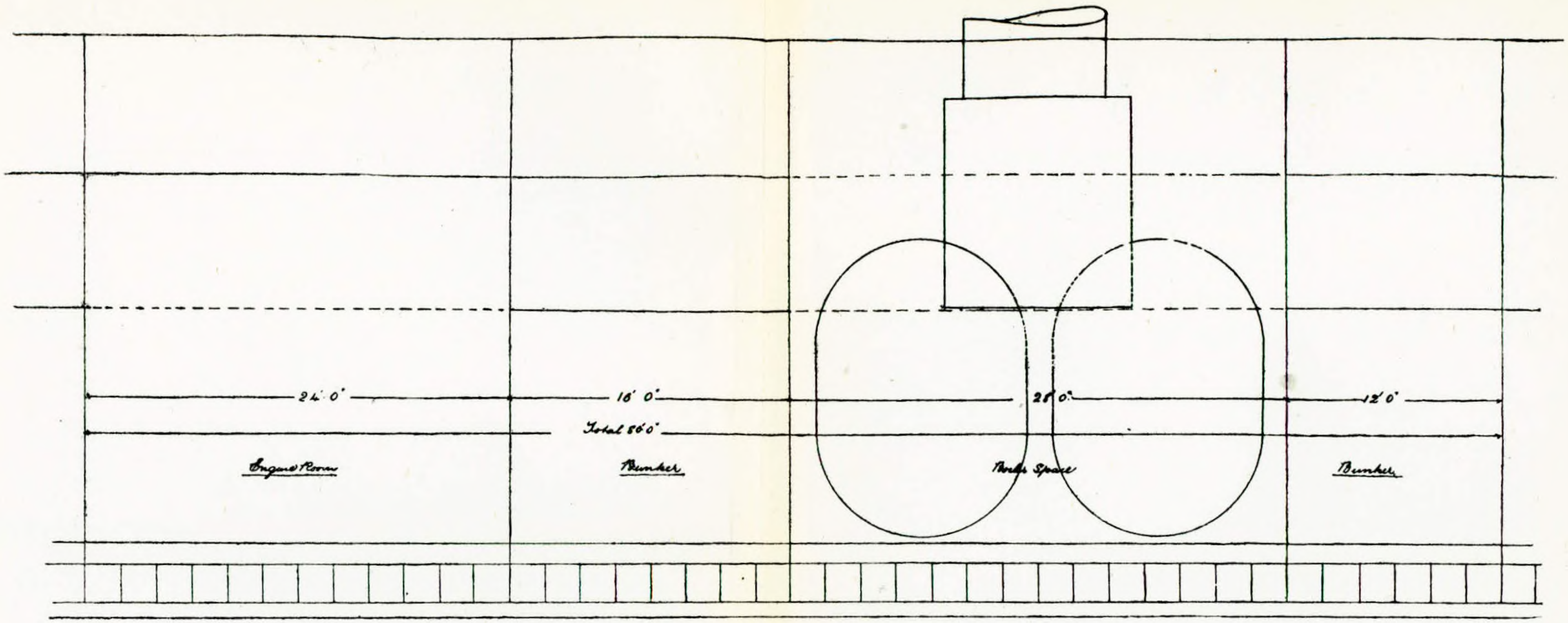


Arrangement of s.s. "Clan Gordon"
Before Alterations.
Scale ¼ in.=1 ft.

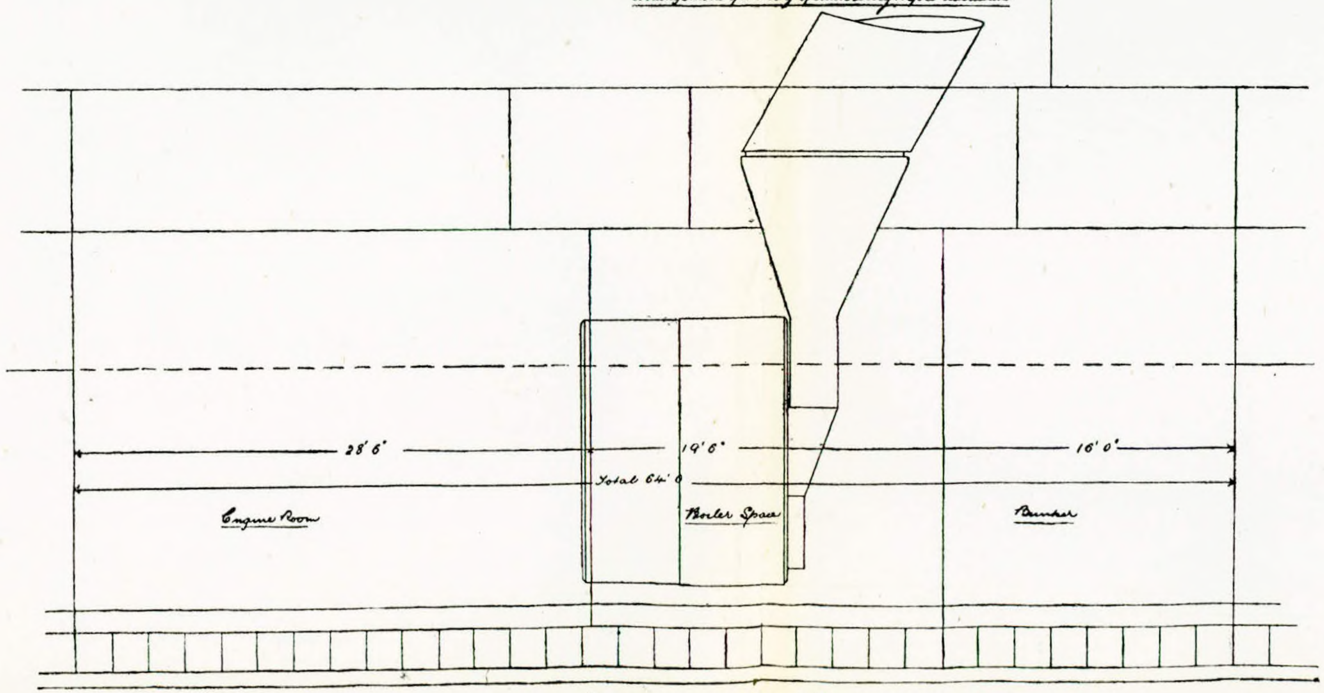
NOTE—6 "Clan Liners" altered like this.



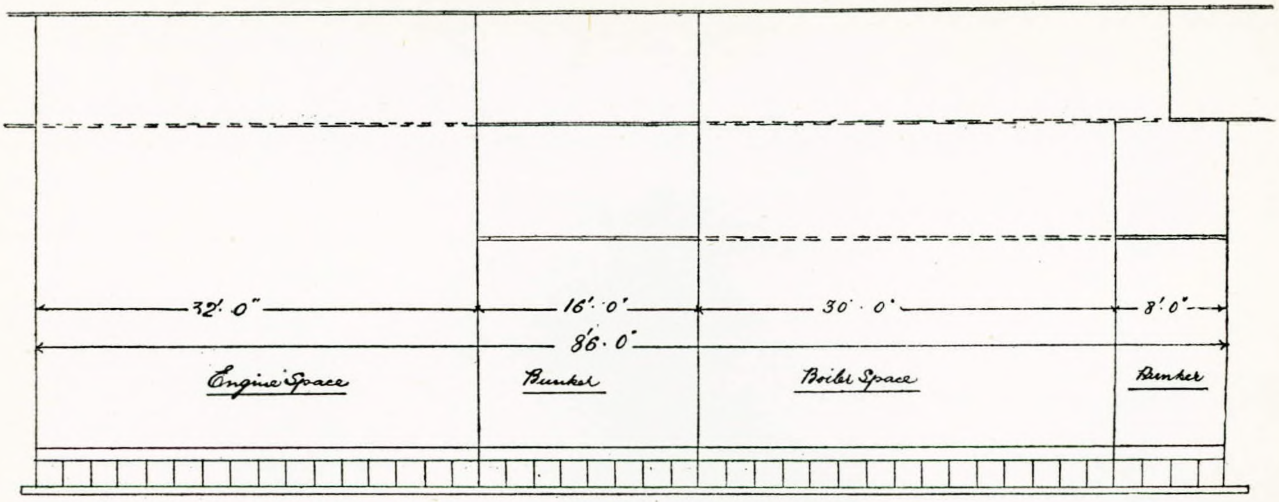
Arrangement of s.s. "Clan Gordon"
After Alterations.
Scale ¼ in.=1 ft.



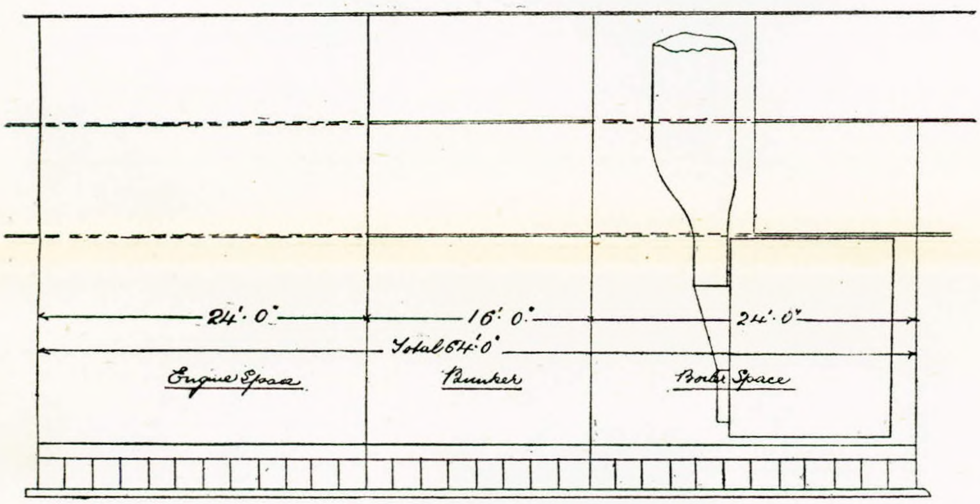
Arrangement of S.S. "City of Canterbury" Before alterations



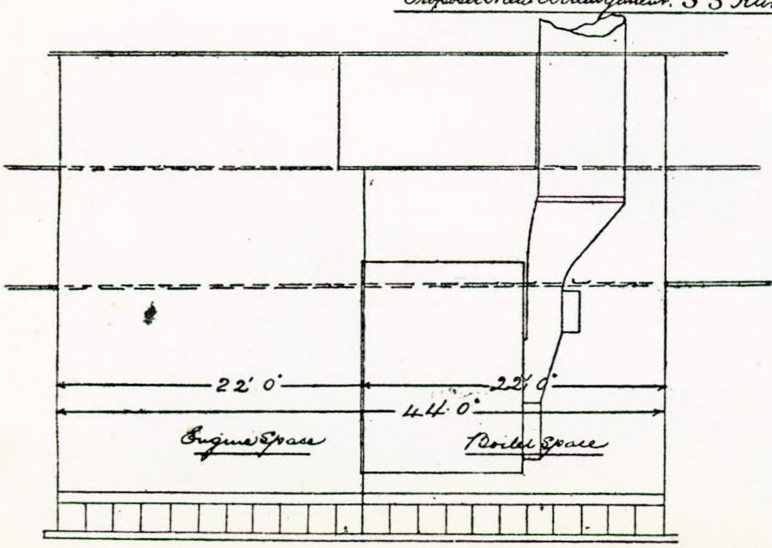
Present Arrangement s.s. "City of Canterbury."



Present Arrangement of S.S. "Illinois" S.S. "Indiana"



Proposed New Arrangement. S.S. "Illinois"



Proposed New Arrangement s.s. "Indiana."

PREFACE.

THE LANGTHORNE ROOMS,

BROADWAY, STRATFORD, E.,

Friday, November 1st, 1889.

The First General Meeting of the Institute of Marine Engineers was held here this evening in accordance with the Regulations. The Meeting was presided over by MR. A. BELDAM, first President of the Institute. The following statement was read by the writer:—

It is with a considerable degree of pleasure that I ask you to look back with me over the past nine months, and trace the footsteps of the Institute of Marine Engineers from the early tottering of childhood to the firm tread of youth. I would also ask you to allow your minds to soar beyond the limits prescribed by time present, gaze fearlessly into the future and behold the Institute in the full force and power of its perennial manhood.

In February of the current year, we may say, the Institute was founded, when the first public meeting was called in order to test the feeling of Engineers on the subject.

The Reading Room was opened about the same time and the table supplied by voluntary contributions.

The Loan Collection—**Malcolm Campbell Memorial**—was then added as a library of useful and pleasant books for the use of Members and has been added to month by month, until now the necessity has arisen for an additional case to contain the volumes.

The collection of objects of interest and specimens is also gradually increasing and many samples and specimens are being held back for want of accommodation.

The seven papers which have been read are now matters of history and the comments of the Press are such that I need not further refer to them, except to express the hope that the papers in preparation may sustain the character earned by their predecessors. I am pleased to note that the attendance at the Reading of papers has been steadily increasing.

The Recreation Committee are now at work arranging for a Social Meeting or Conversazione, to be held in the Town Hall, Stratford, on the 6th December, for members and their personal friends.

The Registration of the Institute was completed in July, when Mr. Neely received the Charter from the Board of Trade and forwarded the same to us.

The names of the Council and Office Bearers are printed in the copies of By-Laws and Articles of Association, which may be inspected by Members in the Reading Room, and in view of the Election to take place at the Annual Meeting in March, members should examine the list with a view to the election of the new Council. Voting Lists and Notices will be posted in due course in terms of the articles in the By-Laws.

The Membership to this date is as under:—

Members	160
Honorary Members	8
Associate Members	9
Associates	9
Graduates	4
Total ..	190

With the addition of several applications which yet remain to be considered, the total will reach 200.

	£	s.	d.
The Receipts up to this date amount to	321	5	0
The Expenditure	201	17	4
	£119	7	8

In connection with this cash statement it may be remarked that there are several Annual Subscriptions due from members who have up to this date only paid their entrance fees, and I may take this opportunity of asking members to bear this in mind.

Mr. NEELY, 25, Old Jewry, who acted as our solicitor in the matter, has our warmest thanks for the manner in which he conducted the negociations and for the personal interest and trouble he took, and in addition for his proferred and courteous offer to act as Honorary Legal Adviser to the INSTITUTE.

It rests with the members, after what has been done by the present Council and Office Bearers, to express their views as to the style in which the business has been conducted, and if they are satisfied that the honour and dignity of the Institute is safe in their hands till the Annual Meeting, to move a vote of confidence accordingly. The Annual Meeting takes place in March, this is merely a formal business meeting, called in accordance with the requirements of law, to give members an opportunity of expressing their satisfaction or otherwise with the Office Bearers and what they have done.

It is highly gratifying to observe that so many of the leading journals and scientific papers are desirous of reporting our proceedings, and have expressed opinions favourable to the INSTITUTE, we would thank the various editors and proprietors for their courtesy and kindly interest, as well as for their good wishes.

It is not many months since—at our third or fourth Council Meeting—when the question arose regarding notices from the Press, I remarked that the time would come when, in place of our seeking to obtain notice from the Press, the Press would seek to obtain notices from us. My remark was prophetic, the time I predicted has come, and the spirit of independence, which animated me to make the remark, has been justified by the event.

It is more in keeping with our life work as engineers to prove what we are, and demand success by results achieved, than to seek by adventitious means to gain that to which we have not proved our title.

In closing I would seek to act the prophet again. We, I speak as the mouthpiece of the present Council, have established the Institute on a good, sound basis; some of us have not spared ourselves in seeking to command that success should crown our efforts, and it remains with every member of every grade to do his utmost to advance the highest interests of the Institute, doing so, I venture to predict a great future for it and through it, the whole trade to which we esteem it an honour to belong.

The CHAIRMAN then commented upon the work which had been done since the 12th February, when the inaugural meeting was held, and asked for an expression of opinion from members present as to the progress which had been made.

Mr. S. C. Sage proposed, and Mr. J. W. Dimmock seconded the motion, that a cordial vote of confidence in the present executive of the Institute should be passed.—This, on being put to the meeting, was carried unanimously.

Mr. Leslie (convener), reported that a committee of ladies is working along with the Recreation Committee in arranging for a conversazione, to be held in the Town Hall, Stratford, on the 6th December. The programme is well in hand and the meeting promises to be a most pleasant one.

The business meeting closed with a vote of thanks to the President.

On the same evening Mr. A. Beldam read a paper on "The Progress and Development of the Marine Engine," which will be found in the following pages, also the remarks made in the course of the discussion, and a lithograph of the Engines referred to by Mr. Wymer. The Chair was occupied by Mr. J. McFarlane Gray.