INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1894-5

President—A. J. DURSTON, Esq., R.N.

Volume VII.

FIFTY-FIFTH PAPER

(OF TRANSACTIONS)

Induced Draught, With Serve Tubes, Retarders, and Heated Air.

BY

Mr. WILLIAM TROWELL

(MEMBER).

READ AT

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD

ON MONDAY, FEBRUARY 11th, 1895.

THE ARTS' SOCIETY GALLERY, SOUTHAMPTON,

ON WEDNESDAY, MARCH 13th, 1895.

DISCUSSION ON TUESDAY, APRIL 2nd, 1895.

PREFACE.

58, Romford Road,

Stratford,

March 11th, 1895.

A Meeting of the Institute of Marine Engineers was held here this evening, when the Paper on "Induced Draught" by Mr. Wm. Trowell (Member), read Monday, February 11th, was further discussed. The Discussion this evening was continued from Monday, February 25th. It is arranged that the Paper shall be read at Southampton and thereafter at Cardiff.

JAS. ADAMSON,

Honorary Secretary.

INSTITUTE OF MARINE ENGINEERS

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President—A. J. DURSTON, Esq., R.N.

INDUCED DRAUGHT, WITH SERVE TUBES, RETARDERS, AND HEATED AIR.

By Mr. William Trowell

(MEMBER).

READ AT 58, ROMFORD ROAD, STRATFORD,
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The attention of those interested in the progress of marine engineering is at the present time taken up by that most important subject, the economical running of steamships, and that this should be so we can understand to be the natural outcome of keen competition, diluted, perhaps, with a little bad trade.

As no body in the engineering profession can have more interest in such a subject than the members of this institution, the writer has decided to bring forward this paper, in the hope that, from the discussion which will probably ensue, our opinions as to the quarter wherein we may hope to look for economy may be more clearly defined.

Being of the opinion that a system of induced draught when fitted with serve tubes and retarders in the ordinary marine multitubular boiler, is a step in the right direction, the writer has for some considerable time noted the results obtained, and now has the intention of briefly laying them before you to-night.

For the information of those to whom the system is not thoroughly known, there is shown, by the aid of the outline drawing before us, the principle and construction of this installation.

The boilers worked under this draught are up to the present time, of the ordinary marine Scotch type, being, however, considerably less in size and weight per I.H.P. than natural draught boilers of similar development.

The escaping gases, as shown on the drawing by the *feathered arrows*, instead of going direct to the funnel after passing the heat-absorbing surfaces of the boiler, as in natural draught, or being forced over the heat-absorbing surfaces and through to the funnel, as in forced draught, are drawn by the aid of fans through and over the heat-absorbing surfaces of the boiler itself, and when they reach the smoke-box, instead of going to waste by being discharged or passing on to the funnel, they are drawn round a series of horizontal air-heating tubes, thereby imparting more of their heat, reaching the fan inlet, and being discharged into the funnel at an exceptionally low temperature. By this process of drawing the escaping gases round these air-heating tubes, all the heat practically possible, is extracted from the otherwise waste gases, and the heat so extracted is given back to the boilers to aid their steam-raising power

As before stated, the *feathered arrows* represent the path of the escaping gases on their way to the funnel; the *balled arrows* representing the path or direction of the bulk of heated air necessary for combustion. The description need hardly be prolonged or this source of economy further pointed out, for it will be plain to everyone that since every unit of heat given out to the boiler, either to the heat-absorbing surfaces in water contact, or to the air supply necessary, is a direct gain. Here we have our air supply raised from an ordinary temperature of the atmosphere—say 80° Fahr. on entering the ashpit or fires—by the system of heating on its passage to the furnace to an average temperature of 280° Fahr.; and this temperature is imparted to the air by the waste gases, which, in an ordinary case, would be lost heat.

This particular feature becomes more marked when the two systems of draught, natural and induced are compared. With natural draught and moderate coal, we know from sea practice that a funnel temperature of fully 800° Fahr. will be needed, making the temperature of the gases on leaving the smoke-box a trifle more, this funnel temperature being of course necessary to form the draught. Then taking the temperature of furnace to be 2,500° Fahr, we have a loss at once of 32%. In contra-distinction to this, we have at the fan inlet, or, in other words, at the funnel, a temperature of escaping gases of 350° Fahr.—an average taken from several steamers—as the temperature when waste begins. Thus the gain might be set down at 800°—350 = 450°, giving us a strong argument in favour of combustion under the induced draught system.

It may, however, be pointed out, that we must deduct from this gain the loss of power due to steam supplied to the fan engines. In sea practice, however, this is very small; the fan engines being triple compound and exhausting to condenser, and in a ship under the writer's notice was merely 1 % of the steam supplied to main engines.

Objections have been raised to employing fans for such a duty on the assumption that their size would need to be great for the increased volume of the products of combustion, also that they are liable to be choked with soot. It might, however, be taken into consideration that in the first place the increase in volume is not great, and would be, using absolute temperatures, about 1 : 1·56, taking temperature at fan inlet as 350° Fahr. or 811° absolute.

In regard to the choking of the fans with soot, this has not taken place, and the objection may be put on one side as disproved by practice, if not by the fact that no deposit will occur at the temperature in the fan; and again, the combustion being excellent, the soot formed is trifling.

We might leave this part of the subject for the present and take the serve tube and retarder into consideration, and the part they play in the economical supply of steam under this system; although these need no description, being so well known, it may be remarked there seems to be a great deal of indecision amongst marine engineers with regard to their efficiency or evaporative power.

For several months a controversy has been waged in *Engineering* as to the qualification of serve and plain tubes. The makers of the former claim for their tube twice the heat absorbing surface of a plain tube of the same outside diameter, while others advocate the use of small plain tubes to acquire the requisite area.

A few months ago Mr. Blechynden, of Barrow, experimented with a serve and plain tube, to ascertain their evaporative efficiency by comparison, and found that when a plain tube gave out 4,500 thermal units, a serve tube of the same diameter gave out 6,000 thermal units, thus clearly demonstrating in a simple and effective manner the superiority of the serve tube.

With reference to the *combination* of serve tube and retarder, it seems to be the acme of efficient heating surface; for the retarder or spiral gives a rotary motion to the gases as they pass through the tube, thereby throwing them, if the term may be used, against the ribs of the tube, and extracting as much heat as it is possible to obtain, consonant with the rate of passage of the gases through the tubes, and when mechanical draught is used the heat absorbing surface of the tube will retain its efficiency from the fact that no deposit of soot will take place, and coke particles will be swept through the tube by the scouring action of the draught. The serve tube may also be used with natural draught, but in such a case it is advisable to dispense with the retarder At the present time there are several ships known to the writer, on which, with marked advantage, the serve tube has replaced the plain tube, such advantage being summed up thus:—while running with plain tubes and 60 feet funnel height, their average consumption on sea voyages was 1·6 lbs. of coal per I.H P., after having the boilers fitted with serve tubes of the same outside diameter as the plain tubes, the consumption averaged 1·35 lbs. of coal per I.H.P. on long runs. Such results as the foregoing carry conviction with them and need no comment.

Returning to the induced draught combination, and referring to the diagram, we see the direction of the escaping gases drawn by the fans, and on their passage how the heat is given out to the air passing through what is commonly called the air heating tubes, and how the air passing down the air casing enters the fires.

The inlet to the fires or the manner in which the distribution of air is carried out leaves nothing to be desired, as by the manipulation of the valves (shown on the drawing marked D) we are afforded the opportunity of regulating the air supply under and over the fires, in strict accordance with what is needed for the class and quality of coal being used.

An objection might be raised that the manipulation of these valves if left in the hands of firemen—for we know in our cargo steamers an engineer stationed in the stokehold is out of the question—may lead to bad results, but practice has clearly demonstrated that these valves may be set at the beginning of a voyage in accordance with what will be judged as sufficient opening; thus for a North-country or American coal, of a very smoky nature, the three valves would be fully opened over the fires, while the valves leading to the ashpits would be closed, all air under the bars being sucked cold from the stokehold through a series of small holes in the closed ashpit door.

A few notes taken from a trial of this system in regard to an analysis of the funnel gases may be interesting, showing as it does a good combination of the fuel used, and a moderate air supply, as follows:—

CO_2	(carbonic acid)	8·6	volumes.
O	(oxygen)	10·5	,,
CO	(carbonic oxide)	0·0	,,
N	(nitrogen)	80·9	,,

while the analysis of the coal used may be taken as:—

Carbon	·7968 lbs.
Hydrogen	·0494 ,,
Nitrogen	·0141 ,,
Sulphur	·0101 ,,
Oxygen	·1028 ,,
Ash	·0265 ,,

In the above analysis note might be taken of the absence of carbonic oxide (CO), which is generally accepted as a proof of good combustion, other items being consistent.

From the foregoing the air supplied is approxi- mately 22·5 lbs. of air per lb. of fuel, this being fair y good practical working.

We are here naturally led to a consideration of the efficiency of the boiler, which is an important item to be considered when comparing the results of different systems.

Using the formula,

$$14500 \left\{ C + 2{\cdot}7\left(H - \frac{O}{8}\right) \right\};$$

where C represents carbon, H hydrogen, and O oxygen, we obtain the equivalent carbon value or thermal units in the coal. Then from the analysis of the coal used we obtain

$$14500 \left\{ {\cdot}7968 + 2{\cdot}7 \left({\cdot}0494 - \frac{{\cdot}1028}{8} \right) \right\}$$

working out to 12986·49 thermal units; and on the assumption that the specific heat of the products of combustion is ·238, the temperature of furnace is $\frac{12986{\cdot}49}{23{\cdot}5 \times {\cdot}238} = 2322°$, the 23·5 in the formula being the total weight of the products.

From a previous part of the paper we can take the statement that the temperature of the escaping gases at the fan inlet was 350°, and as the gases until they arrive at the fan are in contact with what can be truly called the heat-absorbing surface of the boiler, we have data to obtain the boiler efficiency.

When E represents efficiency, T_1 temperature of waste products, and T_2 temperature of furnace, we find that $E = \frac{T_2 - T_1}{T_2 + 461°}$;

$$E = \frac{2322° - 350°}{2322° + 461°} = 71\%$$

efficiency of the boiler. This is undeniably a first-class result, especially at such a high rate of combustion, and speaks, in the writer's opinion, volumes for an induced draught and air-heating system similar to that laid before you to-night.

Mr. Howden claims for his system of forced draught the same results, and better in some cases than that obtained with the induced draught combination. There is no intention in this paper to draw comparisons between the two systems, but there are two important points of difference that need some consideration.

The manner of heating the air used for forced draught under Howden's system is by a series of short vertical tubes; clearly, these cannot be so efficient as the series of horizontal air-heating tubes used with induced draught; for in the latter case the length of contact between the tubes and escaping gases, and the manner in which they are drawn or baffled round the tubes, gives the horizontal tube the advantage of performing the functions of an efficient heat-absorber much better than with short vertical tubes.

The second point of difference which needs to be referred to, is a matter on which at first sight there may be a diversity of opinion—*i.e.*, that the *inertia* of the gases will always be greater with forced draught.

To exemplify the writer's meaning; in forced draught, as the gases go over the bridge, they, by reason of their inertia and the force behind them, continue on their path until after impinging on the back plate of combustion chamber, they are turned and have to force their way through the tubes as the only means of outlet, *and if the draught is of any great intensity, harm to the boilers may ensue.*

With induced draught, however, the tendency of the gases passing over the bridge is to turn towards the tubes, this tendency in a certain degree counterbalancing their inertia, and so preventing impingement on the back and tube plate, and that this is so will be readily granted, when we consider that the vacuum over the fire is ·8 inches and at the fan inlet 4 inches of water; this giving us a less pressure at the tube mouths than in combustion chamber, thereby attracting the gases to such a degree that, as before remarked, their inertia or line of motion is partly overcome, and the more intense the draught becomes the less tendency there is for abrupt changes in the line of motion of the gases, so that induced draught may be considered as natural draught intensified.

We might with profit consider this system from another point of view, *i.e.*, as to weight of installation, size of boilers, space occupied, etc.

It will readily be acknowledged that the outcome of induced draught, the intensity of which may be measured by the vacuum at the fan inlet, which averages, taking the practice of several steamers, three inches of water, is that the amount of coal consumed per square foot of fire-grate is considerably increased, and averages from 60 lbs. per square foot in land service, down, as yet, to about 30 lbs. at sea. We can deduce from these facts that boilers under such a system of draught may be much smaller, how much this decrease may be the following will afford an example. Two ships have come under the writer's notice of the same dimensions and horse power of engines, namely, 2,500 I.H.P. One had *four* single-ended boilers, 15 feet diameter by 10 feet long, running with natural draught. The other had *two* boilers, 15 ft. 6 in. diameter by 10 ft. long, and fitted up for induced draught, showing a decrease in size of nearly 50 per cent.; and no doubt in the near future, when the consumption per square foot of fire-grate is raised in sea practice to what it has already reached on land, viz.: 60 lbs. of coal, still smaller boilers will be used with perfect safety, and this with an absence of what was thought most to be feared, *i.e.*, priming.

As to decrease in weight: In a ship recently built the weight of the boilers and the draught installation, including water and funnel, was $228\frac{1}{2}$ tons, whereas if fitted for natural draught the weight would have been $373\frac{1}{2}$ tons. Clearly a pronounced gain. Or we might ascertain the gain per I.H.P. of this system.

The horse-power developed was 3,000, giving us $\frac{3000}{228 \cdot 5} = 13 \cdot 12$ horse power per ton of boiler. This power was obtained with ease from the boilers and with a consumption of Welsh coal slightly below 1·3 lbs. per I.H.P. per hour, including the power necessary to drive the fans.

It would only be fair, when considering this system, to take into consideration that under it the economy derived means less bunker coal per voyage, therefore, the gain (if a cargo steamer) may be put down to equal the decrease in the weight of the boilers plus the decrease in bunker coal from what would be needed with a natural draught and plain tubes. Our best sea practice is we know with natural draught about 1·5 lbs. of coal per I.H.P. on sea voyages. On the other hand, in cases reported of ships in the Australian trade, some of which go out by the Cape, the average consumption per I.H.P. has been 1·35 lbs of Newcastle small coal, and less than 1·3 lbs. per I.H.P. when using Welsh.

Taking all these facts into consideration with the good results obtained, and likewise that induced draught under this system is in its infancy, we can hope that, when more experience and practice has been obtained by the inventors, and also by those who may have charge of it on board ship, the consumption will gradually be brought down still further; and there is no reason why the consumption could not be in the near future about 1 lb. of good coal per I.H.P. This latter statement being based on the fact that, while at present an excess of air per lb. of coal is used, a judicious manipulation of the air supply and improvements in this direction may bring it to, say, 18 lbs. of air per lb. of coal, and a boiler efficiency of 75 to 80 °/$_{\circ}$, which would certainly be a very satisfactory result.

That this system would be most suitable for our navy the writer feels assured, because by the absence of smoke, non-necessity of funnel, and the large variation of power in boilers ranging as before remarked from 30 to 60 lbs. per square foot of fire-grate, with the fact that no matter how hard boilers are pressed under induced draught—and it will be allowed that 60 lbs. per square foot coal consumption is high for a marine boiler—they remain as safe as if they were under natural draught at ½ inch of air pressure.

The writer has several tables of results in his possession, but thought it better not to include them in this paper, as the matter that has been laid before you this evening partakes more of the character of an essay or criticism on the the induced draught system, than a report of experiment and results obtained on sea voyages.

A general summary of the previous matter may prove an appropriate ending to this paper, and it might be said that the benefits derived already from using an induced draught installation, such as the one laid before you, as against natural draught and plain tubes are:—

Half the number of boilers.

Half the floor space.

Considerably less dead weight in boilers and fuel.

Absence of priming due to steadiness of evaporation.

No danger through back flame.

A clean and cool stokehold.

Boilers possessing the desired quality of variable power, so that a heavy demand for steam or full speed driving can be met with ease.

Cleanliness of serve tube, due to scouring action of the draught and absence of smoke, consequent efficiency of heating surface on long voyages, and considerable economy in fuel.

DISCUSSION

ON

"INDUCED DRAUGHT,"

HELD AT

58, ROMFORD ROAD, STRATFORD, E.

MONDAY, FEBRUARY 11th, 1895.

CHAIRMAN:

MR. J. H. THOMSON *(Chairman of Council).*

THE CHAIRMAN: It is to our advantage that we have with us to-night the author of this paper, and as he has come a considerable distance to be present and read it himself, and explain what may not be considered clear in his arguments, we are all the more indebted to him. I now invite your remarks.

Mr. J. G. HAWTHORN (Member): The author has put the funnel temperature with natural draught at 800°; this is rather high—from 600° to 650° is nearer the practice. With regard to the temperature of the escaping gases, the author says that there is a saving with induced draught of 450°. Now, 450° of heat means something, and I should like to know what is done with it?

Mr. J. JOHNSTON (Member): I should like to ask Mr. Trowell if he can give any instances where forced draught has caused injury to the combustion chamber or furnace plates. I have had experience with forced draught, and never had any trouble such as has been indicated.

Mr. F. W. WYMER (Vice-President): It is an old saying that there is nothing new under the sun. In 1845 or 1846 I was at Liverpool, and there saw induced draught on board an American auxiliary steamer.

It is a strange circumstance that while nearly fifty years ago the Americans were using induced draught, we should now be speaking of induced draught as a new thing. I remember the incident to which I have referred very vividly, and the American steamer on which this induced draught was fitted was either the *Massachusetts* or the *Marmora*. In comparing forced draught with induced draught Mr. Trowell has given figures as to the coal consumption per i.h.p. under the two systems, but before we can judge of the merits of that comparison we require to know more particulars of the engines and what they were doing. Within the last six months I have been in communication with a gentleman who is much engaged with induced draught. This gentleman brought a piece of *scoria*, and said, "That is the effect of induced draught on the ends of tubes." A round washer had actually formed at the back end of the tube, and this occurred in an induced draught boiler within the last six months. From what I saw it is only a question of an Indian voyage for these small tubes to become choked with *scoria* altogether. With regard to the other system, there appears to be forced draught and forced draught. I have seen some mail boats fitted with forced draught, and in one case the experience was rather serious, but whether from carelessness or neglect I am unable to say. There seems also to be a great deal in the application of the system, but forced draught certainly necessitates the best workmanship that can be obtained. One of the speakers has rather implied that as marine engineers they were not inclined to go in for new things, and having regard to the responsibilities that already devolve upon sea-going engineers, I am not surprised that this is so. All honor to those who are still persevering and showing what can be done, but they must not forget the poor engineer who has to manipulate all these things on board ship. It is no sinecure to go on board a large passenger steamer and take charge of all the machinery.

Mr. H. C. Wilson (Member): Referring to Mr. Wymer's remarks as to induced draught having been employed on an American steamer nearly fifty years ago, I should like to ask if it is not a fact that the first locomotive which ever moved on a pair of wheels had forced draught? If you require illustrations of induced draught, what better illustration could be given than the locomotives of to-day?

Mr. Gross (Visitor): There are three steamers trading to this port whose boilers are worked with induced draught, and at least one of the boilers on each ship is never less than ninety days under continuous pressure. And yet these boilers live. The vessels I refer to are the *Perthshire*, the *Buteshire*, and the *Banffshire*—the big meat carriers from New Zealand. They have made a number of voyages, but as yet there has been no failure on either of the three ships; and there have been no failures because the system was thoroughly worked out on land before it was used at sea. The proprietors of the system have now had four years' experience of its working, and as the result of that experience they have said unhesitatingly, "the harder you suck the more uniformly you heat your boilers, and the less the gases come into contact with the tube plates." Induced draught is only natural draught on a much larger scale. The *scoria* to which Mr. Wymer has referred is probably what is known as coke rings, which are common to both forced draught and induced draught with certain kinds of coal. In answer to an enquiry made by one of the gentlemen present, the *Majestic* and the *Teutonic* are now being fitted with Serve tubes; and replying to Mr. Hawthorn, the mechanical stoker has not yet been applied in connection with induced draught.

Mr. R. Bruce (Member): I do not wish to criticise the paper, at any, rate for the present; however, I should like to endorse all that has been said as to the amount of coal that might be burned per square foot of grate surface without the slightest damage to the boiler. The consumption of coal is merely a question of the air supply. With regard to what has been stated by Mr. Trowell as to accidents with forced draught, I have simply to say that under no circumstances, in a properly designed and properly worked furnace could any amount of heat do the slightest damage if there is water behind the plates and the plates are clean.

MR. TROWELL'S REPLY.

Mr. Hawthorn, in his criticism of my paper, has, I understand, asked me the following questions:—

What is the evaporation per lb. of fuel under a system of induced draught, with Serve tubes, retarders, and heated air?

Would the heat-absorbing surfaces of the boiler transmit the heat at a sufficiently rapid rate when the consumption per square foot of grate increased towards 60 lbs.?

If the difference between the funnel temperatures of natural and induced draught is 450°, in what way was the 450° accounted for if the incoming heated air only rises in temperature 200°?

Mr. Hawthorn also held that it would have been more convenient if the mathematical formulæ employed in the paper could have been placed before the members for consideration.

That the statement in regard to the vacuum at the fan inlet being 4 inches of water seems rather startling.

In answer, I might say I cannot give Mr. Hawthorn a definite answer as to the exact amount of water evaporated per lb. of fuel—a difficult matter to experiment on to obtain an exact result when we are considering sea practice; but from my statement that 1·35 lbs. of coal is required per i.h.p., we can approximate our evaporation per lb. of fuel, though in any case the consumption of fuel per i.h.p. is quite sufficient to show us the efficiency of the system.

I consider that the heat-absorbing surfaces of the boiler can transmit with ease the heat evolved from the rapid combustion of 60 lbs. per square foot of grate, and when we consider that in the case of locomotives they burn 120 lbs. per square foot, we can consider ourselves well within the bounds of safety.

In regard to this question, I may state that on account of the beneficial action of the serve tube and retarder with suction draught the temperature of the smoke box is less than 600°, and the residue of the difference in temperature is taken up in heating the air supply.

In regard to the formulæ used, it is so well known to everyone, and the working is so simple, that a correct result is really unavoidable, though I agree with Mr. Hawthorn that it would have been better in every respect had the paper been printed beforehand.

When I made the statement that the vacuum at the fan inlet was 4 inches of water I was rather under than over the mark, as in land service burning up to 60 lbs. per square foot the vacuum at the fan inlet was nearly 6 inches of water.

In reply to Mr. Wymer, I can only endorse what has just been said by Mr. Gross, and although I have not seen the formation of *scoria* round the tube ends which Mr. Wymer speaks of, I have heard that it forms with a certain class of coal; but even so, it is quite harmless. As to the horse-power developed on the ships spoken of in my paper, the trial trip power was 3,000, and ordinary running on sea voyages 2,750.

In reference to the remarks made by Mr. Bruce, I may say I do not, when speaking of forced draught, specially refer to any system. I believe Mr. Howden's to be one of the best systems of forced draught in existence. Still, I consider induced draught infinitely better. Mr. Bruce has taken exception to my statement that with induced draught the gases or products make for the centre of the tube, and in reference to that statement he asks, if this is so the escaping gases do not come in contact with the heat-absorbing surfaces of the tube. Surely, Mr. Bruce does not think I mean what he has just said. Certainly, the escaping gases have a tendency to enter the tube mouths, but they must fill the tube area as they pass through, under any circumstances.

Now, as to the impinging on the back plate when under forced draught. I still maintain that such action is detrimental; a blow pipe action, such as forced draught really is, cannot be efficient, or leave no effect on such surfaces as the combustion chambers, which are at right angles to the line of direction of the gases, as they come over the bridge.

I thank you very much for the manner in which you have received my paper to-night; also for your vote of thanks, kindly proposed by Mr. Ruthven, and so heartily endorsed. I may say this is the first time I have had the opportunity of visiting the rooms of the Institute, and certainly they reflect great credit on the members. For myself I am an engineer belonging to Newcastle-on-Tyne, and I think that some endeavour should be made to form a branch of the Institution there.

ADJOURNED DISCUSSION

ON

"INDUCED DRAUGHT,"

AT 58, ROMFORD ROAD, STRATFORD,

On MONDAY, FEBRUARY 25th, 1895.

CHAIRMAN:—MR. J. R. RUTHVEN

(MEMBER OF COUNCIL).

MR. TROWELL: With your permission, I should like to make a few remarks in reference to my paper and the discussion which followed it at our last meeting, with the hope that the position taken up by me may be more clearly laid before you.

For several years I have been of the opinion that some system of mechanical draught would become absolutely necessary in marine practice, and in consequence I have noted, more or less, the different systems of draught as they were brought forward, the result being, the paper I have brought before you.

What, however, I should like to point out is, that I disclaim having made any direct attack on the systems of forced draught now in use. I simply stated as my opinion that if mechanical draught were used, an induced system seemed the best principle to work on, for the reason that, as the intensity of suction draught increased, it departed further and further from the forcing or blowpipe action of any kind of forced draught.

Let me here state that I neither had, nor have, any intention of making any direct accusation against Mr. Howden's system of forced draught, any more than what I read from my paper, and to which I refer you.

In comparing the action of the products of combustion in the two systems I said, "And if the draught be of any great intensity, harm to boilers may ensue," meaning, that with high rates of combustion, say from 30 lbs. upwards, forced draught becomes a dangerous factor, while suction draught is as safe as with natural draught, and a minimum consumption per square foot of grate.

Mr. Hawthorn, in his opening remarks at our last meeting, asked for information in regard to the amount of evaporation per lb. of fuel. To supply this information was beyond my power, as all my notes and experience had been derived from marine practice, where special arrangements to ascertain the exact amount of evaporation are conspicuous by their absence. I, however, pointed out that I had considered the data given with reference to the amount of coal consumed per I.H.P. would, perhaps, be sufficient for our purpose, which was really to ascertain the safest and most economical system of draught to use on marine boilers of the ordinary Scotch type.

Since our last meeting, through the kindness of Mr. Gross, I have had the opportunity of being present at a short trial on a marine boiler, with serve tubes, retarders, and heated air (working under usual conditions), to test its evaporatine efficiency per lb. of coal. Briefly the result was:—Boiler, 10 ft. 6 in. diameter and 10 ft. 6in. long; furnaces (two), 2 ft. 10 in. diameter; and grate 5 ft. 8 in. long; grate area to heating surface 1:28; Coal (Yorkshire) burned, per square foot of grate, 45 lbs.; vacuum at fan inlet, 4 in. of water; vacuum over fires, 1 in. of water; vacuum in ashpit, $\frac{7}{8}$ in. of water; temperature at smoke box, 630° Fah.; temperature at fan inlet, 430° Fah.; temperature of incoming air, 260° Fah.; temperature of feed water, 36° Fah.; evaporation from temperature of feed, 8·42 lbs.; evaporation from and at 212°, 10·22 lbs.; boiler pressure, 50 lbs. per square inch; temperature of atmosphere at inlet to air heating tubes, 43° Fah.

Now, when we consider such a result, burning, as just stated, 45 lbs. of coal per square foot of firegrate, using a Yorkshire coal, the theoretical heating power of which is only 13,400 T.U., and consequent theoretical evaporation from and at 212° is 13·8 lbs. of water, the result is obviously a good one. I might add, during the trial, smoke was entirely absent, and I could find no signs of priming in the boiler, while the steam gauge varied never so slightly.

Since that part of my paper in which I compare the action of forced and induced draught in the combustion chamber has given rise to diverse opinions, perhaps the following will make matters more clear:

To find the kinetic energy or impinging force of the gases as they pass over the bridge: Assuming a 3 ft. furnace, 6 ft. grate, burning 45 lbs. per square ft., and using 23 lbs. of air per lb. of coal. The coal consumed per hour = 3 ft. by 6ft. by 45 = 810 lbs., air consumed per hour 18680 lbs., products of combustion 19440. Taking sectional area of bridge to be 2 square ft., vol. of 1 lb., air at 32° = 12·4 c. ft., *vol. of 1 lb. air at 2000° = $\frac{12{\cdot}4 \times (2000 + 461)}{493} = 62$ c. ft. The cubic feet passing over bridge in one second $= \frac{19440 \text{ lbs.} \times 62 \text{ c. ft.}}{60 \times 60} = 335$ c. ft. Then velocity of gases in feet per second $= \frac{335 \text{ c. ft.}}{2 \text{ sq. ft.}}$ = 167 ft. per inch. And weight passed over per second $= \frac{335 \text{ c. ft.}}{62 \text{ c. ft.}} = 5{\cdot}4$ lbs. Kinetic energy $= \frac{W \times V^2}{2g} = \frac{5{\cdot}4 \times 167^2}{64} = 2360$ ft. lbs. We can deduce from this fact, that with forced draught the kinetic energy in the products of combustion or what has been previously pointed out, the impinging or blow pipe action on the plate, increases as the square of the coal consumed per square foot, and as an example, if burning 30 lbs. with

* Taking temperature of gases passing over bridge to be 2000° Fah., and treating use of gaseous products as air only.

forced draught, and we wish to rise to 60 lbs., then, K.E. of gases at 30 lbs. : K.E. gases at 60 lbs. : : $30^2 : 60^2$ that is, it rises 4 : 1.

Mr. BRUCE (Member): I, as a member of the Institute, interested in this subject, could not help being struck by the very general manner in which the author has dealt with the subject. There was an entire absence of detail in the paper. There is no information given by which members could arrive at any definite judgment as to the comparative value of the combination which Mr. Trowell advocates. The value of the paper would be greatly increased if we could be told, for instance, the total heating surface of the boilers referred to, measured on the serve tubes, the total heating surface in the air heater, the quantity of air passed through the heater per minute, with the increase of temperature, the grate surface, the number and sizes of the fans, the pressure of steam carried, the indicated horse-power on trial and the average at sea, with the average daily revolutions of the engines, their dimensions, and particulars of steam pressure carried. Without this information it is impossible to arrive at any opinion as to the economy or first cost of the system. The author spoke of the economy of fuel, and 1·3 lb. per I.H.P. is no doubt a very good economy taken by itself, but until we know the heating surface we cannot get at the efficiency of the boiler. The author also made a point of the fan power absorbed in working suction draught; but if he had stated that the power required is probably five times more than would be required with forced draught he would have been much nearer a correct estimate. The estimated boiler efficiency given in the paper is of no value because it neglects the important detail of heat utilised per unit of total heating surface, which surface, in this case, might be not far short of 10,000 square feet—rather an excessive amount for, say, 1,700 I.H.P. in daily work. The value of a boiler can best be established on the basis of water evaporated per square foot of heating surface. From the advantages claimed in the paper for induced draught, it would appear that the author intended members to believe that there is some special interposition of Providence dealing with the fire gases where suction draught is employed. Locomotive engineers, who depend on induced draught, doubtless wish, most devoutly, that it could be so, but alas for the impartiality of Dame Nature, locomotive tube plates crack, their tubes leak, and their troubles are just as great as those of the marine engineer, who, working boilers under natural draught, occasionally experiences a hard time, when one or other of the inexorable laws of nature is defied. There is evidence of a most irreproachable description that boilers might be worked under Mr. Howden's system at the highest rates of combustion, and their longevity, as compared with natural draught boilers, be increased rather than diminished. Mr. Trowell has spoken about the inertia of the gases, but this is a matter that really has nothing to do with the point before us. Under ordinary conditions of working there is practically no pressure in a combustion chamber. Both with reference to coal consumption per I.H.P. and in weight per ton per I.H.P. the figures given by Mr. Trowell do not show so high an economy as has been obtained in steamers working with serve tubes and Mr. Howden's system of forced draught combined; nor do they show such an economical working as is obtained in steamers working with plain tubes and retarders in boilers fitted with Mr. Howden's system of forced draught. That this should be so may be inferred from the author's statement as to the "scouring" action of suction draught, for this scouring action is fatal to its economy. High rates of combustion per square foot of fire grate are solely dependent upon the control of the air supply, and quite independent of the means employed to bring the air to the fuel. What is important is that the cost of producing the required air supply should be a minimum, and this cannot be so if the whole of the gaseous products of combustion are to pass through the fan, at the volume due to the temperature of discharge. When the fan has only to produce the air of combustion at a temperature of 60°, it is obviously the most economical method. Mr. Trowell has said the air heating arrangements in induced draught are more effective than those employed by Mr. Howden, and as the author has not given the least clue to reasons which would establish such an assertion, members must be taken back to references published elsewhere for a refutation of this statement. In the air-heating arrangement shown on the drawing illustrating Mr. Trowell's paper, there may be as much air-heating surface in the air-heater as 4,000 square feet, and a portion, the greater portion, no doubt, of the air supply is heated to 180° above the atmospheric temperature. In the first steamer fitted with Mr. Howden's system of forced draught, now eleven years ago, there were 1,597 square feet of heating surface in the boiler, and 225 square feet of air-heating surface in the air-heater, but the whole of the air for combustion was heated to 180° above atmospheric temperature. These facts will doubtless enable Mr. Trowell to readjust his statement on this point.

Mr. SCARTH (Associate Member): Being specially interested in the life of the boiler, I should like some information as to the longevity of boilers when either induced draught or forced draught is used. We were told at the last meeting that under no circumstances, in a properly-designed and properly-worked furnace, could any amount of heat do the slightest damage if there was water behind the plates and the plates were clean. But in practice we very seldom find the plates of the boiler perfectly clean.

Mr. BRETT (Associate Member): In applying this system of induced draught is it necessary to provide a separate fan and engine for each boiler, and is the system equally applicable and effective for water-tube boilers? What provision has been made for the escape of the smoke in the event of the fan or engine breaking down? It would appear that by employing induced draught, the length of the funnel could be reduced to a minimum, which would be a decided advantage, especially on ships of war, where the present large smoke stacks form a gigantic target for the enemy.

Mr. A. CAMPBELL (Member): I feel that I am scarcely warranted in making any remarks, or in criticising this paper, as I was unfortunately unable to be present to hear it read, and I have only now had a look at the proof. My feeling at present, is, that this plan of increasing draught is exerted at the wrong end. It is well known that by blowing a fire the water in a vessel is more rapidly boiled, and I feel sure that forced draught is preferable to this system, both as to simplicity and economy. As regards forced draught with heated air, I have not the slightest fear of damage to either tube ends, combustion chambers, or furnaces, provided the boilers are kept scrupulously clean.

Mr. GROSS (Visitor): Experience shows that the power required to drive the fans in induced draught average $1\frac{1}{2}$ per cent. of the horse power indicated by the main engines. One of the speakers has asked if it is necessary to have a separate fan for each boiler. It is preferable if the boiler is a large one, but it is not absolutely necessary. This discussion has, somehow, become a question of Mr. Howden's system of forced draught against induced draught, but that is certainly not the intention of Mr. Trowell in reading the paper. The point has been rather overlooked, that while in the one case all the arguments have been on the basis of experience with combustion up to 30 lbs. of coal per square foot of grate, the special object of suction draught is to go very appreciably beyond that limit, and the more we get beyond that point will we find the difference between forced draught and induced draught. It is a pity that Mr. Howden's system has been so conspicuously put forward. I acknowledge that Mr. Howden's is the best of the forced draught systems, but my contention is, that when we get appreciably beyond a consumption of 30 lbs. per square foot of grate induced draught gives by far the best results.

MR. W. TROWELL'S REPLY:

Mr. Bruce's criticism has been of rather a lengthy nature, necessitating on my part an equally lengthy reply. Without, however, taking up too much of your time, I shall endeavour to explain some of the points in dispute.

To begin with, I have been accused of want of detail in my paper, not giving the proportion of heating to grate surface, evaporation per square foot, etc. I think, if you refer to my paper, you will see that to enter into all the small details of different systems would have made the paper of undue length. Nevertheless, I consider that when I gave the sizes of the boilers under the different conditions, the horse-power developed, the consumption per I.H.P. and the I.H.P. per ton of boiler, that sufficient data was supplied for a fair comparison between the three systems of draught under consideration, *i.e.*, "natural," "forced," and "induced."

That my statement in regard to the volume of the products of combustion passing through the fans being to the volume of air supplied (at, say, 80° Fah.) as 1 : 1·56 is correct, may be easily proved, and I wonder what foundation Mr. Bruce can have for the statement he made, which was, that the comparison of the volume of air supply and the volume of the escaping gases passing off at 350° Fah. is 1 : 6? I should consider a very elementary knowledge of thermo dynamics would show the fallacy of such an opinion. Take, for instance, a supply of air per lb. of coal as 23 lbs., then assuming all the coal is turned to gases, the weight of the products would be 24 lbs. Now for the formulæ.

* $v : V :: t^\circ : T^\circ$ will give us the increase in volume of the products (assuming them to have a specific gravity similar to air) for the increase in absolute temperatures, which, in this case, is from 541° absolute to 811° absolute, the $v : V :: 1 : 1{\cdot}56$.

* t° and T° absolute temperatures.

And if we take the volume of the products of combustion as calculated from an analysis of the funnel gases—given in my paper—then the waste gases are to the volume of air supply as 1 : 1·5.

I am afraid that Mr. Bruce's statement that the volumes are as 1 : 6 is founded on the assumption that the escaping gases are at the temperature of combustion chamber—about 2,000°; otherwise, I cannot see how such an elementary point can be disputed.

That forced draught and serve tubes give good results is well known, but I might here repeat, that I am speaking of mechanical draught in the light of burning at a high rate, say from 30 to 60 or even 90 lbs. per square foot of grate, and at these high rates, I do not consider forced draught in any way as safe as suction draught.

Mr. Bruce's view, in referring to the boiler efficiency, has been rather unfortunate for himself. He has taken my simple calculation of the efficiency of the heat units in the coal as the evaporative efficiency, which, of course, is absurd, as it is plain the 71 per cent. of efficiency means that 71 per cent. of the equivalent carbon value of the coal has been utilised.

That no impinging or blowpipe action occurs with forced draught I deny, and may refer Mr. Bruce for my reasons, to the opening remarks made this evening, and the calculation showing the impinging force.

With reference to the remarks on locomotive boilers, I may say I am not willing to discuss them, as being apart from the subject, wherein we are dealing with the "Marine Scotch" type and mechanical draughts.

As to the scouring action of the gases through the serve tube being detrimental to the tube, such a statement does not require an answer, it being quite plain that the scouring action must add to the efficiency of the tube, by keeping the heat-absorbing surface clear of deposit. I have seen tubes after a fifty days' run perfectly free from deposit of any kind.

In answer to Mr. Johnston I may say that induced draught under this system is still in its infancy. However, a few days ago I saw a boiler which had been at work for four years burning up to 60 lbs. per square foot of firegrate, and after a careful examination it seemed to me as good as ever.

Mr. Johnston's remark anent the S.S. *Berlin* Mr. Gross has kindly answered for me.

In reply to Mr. Brett, there is no absolute necessity for separate fans to each boiler, but I should say for sea practice it is advisable.

Induced draught would be suitable, with certain modifications, to water-tube boilers.

In case of a break-down of fan or fan engines, by simply closing one damper and opening another the boilers can be worked under natural draught. In regard to any extra attention to fan engines, they are of the enclosed type, and need only to have the oil chamber kept to its normal level. From engineers' reports, the fans never in any case give them trouble.

A funnel could be entirely dispensed with, and the waste products discharged over the side or stern, but I should still say a funnel is advisable, thus allowing a return to natural draught if required.

Mr. Campbell asserts that working under induced draught is starting from the wrong end. I do not consider it so, nor will Mr. Campbell, if I put it to him in the following light: There would be no objection against working a boiler, say with a chimney height of 200 feet; now suction draught is simply an artificial funnel height, the supposed height of funnel corresponding with the vacuum formed at the fan inlet.

In answer to Mr. Wilson, I may call his attention to the small doors at the bottom of the smoke box (shown on the drawing), which can be opened periodically and the coke particles removed.

In reply to Mr. Smith's natural inquiry as to prevention of a rush of cold air into a furnace when cleaning the fire, a damper can be fitted in the uptake which shuts off that particular furnace while the fire is being cleaned.

Before concluding my remarks I might again refer to the scouring action of the draught through the tubes. It must not be supposed that the escaping gases, having an undue velocity, do not part with their heat. The serve tube and retarder prevent this; and as an example of the remarkable efficiency of the serve tube and retarder, in a recently built steamer, when burning 30 lbs. per square foot with $3\frac{1}{4}$ inch serve tubes and retarders, when the temperature of the combustion chamber was 2,300°, the temperature of the smoke box was 546°.

ADJOURNED DISCUSSION

ON

"INDUCED DRAUGHT,"

HELD AT

58, ROMFORD ROAD, STRATFORD,

On MONDAY, MARCH 11th, 1895.

CHAIRMAN:

MR. F. W. SHOREY *(Member of Council).*

The CHAIRMAN: In opening the proceedings I would briefly call attention to some of the points dealt with in the paper. I certainly do not share the author's very strong feeling in favour of Serve tubes. The introduction of retarders makes the ordinary straight tubes much more effective, and I would very much rather be shipmates with a boiler fitted on this plan than with Serve tubes.

Mr. H. C. Wilson (Member): I am not in a position to offer any very practical contribution to this discussion, because I have not had actual experience at sea with other than natural draught, but I certainly think that this system of draught, called induced draught, is a step in the right direction, because engineers have now produced such engines that they are practically waiting on the boilermakers to provide them with the necessary pressure to give the full economy. The only way in which this difficulty could be solved appears to be in the direction of increasing the rate of combustion, which naturally points to some system of forced draught, by which I mean some system other than natural draught. Great stress is laid by the author on the effect of what he calls the blow-pipe action of forced draught on the back plates of the combustion chamber. But really I do not see that there is anything in this point, and do not think that the combustion chamber would suffer very much from the effect of the impingement of the hot gases on the back plates. I do not believe that under any system of forced draught this so called blow-pipe action would have the destructive effect which Mr. Trowell describes. I was once sailing with a fireman who proved exceptionally successful in maintaining steam, and I discovered that this man, when he went on watch, placed a fire brick in a certain position on the bridge so as to divert the gases, the brick being removed when he went off duty. The idea of retarders, which consist of spiral pieces of iron put into the tubes so as to check the too rapid passage of the gases, is in itself very good; but on one occasion I went on board a ship that had recently been fitted with retarders to see how they worked, and the chief engineer of that vessel was very emphatic in his condemnation of them. In a very short time the retarders in that vessel were done away with altogether, and the chief engineer found the steam-producing qualities of his boilers practically unaltered. That ship has in consequence been running without retarders ever since.

Mr. J. T. SMITH (Member): I fully agree with much that has been said by Mr. Wilson as to the effect of the impingement of the gases on the back plates. The gases have a certain velocity in the furnace under both forced and induced draught, and I cannot see how they impinge more on the back plates with forced draught than with induced draught. Indeed I think they would strike the back plates with greater force with induced draught than with forced draught, because with induced draught there is a partial vacuum in the combustion chamber. I believe it is one of the conditions of efficient heating surfaces that there should be a time given for the transmission of heat, and it appears to me that induced draught rushes the gases away out of the combustion chamber. With forced draught a longer time seems to be given for the transmission of heat; there is a pressure in the combustion chamber, and there is a great chance of the heat being transmitted.

Mr. J. R. RUTHVEN (Member): The size of the fans employed for drawing out the heated air in induced draught seem very large, and the fans used for supplying the cold air in forced draught appear to be not much more than half the size. This is a considerable item in favour of forced draught, for we have been told in the course of the discussion that 0·4 per cent. of the power indicated by the main engines is sufficient to drive the fans in Howden's system of forced draught, while the representatives of the induced draught combination do not claim to be able to work with less than $1\frac{1}{2}$ per cent. I understand that after ten years' experience all the indications go to show that boilers worked with forced draught last practically as long as those worked with natural draught.

The CHAIRMAN: As marine engineers it matters not to us whether the system employed is induced draught, forced draught, or natural draught. What we want to get hold of is the best method of getting the most heat out of the coal—the most perfect combustion. In the early days of this Institute, when forced draught first came out, we had a discussion on the subject at the Langthorne Rooms, and there was present on that occasion a gentleman who had something to do with the steamer *New York City*, and complained rather loudly about forced draught, which he said was injuring the combustion chambers of the boilers through the gases impinging on the back plates, and he told us then that he had to build up some fire bricks so that the flames attacked the bricks instead of the back plates of the combustion chamber. (A MEMBER: The boilers of the *New York City* are still working under forced draught.) In the course of his paper Mr. Trowell said that the manner of heating the air used for forced draught under Howden's system was by a series of short vertical tubes, and that these could not be so efficient as the series of horizontal air-heating tubes used with induced draught. It seems to me that if the vertical tubes are an objectionable feature in Howden's system it is an objection that might easily be overcome, inasmuch as Mr. Howden could introduce horizontal tubes. But we have been told during this discussion that vertical tubes are far better than horizontal because of the dirt and soot which accumulates in them when they are horizontal, so that instead of this being an objectionable feature in Howden's system it would appear to be an advantage. The steamer *Perthshire* is fitted with induced draught, and the chief engineer of the vessel says he likes the system very much. He also says that the stokehold keeps very cool. The chief engineer told me further that the consumption of coal was only 1.23 lb. per I.H.P., which is about the lowest figure that I have ever heard of. Mr. Ruthven has spoken of the cost of the fans, but in these days of competition we want to make fast passages, and the object is to obtain that which will ensure the most perfect combustion of coal, regardless of cost. I am not in favour of one system more than another, but any step that can be taken towards the more perfect combustion of coal is a step in the right direction for engineers. The British Government is very conservative in matters of this kind, and will not adopt a new system until it has been thoroughly considered, and, as is well known, forced draught is used in most of the vessels of the Royal Navy.

Mr. BRUCE: Referring to the fatal accident on board the *Barracouta* which was cited at last meeting as an illustration of the dangers of forced draught, the system in use on board the *Barracouta* at the time was not Mr. Howden's. It was the ordinary type of Admiralty closed stokeholes. After the accident there was an investigation by a committee of experts, and they came to the conclusion that the casualty was primarily due to the shortness of water. A question has been asked as to what would happen in the event of a break-down. To my knowledge there has never been a single break-down with Howden's system of forced draught during 11 years' working. But if the forced draught should fail you can revert to natural draught, open up the ash pits, and proceed as in a natural draught boiler. As to the power required to drive the fans in Howden's system, 0.4 per cent. of the power indicated by the main engines is found to be sufficient. There is absolutely no limit to the rate of combustion with forced draught. It is purely a question of the air supply.

Mr. BRETT: Would not the fans be an obstruction?

MR. TROWELL'S REPLY.

I reply to the Chairman's remarks in regard to the efficiency of the serve tube. I cannot agree with his opinion that a plain tube with a retarder is much more effective than a serve tube. The retarder, as its name implies, certainly decreases the velocity of the gases through the tubes, but does not offer any greater heating surface; whereas the serve tube, to be brief, offers double the heat absorbing surface of a plain tube of similar ouiside diameter, the ribs penetrate into the centre of the column of gases passing through the tube, which ribs, unlike the retarder, are part of the tube itself, and so conduct their heat to the water.

As to the system of heating the air, and the comparison of vertical and horizontal air heating tubes; the air passes through the tubes, in the system of suction draught under discussion, and the escaping gases are drawn round the outside of the tubes, they are longer in contact with the tubes than the short vertical tubes could allow of, and as to soot, with suction draught and proper attention, none is formed, while any coke particles that may enter the air heating boxes can easily be removed at periodic intervals.

Mr. H. C. Wilson's opinion expressed in his opening remarks, is mine exactly, if mechanical draught is to be used, induced system ts the right direction.

In Mr. Wilson's reference, however, to my statements regarding the blow pipe action of forced draught, if he carefully studies the action of flame under a forcing or blowing action, it will be noticed that the tip of the flame differs both in colour and temperature from the rest, in fact this tip is at an oxidising heat. Now the striking of the tips of such flame against the heating surfaces must cause an intense *local* heat; that under its ordinary conditions the plate is unable to stand without injurious effect.

Probably the ship Mr. Wilson refers to, where the retarders were no use, had an insufficient funnel height, which would account for the result stated.

I should not consider the deviation of the flame caused by the placing of a firebrick on the furnace bridge would at all tend to economy through such a cause. Rather, the placing of such an obstruction, lessened the area over the bridge to its most economical size.

In reply to Mr. Smith and his reference to the action of the gases as they pass over the bridge, might I again point out that the behaviour between the two systems of forced and induced draught, are entirely different. With induced draught the vacuum at the tube mouths is greater than the vacuum registered as the gases pass over the bridge; now we must admit that gases will make for the point of least pressure, or towards the origin of the generating force, which is the *tube mouths*, or, to trace it further on, the fan at the base of the funnel; so that the tendency is to turn as they pass over the bridge in a curve more or less pronounced according to the ratio of the area over bridge to area through tubes, and to pass into the tubes without the *flame* ever coming into contact with any of the heating surfaces; though at the same time no loss is experienced by such action. the heat in the gases is simply distributed throughout the boiler instead of being entirely local.

Now, under a forced draught action, it is entirely a question from the first instant that the air under pressure enters the fires, of the products of combustion having to force their way through to the funnel; if this is so, there can be no tendency to turn towards the tube mouths, they must, and are forced there as the only means of outlet. But before this occurs the line of direction of the gases must have been changed from their line of motion over the bridge to one diametically opposite, which they must tnke to pass through the tubes. Thus the change in direction must have been due to the impact of the gases against the back of combustion chamber, their elasticity causing them to rebound, thus striking against the tube plate and entering the tubes.

With reference to Mr. Smith's statement of time being allowed for transmission of heat, one can readily understand that, if under a suction draught system, we can have a temperature of smoke box under 600°, and burn 35 lbs. per square foot of fire grate, nothing has been lost through the gases passing along the heating surfaces with too great a velocity.

I might conclude by saying it has been a great pleasure to me to read this paper before such an appreciative audience, and the discussion which has followed will, I hope, prove beneficial to all of us.

ILLUSTRATION OF ELLIS & EAVES SYSTEM OF INDUCED DRAUGHT WITH SERVE TUBES & RETARDERS