DISCUSSION

MONDAY, NOVEMBER 14th, 1898.

CHAIRMAN:
ALDERMAN G. W. KIDD (VICE-PRESIDENT).

THE CHAIRMAN: The paper that Mr. Halliday has read to-night is one deeply interesting to engineers, and if there are any young men present with latent talent in them this is the place and this is the occasion to bring it out. If anyone present has anything to say on the subject, you may depend upon it his remarks will be welcome even if it is only to ask a question or offer a suggestion, and by anything he may say on the subject he will not only be doing himself good, but he will also be helping the debate which is for the good of the members generally. I will now call upon Mr. Halliday to describe some views which will be placed on the screen to illustrate some of the types of feed-heaters.

Mr. HALLIDAY then described some views of a number of feed-heaters and other apparatus shown upon the screen.

Mr. J. G. HAWTHORN (Member of Council): The evening is now so far advanced that it is quite impossible to go into the numerous questions which are raised in this paper, and which really deserve our most careful thought. It is a very valuable paper beyond doubt, and contains a collection of facts and data which certainly cannot be gone through in two or three minutes. It is necessary that we should read this paper through five or six times and pick out the particular facts or points that may strike us, and then think over what we should say about them. It seems

to me that, to a certain extent, we are only beginning to grapple with the economy of the feed-heater; and my belief is that the day is not far off when we shall convert our condenser into a feed-heater. When I say that, I mean that we shall ignore the vacuum altogether in the engine-room. In a triple expansion engine, using, say, steam of 180 lb. pressure, it is necessary, in order to get a free exhaust from the low-pressure cylinder, that the steam shall not exhaust at a lower terminal pressure than from 7 lb. to 10 lb. absolute, at, say a temperature of 190° Fahrenheit, and after rejecting the steam at that temperature, then we cool it down to a temperature of, say, 120° Fahrenheit, to get what? Well, about 24 or 25 in. of vacuum, and this vacuum contributing perhaps from 8 to 10 per cent. of the power of the engine, considered collectively. Having obtained this vacuum and consequent temperature of feed-water of 120°, we then pump it up into a feed-heater, and in most cases heat it up to the same temperature as the steam is now rejected at. Now, would it not be better and more economical to exhaust direct from the last cylinder at a pressure of about the atmosphere temperature—212° Fahrenheit—and then, taking out of it a little more than its latent heat, leave the water at about 190° Fahrenheit to 200° Fahrenheit? This could be brought about by putting the condenser higher up in the engine-room, so as to get a good fall of water to the feed pump. That the vacuum was an important item when the pressures ranged from 30 or 40 lb. to 60 lb. is beyond question; but very different conditions prevail with the high pressures of to-day.

Mr. Hawthorn then described an experience that had come under his notice of a broken air pump and an impaired vacuum. The pump bucket, being packed too tightly, had allowed the pump rod to go up without the bucket, and on the return stroke it broke up the bucket valves, bucket and foot valves; the air pump chamber had a fall of from 12 to 14 in. from the bottom of the condenser. The engineers, having

nothing to repair with, blocked up the overflow from the hot well, made sure that the air pump discharge was air-tight, and easing back the feed escape from the feed pump, then removing all broken parts, the engine was started. As soon as the feed began to be discharged from the feed escape it was shut down, and the vessel proceeded to her first port and several others, the result being no vacuum for most of the time, at others from 8 to 10 in., and the ship fell off, on an average, one knot per hour, the engines making an average of from three to four revolutions less. In his opinion, therefore, their thoughts should be directed to considering or inquiring whether the feed-heater should not to some extent supersede the condenser, as far as obtaining a vacuum. The paper just read by Mr. Halliday was a very valuable contribution to the literature of the Institute, and would add greatly to the knowledge of the members on the subject.

The CHAIRMAN related an experience somewhat similar to that described by Mr. Hawthorn, when the air pump broke down, and said that in his case, which occurred on board a P. and O. steamer, they got from 15 to 17 in. of vacuum without the air pump at all, but of course, with the feed pumps working. He hoped to see some experiments tried on the lines suggested by Mr. Hawthorn, and thought it quite possible that with triple expansion engines there would be an economy, but he was not yet prepared to discuss the matter on the present occasion.

The discussion on the subject was adjourned until Monday, November 28.

Mr. AUKLAND proposed a hearty vote of thanks to Mr. Halliday for his paper, and the motion having been seconded by Mr. ELMSLIE was carried unanimously.

A vote of thanks to the chairman for presiding concluded the meeting.

Mr. J. R. RICHMOND (Messrs. G. and J. Weir) writes to the author as follows :

I must apologise for not returning the proof of your paper sooner. I have, however, been extremely busy on account of Mr. Weir being away in the south of France and in Italy, and even as it is I have not had time to give your paper the attention I should have wished, but I feel that I must return it to you without delay. Taken generally, it seems to me that the point of your paper is to give a satisfactory explanation of the direct contact feed-heater, and your explanation is certainly ingenious. You do not, however, point out its precise effects. Feed heating may be considered from two points of view: first, as it affects the engine; second, as it affects the boiler. Direct steam feed heating affects the boiler only, and according to your experiment shows a gain due merely to increased circulation, that is to say, the worse designed the boiler is as regards circulation, the better result is obtained from direct feed heating. In well designed boilers it is perfectly clear from experiments made by ourselves and corroborated by the experience of Professor Unwin and Mr. Dalrymple, to whose letter I drew your attention, and others, that there is no gain obtained by direct steam feed heating. To show that an arrangement makes a bad thing better is certainly helpful, but to generalise from this as to its application on well designed boilers is scarcely correct. As regards the source of steam in feed heating, your paper shows that the Weir system certainly results in a gain, so that we combine in our system an economy due to a certain *method* of feed heating, while at the same time we combine a gain from the *result* of the feed heating. If there be any economy in direct feed heating, it is perfectly obvious that only the second gain can be made.

Another point you ignore is the Weir method of eliminating the corrosive gases. Certainly you mention

it as a feature of the Lundkvist heater, but the fact that air present in the feed water was the means of causing corrosion in the boilers was first shown conclusively by our Mr. James Weir years ago, and his method of freeing the corrosive gases in the heater is the direct outcome of his experiments. If you look up the paper he read at the Engineering Congress at Chicago, you will find some rather interesting remarks on this question. I should like to have given a little more attention to discussing this matter with you, but cannot spare the time at present. Your paper is extremely interesting and seems to me to be an honest attempt to get at the *rationale* of direct steam heating, and the fact that I am scarcely able to accept your conclusions will not, I hope, prevent you from letting me have a copy of any further articles you write on the subject.

DISCUSSION CONTINUED

MONDAY, NOVEMBER 28th, 1898.

CHAIRMAN:

ALDERMAN G. W. KIDD (VICE-PRESIDENT).

MR. W. LAWRIE (Member): In bringing this paper before the Institute, Mr. Halliday has again placed the members under a great obligation to him, and I am sure I only voice the feeling of every member present when I thank him for the manner in which he has dealt with the subject. In his opening sentences the author reminds us that the action of the ordinary surface condenser is somewhat in the nature of a feed-heater, and I think that most marine engineers of the pre-feed-heater period will fully endorse this statement,

remembering as they do that by a judicious manipulation of the injection valve they have many times helped themselves to increased revolutions. Formerly the main idea of feed heating was the saving of waste heat —using gases that would otherwise be lost—but engineers were always alive to the fact that hot feed was a necessity for producing and maintaining high steam. How often have we had a dispute at the end of a watch about the height of the water level, and why did we always keep the water level as low as possible consistent with a good relief? It was because the water necessary for raising the level in the boiler had to come from the supplementary feed at a temperature much below that of the water in the boiler, and the admission of this feed produced a serious reduction in the steam pressure. We all know the value of hot feed water, and why we stopped so long at the hot well without going further is to me somewhat of a mystery. But on the other hand how many of us have had a try in our time at feed heating? In 1863 I was the second engineer of a steamer running from Liverpool to Bombay, and the chief engineer of that steamer conceived the idea of taking a steam pipe from the boiler and running it into the hot well, thereby increasing the temperature of the feed. At that time I was a young man, and like most young men I thought I knew something. I predicted failure. Well, the attempt was not altogether a failure, but it was not altogether a success, and it was discontinued. It shows, however, that we are sometimes very near success without knowing it, and with better materials and appliances for the purposes of that experiment in 1863, there is no saying what might not have been the result. The idea of the chief engineer in making the experiment was not primarily for the purpose of heating the feed. He thought that when the natural draught was so very sluggish, as it often was in the Red Sea, this heating of the feed water would enable him to get better steam and thereby increase the speed of the vessel. I said at the time it was very much like

robbing Peter to pay Paul, but the chief engineer said he would not mind robbing his own father if he could reduce the time occupied between Suez and Bombay by only two or three hours. With reference to the trial trip of the *Oriole*, Mr. Halliday says:

"On a trial made on the *Oriole*, a small paddle steamer plying between London, Margate, Ramsgate, Deal and Dover, to find out if any advantage was gained by the use of the feed-water heater, it was shown that without the heater 85 lb. pressure was maintained with difficulty by the stokers. At the end of three-quarters of an hour the feed-water was sent through the feed-heater. In about a quarter of an hour the feed rose from 140° to 220° and the boiler pressure to 97 lb. and remained there."

That seems to me to be a remarkable increase —a rise from 140° to 220°—by the use of the feed-heater. I do not know if Mr. Halliday can give us any explanation, but I think that it requires explanation. Not that I doubt it, but I should like to know the whole facts. I should like to know, too, if there is any difficulty in putting the feed in at a temperature of 220° with an ordinary feed pump, or whether it requires something in the nature of a Weir's feed pump. On page 15 of the paper Mr. Halliday refers to some trials that were made on board the Palace steamer *La Marguerite*. Of course it ought to be "the New Palace steamer *La Marguerite*." I do not think I can add very much to what Mr. Halliday has said. He has very fully described the experiments that were carried out. He says:

"The feed from the hot well was about 120° Fahrenheit, and the temperature of the feed-water when the feed-water heater was in use, stood about 170° Fahrenheit. In the observations made, the feed-water heater was first in use, and afterwards the steam was turned off from it, allowing the water to flow through it without being raised in temperature.

It was sought to keep the pressure of steam constant without varying the amount of opening of the stop valve. Should it be found that the pressure of steam fell, the draught was to be increased by raising the damper door. At first the feed-water heater was in use and the steam which stood at 105 lb. kept rising."

By way of supplementing the information in the paper I may say that that 105 lb. was a very easy full speed for *La Marguerite*. We happened to be on a run where full speed was not required, but, as Mr. Halliday explains, when the feed-heater was used the steam kept rising and we had to close the dampers. When the feed-heater was turned off we had to reverse the operation and open the dampers. So that by using the feed-heater the advantage was in keeping the steam pressure at the same height with a considerably less coal consumption and a restricted draught. I was a little bit surprised to read a leading article in the present number of the *Engineer* on this subject. The writer refers to this particular trial on *La Marguerite*, but he does not seem to fall in with Mr. Halliday's ideas on the subject at all. In the early part of the article the writer says: "From first to last we are beset with puzzles; thus the steam can only communicate to the water, heat which it has already obtained from the coal. Waste heat is not utilised in any way." That is a statement I should like to call your particular attention to. Then, after commenting upon several points in Mr. Halliday's paper, including the trials on *La Marguerite*, he winds up by saying: "As nothing is to be had for nothing in this world, it would seem clear that there must be a reduction in the temperature of the waste heat; but we are not certain of this. When the heater is used, other things being equal, less coal is burned per hour in the furnaces, and the temperature of the products of combustion might remain unaltered; the economical difference being that there was less of them, the whole volume of air passing through the furnace bars being

diminished." In the first place, he says that waste heat is not utilised in any way. Now, if by closing the dampers I am consuming less coal per square foot of fire-grate, with a very much lower rate of combustion, and still retain the same funnel temperature, I maintain that there is a saving of waste gases. You are putting less air through the furnace, and it is going at a much slower rate, and there must surely be a saving of heat; otherwise, where does the heat come from that produces the steam? Then the writer says that the steam can only communicate to the water heat which it has already obtained from the coal, and that nothing is to be had for nothing in this world. If you read through the whole of Mr. Halliday's paper, I do not think you will find he says that there is any suggestion that any more heat is taken out of the steam than is put into it. In fact, if you read the paper through, you will find that the author very distinctly says that by the use of the feed-heater he makes a better use of the gases; and why the *Engineer* should say in this article that you cannot take more heat out of a thing than you put into it passes my comprehension. Again, the *Engineer* in the same article says: "Explanations like those of Mr. Halliday, and even our own, only push the puzzle a little further back. Neither Mr. Halliday nor anyone else can positively say that the reason why flowing water takes up in a given time more heat than water at rest is known to him. The very fact that the reason is apparently obvious inclines us to regard it with extreme doubt." Mr. Halliday's explanation of the economy of the feed-heater is, I think, clear to us. He says that you must take into consideration not only the heat that is put into the boiler in the feed but also that more heat is taken through the heating surfaces. The *Engineer* says that it will not accept this theory, because it is an obvious theory; but as engineers we cannot go on such lines as that. If a theory that is obvious is put before us, and we have not a better one, I think we must accept it. The

whole kernel of this paper comes on page 6, where the author shows that the higher the temperature of the feed the greater is the speed at which the water moves in the boiler over the heating surfaces, and the quicker does the water carry away with it the heat from the surface of the plates. In other words, when the feed is heated it influences not one but two things—the heat taken from the steam and the heat taken from the hot gases. That is the explanation put before us by the author, and as it seems to me to be the only reasonable theory that has been put before us I think we are bound to accept it. If this explanation on page 15 of the paper does not satisfy the members of this Institute I shall be very much surprised. Even at the Institution of Naval Architects in the early part of the year Mr. Macfarlane Gray explained the greater efficiency obtained by the feed-heater as being due to the increased motivity of the water at the heating surfaces; and when men like that miss the point it is very much to the credit of Mr. Halliday that he has put his finger on the spot.

The CHAIRMAN: Before Mr. Lawrie sits down I should like to ask him if he can give us any opinion upon the suggestion that was made by Mr. Hawthorn at our last meeting, when he said he thought the time was fast approaching when the present surface condenser would be done away with altogether, his idea being that there is more force or power wasted in using the air pump than is gained by means of the vacuum obtained.

Mr. LAWRIE: There have been experiments in that direction, and an attempt has even been made to pump the steam right back into the boilers. Indeed I believe an idea was propounded for sending a thousand-ton steamer round the world on a consumption of about ten tons of coal. It was a most wonderful statement of what might be done, but I am not aware that any attempt was ever made to carry it out.

Mr. SAGE (Chairman of Council): A vast amount of ingenuity has been exercised in designing and constructing feed-heaters which heat the feed by means of steam taken from the boilers when there is a great amount of waste heat which might very well be utilised in some manner. There have been several patents for utilising this waste heat, but owing to explosions or failure in the feed they have been very much decried. Referring more particularly to feed-heaters placed in the smoke box or in the funnel, these utilise heat that would otherwise be utterly wasted. I believe that the celebrated *Inchmona*—the five-cylinder job of the late Thomas Mudd—was fitted with a feed-heater in her smoke box, and a live steam feed-heater as well. I have here a paper giving particulars of a feed-heater which is claimed to be a circulator as well as a feed-heater, and which is entirely automatic in its action. Only the waste heat is utilised; and when the engines are stopped under banked fires the apparatus keeps up the circulation in the boilers. When the engines are under way it acts as a feed-heater only. It is not beyond the ingenuity of the engineers of the present day to design some satisfactory method of heating the feed by means of the heat that would otherwise be wasted or thrown away, and such a method would result in far greater economy than that attained by the system referred to by Mr. Halliday.

The CHAIRMAN: I have never been shipmates with any of the new feed-heaters, but it is apparent to all engineers that something ought to be done with the waste gases. I remember the patent of Mr. Lamb, of the P. and O. Company, who designed a kind of feed-heater that was fitted in the smoke box. But the great objection to that heater was that it stopped the draught; and another objection was that after two or three days the tubes choked and had to be cleaned out. When the steamer reached her outward port this water-heater was removed, and they put a pipe from one end of the boiler to the other; and, as a matter of

fact, the vessel steamed a good deal better without the feed-heater than she did with it. I am not yet aware of any engineer who ever stood up for that water-heater of Mr. Lamb's; but still it was a step in the right direction, and it is by steps that we might ultimately attain perfection.

Mr. McLaren gave some particulars of a system which it was stated conduced greatly to boiler economy, and which consisted in pumping a special mixture into the boiler along with the water. The object was the same as that of the feed-heater—to increase the economy of the boiler.

The CHAIRMAN: Have you got the price of the mixture, and how it is used?

Mr. MCLAREN: I do not know the cost, but it is pumped into the boiler along with the water.

The CHAIRMAN: Some people would put whisky into a boiler. You would have to provide tanks in which to carry this mixture, and it is impossible to tell whether there would be any economy by its use until you know the price, how much to use and how to use it.

Mr. MCLAREN: I should like to ask Mr. Halliday a question. When he replies, will he kindly tell us which system of feed-heating he considers has the greatest advantages—heating from the waste gases, from live steam or from exhaust steam? My experience is that in heating from the gases—whatever system is adopted—it is always a case of being soon furred up. Then with live steam we find ourselves in almost the same predicament. We have the water inside the tubes and the steam outside; and there is always a difficulty with the scale. With the exhaust steam we have the grease difficulty to get over.

The CHAIRMAN: You will remember that at our last meeting very satisfactory results were shown in

the case of the Yarrow boiler, by cutting off three tubes and heating them with the funnel gases.

Mr. LAWRIE: There is also the question of the effect upon the wear and tear of the boilers, upon which we want some information.

Mr. SAGE: With reference to the remarks of Mr. Hawthorn at the last meeting, did I understand you to say, Mr. Chairman, that he broached the idea of abolishing the surface condenser? It was only the air pump, I think. If we do away with the condenser where is the fresh water feed to come from?

The CHAIRMAN: I do not understand that he meant to do away with the condenser altogether, but to have a modified form of condenser.

Mr. COOK (Visitor) said he regretted that he did not have the opportunity of being present when Mr. Halliday's paper was read, but he thought there was little doubt among those present that there was an advantage to be gained by using a feed-heater of some description. The main difficulty was to get the best form—the form that would give the greatest economy. To his mind the greatest economy would be obtained by using the waste gases. The great difficulty was to get the heater fixed in such a place that it would not be in danger of being injured. He had not himself had very much experience with feed-heaters. He had been with one form—and that not one of the best—and they did not find that they derived any particular benefit from it.

The CHAIRMAN: That may have been a case where there was an economy but you did not know it.

Mr. COOK: Yes, I cannot guarantee that there was not an economy, because one of the points of the feed-heater is that it is a protection to the boiler.

Mr. LAWRIE said he could testify from personal experience that the use of a feed-heater had a beneficial effect upon the life of a boiler.

Mr. HALLIDAY, in the course of his reply to the discussion, said: To understand the advantages of the feed-heater, it is perhaps best to place before one's mind the ideal state of things to be aimed for in the steam boiler. The ideal state of things in the steam boiler is attained when the boiler is only employed in evaporating the water. That being so the feed-water must be supplied at the temperature of the steam in the boiler. The question then arises, Why is it best to supply the feed-water at the same temperature as the steam in the boiler? The answer is, it allows better circulation in the boiler. In what way does it allow better circulation in the boiler? And the answer to that can best be understood by taking into consideration a case where the feed is supplied at lower temperature than the water in the boiler. When the boiler has water in it which it is simply evaporating there is set up a normal undisturbed state of circulation. And under these conditions a rate of speed of water over the surface will also be maintained. Now, suppose that water is introduced at a lower temperature, and consequently different in density from that in the boiler, the normal condition of circulation will be destroyed, and the speed of the water over the surfaces will not be maintained. This is one change in the condition of the water; but there is another change, and that change is a less transmission of heat from the hot gases to the water than there was before It is not said those two changes are inter-dependable; it is only asserted that they always exist together. Then there comes the further question of the more rapid absorption of heat by the water when it bursts into boiling. Why is this? Consider first the cause of the circulation of the water before it begins to boil. The circulation is produced by the descending water being more dense than the ascending water. Under this

force the water does not move very quickly, and it moves across the hot plates at a comparatively slow speed. When ebullition takes places the bubbles hurry to the surface, and the friction between them and the water through which they rise causes the water to move in their train. This is an additional circulating force, much stronger than the other, and producing a much greater effect. The movement of the water in the path of the steam bubbles may be two or three times greater than it was before. And the speed of the water across the heating surface will also be two or three times greater than it was before. Experiments have proved that the absorption of heat is almost directly proportional to the velocity of water over the heating surface. Make the speed of the water over the heating surface increase, and the absorption of heat by the water will increase at the same rate. It is seen, then, that due to the entraining action of the steam the movement of the water in its path of circulation and over the heating surface is two or three times greater than it was before, and it has been observed that when entraining action takes place the absorption of heat is two or three times greater than before. Other things may change, but it is not necessary to suppose they do in order to find an explanation for the increased absorption of heat by the water at this stage. Then there comes another point. Why is it that greater absorption of heat takes place when steam from the boiler itself is used to heat the feed, notwithstanding the circumstance that in the heater itself there is a loss? The reason was pointed out above. The normal circulation of the water is not disturbed by hot feed. Hot feed-water mixes easily with the boiler water, and, being nearly of the same temperature as the boiler water, joins in the normal circulation at once. There is, therefore, the rapid ebullition continually going on, strong entraining action and continuous rapid motion of the water over the hot plates. Hence high absorption of heat by the water. There is loss by the feed-heater itself, but the gain by the more

rapid circulation is greater than the loss. The next question is, Where does the heat come from ? It is known that heat comes from the live steam into the feed-water, but that heat comes from the boiler water, and consequently there is a loss in the process. Can it be proved that more heat comes out of the gases when the evaporation of the water is conducted separately from the heating of the water ? The experiments made by Mr. Yarrow give the proof of this. When one part of Mr. Yarrow's boiler was engaged evaporating the water the temperature of the gases as they escaped to the up-take was much lower than when both processes proceeded together. The circulation of the water in the part of the boiler engaged in evaporation only was more rapid, and so greater absorption of heat took place, and that heat came from the gases, as was shown by the pyrometer. In the case where both processes were mixed, the circulation was disturbed and slower; in the other case the circulation was undisturbed, and the absorption of heat quicker. But why should the water take up more heat when it moves over more heating surfaces per second ? Is it not because more particles of water come in contact with the plate ? Suppose in a certain place there is a pound of water moving through a foot length of tube per second. The particles of water do not move in straight lines. The particles are continually changing their positions. Should then this pound of water move through two feet of tube instead of one foot, per second, twice the number of particles will come in contact with the plate, and become heated to about the same temperature. About double the quantity of heat will have entered the water in the second than did so in the first. Is not this the explanation of the greater absorption of heat by the water when its velocity increases ? What then is the conclusion of the whole matter ? For rapid circulation and high absorption of heat allow the boiler to evaporate steam only. That means send the feed-water in at the temperature of the steam. But live steam cannot heat the feed-

water up to the temperature of the steam. It follows that the feed must be heated by the hot gases to reach the temperature of the steam. And it is probable that feed-heaters will form a part and not an adjunct of boilers of the future.

The CHAIRMAN proposed a vote of thanks to Mr. Halliday, and said he was sure they all felt greatly indebted to him, not only for his most interesting paper but also for the further very instructive information which he had afforded them in the course of the discussion.

Mr. AUKLAND seconded the motion, which was carried unanimously, and

Mr. HALLIDAY, in acknowledging the vote, spoke of the valuable assistance which he had received from Mr. Lawrie in making some of the tests.

A vote of thanks to the Chairman, proposed by Mr. SAGE, concluded the meeting.

DISCUSSION CONTINUED

MONDAY, DECEMBER 12th, 1898.

CHAIRMAN:
MR. J. E. ELMSLIE (MEMBER).

MR. R. D. KEAY (Member): The author appears to state that Watts' object in introducing the condenser was to heat the feed-water. The *primary* object of the separate condenser was to improve the efficiency of the engine by doing away with the barbarous plan of using the same vessel as a cylinder and condenser

alternately. The separate condenser also made expansive working possible in the days of low pressure, and this resulted in a much higher efficiency.

The author's statement as to why feed-heating results in higher efficiency than theory accounts for are not quite convincing. So far as the feed-water is concerned, it certainly cannot gain more heat than is taken from the engine for feed-heating. There appears to be no doubt, however, that the efficiency of the boiler is increased by feed-heating, i.e., for each pound of coal consumed there will apparently be a greater number of units of heat taken up by the water in the boiler. I am not aware of any careful experiments having been made to show how far increased efficiency is accounted for by the reduced temperature of the chimney gases, but this would be an interesting point to determine. Possibly the elimination of air from the feed-water may have more effect on the efficiency than is generally supposed. Air is certainly a bad conductor of heat. Recent engineering experience all tends to show that the ideal way of generating steam would be to heat the feed-water up to about the boiler temperature before pumping it into the boiler.

Some surprise was caused by the results of experiments made on Mr. Druitt Halpin's heat storage system to which the author refers. In electric light stations the engines and boilers usually have very little to do during the day, but the plant must be able to deal with the maximum night load. To reduce the number of boilers necessary, a large tank has in some cases been arranged so that during the day the steam generated by some of the boilers may be used to heat the water in the tank. When the heavy demand comes on, the boilers are fed with hot water from the storage tank and so can more easily evaporate the amount of steam required. As mentioned by the author, this system has resulted in an increased efficiency of as much as 19 per cent. in spite of the fact that heat must be lost by radiation

from the storage tank. In this case the increased efficiency seems to be explainable only in the supposition that the evaporative efficiency of the boilers is increased, probably owing to more rapid circulation. The effect of increasing the velocity with which water moves over the heating surfaces was shown by Professor Ser, of Paris, to be very important; and in a given case the effect of increasing the velocity from six metres per second to sixty metres per second was to increase the co-efficient of evaporation 2·6 times. The least possible resistance should therefore be offered to the natural circulation in a boiler, and for this reason the tubes should be as nearly vertical as is convenient, and straight if possible. It is certainly wrong in principle to compel the steam and water to climb up a long and awkward ladder, as it does in the Belleville and some other boilers. The necessity of fitting a non-return valve to prevent the reversal of the circulation shows how unreliable the circulation really is in such boilers. In 1895 Messrs. Fairburn and Hall, of Manchester, used a supplementary boiler to heat the feed-water, and sent the feed to the main boiler at a pressure above its normal working pressure. With this system they claimed to have got 100 horse-power from a boiler which formerly gave 80 horse-power, the total coal consumed in the two boilers to produce 100 horse-power being the same as that used in one boiler to produce 80 horse-power. I have not heard if this system has been introduced to any great extent, but it seems to be a step in the right direction.

The author says that Mr. Yarrow's system of feed-heating is on the same principle as the Druitt Halpin system, but I see no reason for such a statement, as there is no attempt at heat storage in Mr. Yarrow's arrangement. Mr. Halliday's remarks about the lowering of the temperature of the flue gases "after they have come past" the feed-heating tubes are not quite clear. Such lowering of temperature can only be accounted for by radiation to the atmosphere. The

lower temperature of the flue gases is accounted for by their passing over colder tubes, for rate of transmission of heat is proportional to the square of the difference of temperature. I do not agree with the author when he says that the increased efficiency "is not due to increased efficiency of the heating surfaces." Even supposing the results obtained to be due to better circulation, and in no way dependent on the reduced chimney temperature, we would be quite justified in the present state of our knowledge in saying that the improved circulation has made the heating surface more efficient. I do not see that Mr. Halliday is justified in taking Mr. Yarrow's experiments as explaining the efficiency due to using live steam for feed-heating. In the usual application of live steam for feed-heating, it has not yet been shown that the temperature of the chimney gases is reduced, whereas in Mr. Yarrow's experiments this was necessarily so. It seems to me that with bad circulation, part of the heat taken up by the steam may be absorbed as work in overcoming the resistances which the steam meets with in rising. (Theoretically such work, being frictional, should be again converted into heat.) If this be so, then with increased circulation we might have *apparently* more heat taken up by the boiler per pound of coal consumed, without any reduction in temperature of the chimney gases. In reference to Weir's feed-heater there can be no doubt that Mr. Weir was the pioneer in feed-heating, but the advantages he sought by its introduction were rather in the direction of doing away with the troubles caused by using cold feed in the boiler, and he maintained that there could be no improvement in efficiency due to using live steam for feed-heating, and consequently he arranged to use steam which had done some work in the engine. From personal experience as engineer on a vessel which was "stiff for steam" I can assert that the effect of using the heater was so apparent in improving the steam raising qualities of the boilers, that the firemen knew whether the heater was on or off, merely

by the difficulty or otherwise of keeping steam. A practical point of much importance is that if a boiler steams easily the fires will not require so much working, and this will result in saving of coal. The ideal way of heating feed-water would be to heat it gradually in a long pipe, having hotwell temperature at one end and boiler temperature at the other; the temperature of the water and the source of heat being the same at each point in the pipe. These conditions cannot be fulfilled in practice, but the late Mr. Thomas Mudd carried out stage feed-heating on the ss. *Inchmona*, in conjunction with Mr. J. B. Edmiston, of Liverpool. The engines were quadruple-expansion, with a boiler pressure of 250 lb. Drain water from the cylinder jackets was used as the source of heat in a series of feed-heaters, and the feed-water was heated to as high as 380° F. in the last heater before passing to the boilers. In reference to the author's method of tabulating the various kinds of heaters, it seems incorrect to state that "the heat lost by the waste gases shows the entire gain." The improved circulation results in increased efficiency, but it has not yet been shown that the increased efficiency from this cause bears any strict relation to the temperature of the chimney gases. Case 3 seems to come under the same heading as case 1, for, taking the steam from the intermediate receiver is simply a case of exhausting at a higher pressure. I have already commented on case 4, and think further experiment is required before its statement can be fully accepted.

The author speaks of a compound interest law to explain the efficiency attained by live steam heaters. As he himself points out in another part of the paper, the heat returned to the boiler by heating the feed must be less than the heat taken from the boiler for this purpose; and so it is wrong to state that the higher quantity of heat going back to the boiler is *directly* a reason for the increased efficiency. I do not think it has been proved that when feed-heaters are

used, higher chimneys are necessary, though it may be so where a Green's economiser is used. The reduced chimney temperature and increased resistance may necessitate a longer chimney in such cases.

A method of feed-heating adopted some years ago by Mr. Morrison of Hartlepool is worth referring to. Advantage was taken of the fact that the pressure in the feed-pump air vessel rises above the boiler pressure

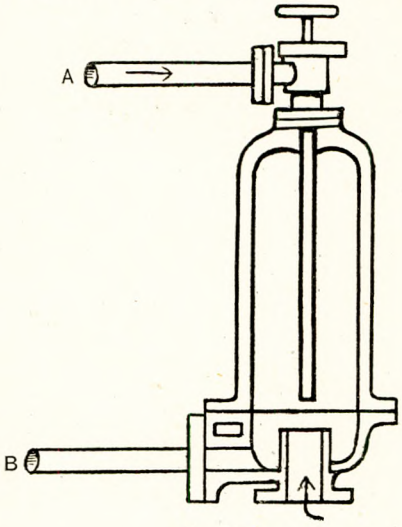

FIG. 17.

during the working stroke of the pump, and falls below the boiler pressure during the suction stroke, owing to the momentum of the water. The sketch shows the feed pump air vessel with its connections.

B is the ordinary discharge to the feed-check valve. A is a pipe connected to a stop valve in the boiler, and near the water level. There is also a non-return valve in pipe A. During the suction stroke, water passes along A from the boiler, and by this means the feed may be heated to 240° F. Some of our members may know if this system gives satisfaction in practice. I have had no personal experience of it. There are

many other points in Mr. Halliday's paper which I would like to comment upon, for the subject is a suggestive one; but I have already occupied too much of your time.

Mr. W. LAWRIE (Member): It would probably be interesting and instructive to several gentlemen present if Mr. Halliday would further explain his reference at the last meeting to the entraining action of the steam in the boiler.

Mr. JAMES ADAMSON (Hon. Secretary): I have been reminded, by some remarks that fell from Mr. Halliday on this subject at our last meeting, of a system which I saw fitted in a steamer at the Royal Albert Docks some ten or twelve years ago. Connecting tubes were taken through the furnaces, one on either side, and were carried up the fire-box at the back end; the water in the pipes, which thus added to the heating surface, was heated in its passage through the furnace, and induced circulation in the lower parts of the boiler with which the pipes were connected.

The system formed a combined arrangement of water-heater and circulator. There were several details in the arrangement which required improvement, but I have not seen or heard of any other steamers being fitted since the time I speak of; but possibly some members may have had experience of it and how the system works in practice. Kirk's feed-heater was put in at the root of the funnel and had the object in view of heating the feed by means of the waste gases. A remark was made in the course of the discussion that sufficient allowance has not been made for the benefit which the boilers themselves derive from the feed-heaters. But we all admit that through the feed-water being put into the boiler at a temperature as near the temperature of the water in the boiler as possible the boiler has certainly a benefit. There are fewer leakages, because the strains are more equalised, especially if the pumps are arranged to act as circulators.

Mr. HALLIDAY: I do not know that there is much to add to the reply which I gave on the last occasion. In answer to Mr. Keay, with the exception of calling attention to his expression, "efficiency of heating surfaces." I confess I hardly know what that expression means. The quantity of heat transmitted by the plate is something I do understand, but to talk about increasing the efficiency of heating surfaces does not seem to me to be at all a scientific way of expressing it. Mr. Lawrie's question about the circulation is very important; but since coming into the room I have received encouragement from Mr. Adamson as to the supply of apparatus for making further experiments, and I would rather that nothing further should be said until some more experiments have been made. Mr. Adamson assures me that he will be able to communicate with some one who has the interests of the Institute at heart, who will supply the apparatus for the furtherance of its scientific researches. Curiously enough, the Institute of Engineers and Shipbuilders in Scotland discussed at their last meeting a similar question on a paper which I myself contributed. That question was the transmission of heat through plates, from hot gases to water. Professor Perry, of the Royal College of Science, and Professors Barr and Watkinson joined in the discussion. We had each been working at this question, and there can be no doubt that several steps have been advanced lately, and our investigations probably have shown us more clearly than before the extent of the field of further experimental investigation which lies in front of us. Institutions like that of the Engineers and Shipbuilders and the Naval Architects have these investigations as a part of their work. The members of these institutions have facilities for investigation, but there is nothing of this kind as yet in connection with the Institute of Marine Engineers. There ought to be a friendly rivalry between the several engineering institutions throughout the country. It ought to be the aim of each to further the interests of scientific investi-

gation. At the Royal Institution there is the old laboratory in which Michael Faraday spent the best years of his life and discovered all the laws which govern the construction of electric lighting machinery. There is at present a movement on foot for a physical laboratory. I submit that the Institute of Marine Engineers is powerful enough to provide apparatus for the original investigation into the laws which govern marine engineering problems. It is an old idea of a past president, Sir John Durston, that there should be a permanent laboratory where experimental work should be continuously carried on. Such work does not interfere with useful work elsewhere, but it would assist the Institute in keeping its place in the production of results of scientific research. This Institute has taken its place in the discussion on water-tube boilers, and now it has had a theory of the live steam feed-water heater before it. It should be continually tackling questions of that kind; and the matter has only to be placed clearly before the members, if one may judge by the discussion, for them to take it warmly up. I should like to express my thanks for the willing way in which Mr. Lawrie placed the engine-room of *La Marguerite* at my disposal. Messrs. Caird and Rayner also kindly prepared a feed-heater for me to experiment with. The Vauxhall Ironworks Company have also arranged to make experiments. I am sure that the scientific investigation of our engineering practice will be advanced by these steps.

Mr. KEAY: Mr. Halliday has made some observations about an expression which he says I used in the course of my remarks. The expression which I used was not "efficiency of heating surface," but the "co-efficient of transmission," which is a term well understood among engineers. It will also be noticed that Mr. Halliday himself uses the expression "efficiency of heating surfaces" in the course of his paper.

PREFACE.

BRISTOL CHANNEL CENTRE.

35 STACEY ROAD, CARDIFF,
December 14*th*, 1898.

A Meeting of the Bristol Channel Centre of the Institute of Marine Engineers was held this evening at the University College, Cardiff, Professor A. C. ELLIOTT, D. Sc. (President of the Centre), in the Chair, when the Paper on Feed-Water Heaters, by Mr. GEORGE HALLIDAY (Member), was read and discussed as follows.

GEO. SLOGGETT,
Hon. Local Secretary.