BRISTOL CHANNEL CENTRE.

DISCUSSION

ON

FEED-WATER HEATERS.

DECEMBER 14th, 1898.

CHAIRMAN:

PROF. A. C. ELLIOTT (PRESIDENT).

THE PRESIDENT said he had been interested by the paper, because to some extent he was familiar with the controversies which had raged around the subject. The first paragraph of a paper was, in his experience, always a difficult thing to write, and the first sentence still more difficult. He was afraid the author of the paper had experienced similar embarrassment, because he had difficulty in making out what the first paragraph meant. Mr. Halliday said: "When James Watt condensed the steam coming from the cylinder of his engine and pumped the condensed steam and water into the boiler he heated the feed-water." Now, this remark seemed to apply to an ordinary jet condenser. If it applied to the surface condenser, then it did not apply to Watt's engine, because James Watt, although he invented the surface condenser, never used it. The only thing that Mr. Halliday would seem to suggest was that it was a mistake to carry a high vacuum, in other words that it was better to run at a low vacuum and have a high feed temperature. How Mr. Halliday reconciled that with James Watt's belief that a condenser should be the coldest thing about an engine and the cylinder the hottest, he did not quite know.

The first kind of feed-heater that was dealt with was that which abstracted heat from the furnace gases. That was a fairly obvious direction in which to seek increased economy. No matter how they feed-heated, or what they did, they were always face to face with the fact that about 70 per cent. of the heat that was rejected by any engine whatsoever must go to waste; they could not possibly get it back to the boiler, or do anything with it so far as the engine and boiler were concerned. He was acquainted with an installation in which the whole of the heat rejected by the engine was utilised, the 70 per cent. or more of which he spoke being used for heating the building and partially heating the feed-water. Sometimes there was more than enough steam to heat the building and the feed-water too. The economiser of the Green type was, of course, familiar to them. As had been pointed out, time and again, by its adoption in very ordinary cases a saving could be effected of from 15 to over 20 per cent. This was done by reducing the temperature of the chimney gases. It had often been urged that inasmuch as the boilers of a certain plant were already hardly pressed the introduction of economisers would be impolitic on the ground that the draught must be so greatly reduced as to cripple the already over-worked boilers. But this was an error in most cases. So great was the relief on the stoking that the small effect in reducing the draught was more than compensated by thinner and cleaner fires and a less volume of chimney gas. The marine practice, heating the feed-water in the uptakes, was coming to the front again. Long ago there were super-heaters in the uptake, but one had to come to comparatively recent times to find feed-water heaters in the uptakes. However, it was not quite such a new thing as Mr. Halliday made out. Five or six years ago he himself inspected a steamer having a feed-water heater in the shape of a boiler full of feed-water under pressure between the uptakes and the funnel. The engine was a triple, and the resulting economy very considerable, but the size and weight of

the thing seemed to have killed it, because he had not heard of any other steamer being fitted in that way. However, it was a realisation of the principle that if feed-heating was to be done at all in marine practice in the uptake it must be done under pressure. If it was not done under pressure, they had only a range of from 110 to, say, 180 degrees, if the water was to be dealt with by the ordinary feed pumps. To obtain a small effect like that did not seem to justify any move. But once they conformed to the principle of heating under pressure then they had to look at the resulting addition to their dead-weight. The Admiralty were more concerned than other people in the question of dead-weight efficiency, and even they had recognised the ultimate advantage of heating in the uptake under pressure, because they had lately adopted the economiser in connection with the Belleville boiler. Before that economiser was used, he ventured to say that a saving might possibly be effected of from 15 to 20 per cent., and he was glad to glean from the results of a recent trial made by R.N. engineer officers that the saving came very near that estimate, even with a forced or assisted draught that was sufficiently strong to burn about 37 lb. of coal per square foot of grate per hour. The author made reference to Mr. Yarrow's adoption of the same principle in some of his recent boilers. That was to say, he took a section of the back end of the boiler, cut it off from the rest, and passed his feed-water through that section or nest of tubes, thereby obtaining a certain expected economy. If that cut-off section instead of being placed exactly at the end were situated somewhat farther towards the front, he should expect not a less degree of efficiency and a greater immunity from trouble under forced-draught trials. The author had referred to Weir's feed-heater, but he seemed to have failed to realise the principle that James Weir, wittingly or unwittingly, had introduced into modern steam practice. Weir's feed-heater was received with anything but demonstrations of approval. Mr. Macfarlane Gray coined a phrase calculated to kill

it. He said it was robbing Peter to pay Paul; and so lately as 1890 nobody knew exactly why Weir's feed-heater should effect any economy at all. About that time he (Prof. Elliott) pointed out that there was an analogy between the steam engine and the air engine, and if the Carnot cycle was not the uniquely perfect cycle for the air engine there was every reason to suppose that there must be a "regenerative" cycle for the steam engine equally perfect with, but entirely different from, Carnot's. The perfect regenerative plan was simply Weir's feed-heater writ large; and Mr. Gray was among the first to admit that in this case at least the joint affairs of Paul and Peter showed a profit. The controversy of 1892 had been to some extent revived by a committee of the Institution of Civil Engineers which recently sat upon the question of a standard of efficiency for steam engines. Despite the findings or defences of that committee, there could be no ultimate standard of efficiency for steam engines which was not the truly rational one, and the plea that the steam engine should be dealt with on some different basis from any other heat engine, because the perfect cycle was practically unrealisable, had been shown to conflict with present-day knowledge and experience. The fact was, by Weir's heater, carried to extreme limits—say a quadruple or quintuple expansion engine, the feed could be returned to the boiler at very nearly the boiler temperature, having picked up heat from the successive receivers as it went along. Mr. Mudd and Mr. Edmiston, a Member of the Institution, resolved to practically realise this idea, and with the engines of the *Inchmona* conducted some of the most remarkable experiments in marine engineering of recent times. The feed was first heated in the ordinary way by mixing with steam from No. 3 receiver —mixing was much easier and more effective than conduction from the outside. Then it passed through a coil which was in communication with the next highest or No. 2 receiver, and, thanks to another coil which communicated with the next, or the highest,

receiver, finally attained within a short step the boiler temperature, thus fulfilling, in fact, the conditions of a reversible and maximum economy cycle. At the time Mr. Edmiston was considering the possibility of making this plunge, he (Prof. Elliott) ventured to say that he thought, after making practical deductions, they would realise about 8 or 10 per cent. of economy due to quadrupling at 250 over a triple at 180, and that on the feed heating they would gain another 8 per cent. So that the whole gain of the quadruple engine at 250, with a feed-heating system over the triple engine at 180 would be something like 16 per cent. A good triple could do a horse-power for about 1·4 lb. of coal per hour. If they took 16 per cent. on that it was about one-sixth. That would be 1·2. The actual consumption claimed was about 1·10 lb., but he did not know whether that was the result of day in and day out work, which was what he (the speaker) discussed, and not what might be got out of a trial trip. At the bottom of page 10 of the paper, Mr. Halliday had given some results, but had muddled up in some strange way the economical returns from the principle of Weir's feed-heater, and the economical results which he claimed for the principle of live steam feed-heating. Weir's feed-heater could be demonstrated on a rational basis, but there was no class scientific principle involved in the live steam feed-heater. They took the heat, which they had already paid for, from the boiler and put it into their feed, putting, as Mr. Gray said, their hand in one pocket and sparing some money to the other pocket, the operation leaving them as rich as before, except for dead loss on exchange. But although that was the case one might reconcile certain statements as to economy obtained by the use of the live steam feed-heater by considering that the boiler efficiency was to some extent a function of its circulation. That was to say, if the circulation of a boiler was sluggish the steam particles stuck to the surface from which the heat was coming, and increased abnormally the sur-

face resistance to the transmission of heat. If they could stir up a current which would continuously wash the surface of these particles of steam, then obviously they would increase the efficiency of the heating surface. Now, it was just possible when they introduced cold water into a boiler with a sluggish circulation they killed to a large extent the poor circulation which it had already got, whereas if they took some live steam out of the boiler and put it into the feed, and then injected their feed-water, they would do less damage to the circulation. Some four years ago he propounded that view, saying he did not believe that the live steam feed-heater applied to a boiler with a decently good circulation would effect any marked economy, but that applied to a boiler which had a sluggish circulation—to a boiler where the feed was injected at the wrong place, in such a way as to kill some of the outgoing currents—then there might possibly be a small economy; but at that time he had not made any satisfactory experiments. From time to time since then he had tested the principle of live steam feed-heating, but mostly on a boiler which had a magnificent circulation, and he had never been able to get anything like a show of additional economy, the difference between hot and cold feed being neither here nor there. The author of the paper had apparently quoted or adopted some phrases from an old paper of his (the professor's), and had gone on to say that his statement was wrong, that if the live steam feed-heater did anything at all it operated to increase the efficiency of the heating surface. Mr. Halliday merely made that assertion; at any rate, what reason he did give worked entirely to the opposite conclusion. The trials which the author quoted showing the great economy due to the live steam feed-heater were not very satisfactory. Until the author could establish his declaration that the live steam feed-heater effected greater economy on a boiler of the Yarrow or Thornycroft class, having a very strong and rapid circulation, than it did when

applied to, say, an ordinary Scotch or Lancashire boiler, with a pell-mell circulation—until he established this by experimental evidence, he (Dr. Elliott) declined to take one or other of these statements about the live steam feed-heater. Morison's evaporator, which in some of its forms undoubtedly did something to heat the feed. If they had lost, say, a pound of steam, obviously the heat had gone with the steam, and that loss was irreparable; their object was to replace that pound of steam in the most economical way. It was obviously better, if possible, to send the new steam and its heat into the boiler or into the feed rather than into the condenser from whence all latent heat went overboard. Briefly it was true economy to pay a little longer price for the make-up feed by evaporating at a higher pressure than that of the condenser, and counting on the set-off got by the saving which resulted from the higher temperature—the avoidances—namely, of the necessity for sending the latent heat of the evaporated make-up feed overboard. Of course the temperature of the rejected brine had to be considered, and other things; nevertheless his statement was correct.

But Morison's evaporator, or some modifications of Weir's evaporator, could hardly be looked upon as a feed-heater, strictly speaking, since the whole affair of make-up feed was, or ought to be, a matter of 4 or 5 per cent. to begin with. Mr. Halliday referred to some experiments related by Prof. Ser, as showing that the more rapid the water and steam current over the heating surface the greater must be the co-efficient of transmission. That meant, of course, the greater must be the efficiency of the heating surface, but this experiment seemed to be open to an objection, and a very serious one. It was well-known that the specific heat of water was higher than that of any other substance; that its co-efficient of conduction was extremely low and excessively difficult to measure; and that surface resistances in heat transmission as

compared with mere conduction were of almost transcendent importance. The experiment referred to by the author was crude in the extreme: the horizontal pipe contained no agitator; the conditions simply realised in a small way the state of affairs when steam was attempted to be raised at short notice in the ordinary Scotch boiler unprovided with a hydrokinetor or the necessary donkey connections—any amount of pressure on the gauge and bottom of boiler cold to the touch. The less Prof. Ser opened his tap the less was the agitation of the heated layer at the bottom of his tube, the higher was the average temperature of its contents, the less was the head of temperature acting to force the heat through against the resistances. Naturally, the harder he turned his tap the more the agitation of the dead water, the lower the average temperature of the tube contents, and so on. The experiment might serve as an illustration of perhaps homely truths—bearing in mind the domestic kettle—but as a research in boiler problems the thing was simply out of the question.

Mere velocity of matter, apart from thermal and other conditions, over a heat-transmitting surface could account for nothing unless the velocity were comparable with the speed of light, when some curious but not practical questions would arise. In boilers with sluggish circulation they had probably small differences of temperature in the contents. Greater differences he meant than could be accounted for by differences of pressure due to depth below water level—and a kind of streaky distribution of temperature and density due to "stiction" (adopting a happy impromptu attributed to no less a person than Dr. Whewell) between the water and steam globules and the steam globules and the inner side of the heating surfaces. In boilers of the small and even big water-tube type, they had on the other hand an enormous commotion not confined to one place but pretty well distributed over the boilers. This commotion was totally inconsistent with what he ventured to

call the streaky condition. But again there was a distinction. In the Scotch boiler the circulation of the fire gases was constrained ; in the water-tube boiler the fire gases were constrained only in a sort of a way, while in some types of water-tube boilers—as the Thornycroft and Belleville—the water and steam circulation was absolutely constrained. The consequences appeared in the fact that densities in water-tube boilers varied from point to point enormously ; in fact he had shown that the deliveries to the steam collector or upper drum might by volume contain from 50 to 90 per cent. steam which in comparison with water had practically no mass or weight. Was it to be believed that these varying densities had no relation to the efficiency of the heating surface ? All experiences pointed to the contrary. Everybody knew, or at least believed, that to offer steam a harbour under a landing or the like meant the burning of plates and rivets and leaks in good time.

He might say that he himself had made a considerable number of experiments upon the velocity of currents in boilers and the effect as observed on the transmission co-efficient, but these experiments were difficult to perform in an actual boiler. They were not difficult to perform with bits of tin pipe, India rubber, Bunsen burners, etc., at atmospheric pressure ; but this was not the sort of thing that was of the smallest use to an engineer. One of the objections of practical men, who had no experience of the type, rested on getting scale inside a water-tube boiler, but fortunately it was only very bad water indeed that was able, even in a land boiler, to deposit to such an extent as to withstand the tremendous momentum of the currents in water-tube boilers as he had occasion to know. The ordinary injector was a far better feed-heater for land boilers than the tin-pot arrangements in vogue, which radiated heat all over the place. The injector was at once a beautiful pump and a far more powerful live steam feed-heater than any of these much

testimonialed contrivances, and if there was any power in the live steam feed-heater at all they had it in the injector. Not only that, but they saved the steam which they were wasting in their pumps. The feed-pump was the most wasteful machine it was possible to imagine; direct or steam-driven machinery of that class on board ship at any rate took ten or twenty times the steam power for power of the main engines.

What he had said about the live steam injector applied with even more force to the exhaust steam injector—an admirable pump and feed-heater combined in the circumstances where it was applicable. Though these scattered remarks had ended with the exhaust, it did not follow that the subject was exhausted.

Mr. SUGDEN said the scouring action of rapid circulation was often seen in flutes and grooves. He agreed with the President that the injector was a perfect instrument for heating the feed-water, because they got back all the steam they put in, and there was no loss. Nevertheless, injectors were very tricky things. With some kind of bad waters they got perforations and consequent stoppages, and thus the pump was considered more reliable. He failed to see why, with live steam feed-heaters, the steam should be heated by conduction. Then it seemed to him that the proper place to feed-heat was inside the boiler, not outside. In all live steam heaters there was the difficulty about sulphates and carbonates. Any live steam heater that was outside must be made less efficient in course of time owing to the sulphates and carbonates deposited on the outside of the tubes. In an arrangement which the speaker sketched on the blackboard, they got all open to the inside of the boiler. It had been tried with perfect success on the outside of the boiler, but not yet inside, although he did not see why it should not act equally well there. If it was simply for the sake of heating the feed-water, why have it outside at all?

Mr. SCOTT described an arrangement with the feed-heater inside the boiler. Here the ordinary feed-valve was put at a higher level than usual, with a small live steam connection attached. The necessary internal feed pipe was led right round through the steam space, and thence to the boiler bottom. It was really an injector of live steam. When it got inside the water it was reheated in the pipes and delivered down underneath, so that the feed-water always replaced the water that rose from the heat surface.

The PRESIDENT: Has it been fitted to any boiler yet?

Mr. SCOTT: We are busy making it now.

After some further discussion the meeting closed with votes of thanks to the Author of the Paper and to the President.

REPLY BY THE AUTHOR.

Mr. HALLIDAY: Two of the main points raised in this paper have been, I think, fairly settled. The first was the theory of the live steam feed-water heater; the second was the advantage or disadvantage of circulation in water-tube boilers in promoting the efficiency of heat transmission. The later experiments which have been made at the Institute have furnished very good proofs to both.

Mr. J. R. Richmond, of Messrs. J. & J. Weir, Limited, Glasgow, has sent a very valuable contribution to the discussion. He says: "Feed-heating may be

considered under 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." But in the face of the results of the experiments by Messrs. Yarrow & Co.—those on the *Oriole* and *La Marguerite*—it is a pity to read this : "In well-designed boilers it is perfectly clear from experiments made by ourselves, and corroborated by the experience of Professor Unwin and Mr. Dalrymple, . . . that there is no gain obtained by direct steam feed-heating." Mr. Richmond is quite right, however, when he says that the Weir system combines an economy due to feed-heating from condensing steam, and also from the better circulation produced by sending in the water heated to the boiler. My point, of course, is that when the feed-water is heated it influences not one, but two, things, the heat taken from the steam, and the heat taken from the hot gases—heat by condensation, and heat by rapid circulation.

Mr. Lawrie has placed before the members a record of the experiments, on which I cannot very well improve. But there is one point to which I should like to refer, because it may lead to some misconception. I mean the temperature of the waste gases when the hot gases are being utilised with greater efficiency. Mr. Lawrie says : "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." My impression is that the funnel temperature would be lower although it was not shown by the thermometer. Heat not shown by the thermometer was due probably to the irregularities of the stoking.

Professor Elliott is not a little amusing in his reference to the difficulties I experience when writing my first sentence.

His description of the work of Mr. Mudd and Mr. Edmiston are of more profit. On page 78, Professor Elliott says: "From time to time since then he had tested the principle of live steam feed-heating, but mostly in a boiler which had a magnificent circulation, and he had never been able to get anything like a show of additional economy, the difference between hot and cold feed being neither here nor there." Well, the point of course is this. The advantage gained by any feed-heater is in the separation of the two functions performed in the ordinary boiler. The first is the raising of the water to the boiling point, and the water so raised must take its heat from the surrounding water and so disturb the circulation. The second function is the evaporation of steam when the water has been raised to the boiling point. It is found more efficient to perform these two functions separately. I can hardly do better than give a quotation from my little book on "Steam Boilers":

"If no feed-water is being supplied, and if under that condition steam has been generated for some time, then all the water in the boiler is at the same temperature, the circulation of the water is normal. That circulation will continue to go on in the same way. It will be the circulation necessary for the generation of the steam, and it will depend for its movements on the manner in which the boiler is fired.

"If water be fed into the boiler at a different temperature from that of the water at which steam is generated it will naturally disturb the circulation of the water from which steam is generated. If water is introduced at the same temperature as the water in the boiler, then, however it may be introduced into

the boiler, it will not disturb the circulation very much, since the density of the water introduced will be the same as the density of the water giving off steam in the boiler. Should such water be introduced into the boiler in the course of a current of circulation, and flowing in the opposite direction to the course of that current, then the hindrance to the normal circulation of the water will be considerable. If, however, the feed-current is introduced flowing in the same direction as the current of circulation, then the circulation will hardly be hindered at all, and it is possible it may be promoted. In any case it will only be faster or slower in the same direction. If the feed be introduced in some other direction than with or against a normal circulation current, it will have some intermediate effect lying between the effects above discussed. . . . . But the feed-water may be introduced into the boiler at a different temperature from that at which steam is being generated. It will then have a different density, and will, in whatever way it may be introduced, disturb the normal circulation of the water in the boiler. It will thus have an injurious effect on the circulation of the water in the boiler. The greater the difference in temperature the more injurious will the effect be."

Professor Elliott does not take kindly to the experiments of Professor Ser, which proved that the coefficient of transmission of heat through a hot tube could be raised by an increased velocity of flow of the water through the tube. He thinks they prove nothing, although Mr. Thornycroft, Mr. Yarrow, and all the makers of the express water-tube boiler pin their faith to that doctrine. Professor Elliott's words are : " Mere velocity of matter apart from thermal and other conditions over a heat-transmitting surface could account for nothing unless the velocity were comparable with the speed of light, when some curious, but not practical, questions would arise."

What Professor Elliott will think of the investigations made on this subject at this Institution one hardly cares to think. But the members who have seen them conducted will, we think, be convinced enough.

With regard to the advantages of rapid circulation, I might refer to the splendid experiments made by Mr. Stanton, and published in the *Philosophical Transactions*, Vol. 190, where the law laid down by Professor Ser is more carefully proved.