INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1899-1900.

President: SIR JAMES LYLE MACKAY, K.C.I.E.

Volume XI.

EIGHTY-SEVENTH PAPER

(OF TRANSACTIONS)

EXPERIMENTS SHOWING DECREASE IN THE RATE OF EVAPORATION IN CONSEQUENCE OF INCREASE IN THE RATE OF CIRCULATION THROUGH TUBES.

BY

Mr. GEO. HALLIDAY

(MEMBER).

READ AT

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD.

ON MONDAY, DECEMBER 11th, 1899

PREFACE.

58, Romford Road,
Stratford, E.
Dec. 11*th*, 1899.

A Meeting of the Institute of Marine Engineers was held this evening, presided over by Mr. T. F. Aukland (Companion), when a Paper, by Mr. Geo. Halliday (Member), was read, on "Experiments showing the Decrease in the Rate of Evaporation in consequence of Increase in the Rate of Circulation through Tubes."

This Paper was prepared in order to give to the Members the results obtained from the experiments which have been conducted here by the Experimental Committee, of which Mr. Halliday is Convener, with the apparatus presented to the Institute.

Members are invited to take part in the experiments, and to offer comments on the Paper now published.

JAS. ADAMSON,
Hon. Secretary.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1899-1900.

President: SIR JAMES LYLE MACKAY, K.C.I.E.

"EXPERIMENTS SHOWING DECREASE IN THE RATE OF EVAPORATION IN CONSEQUENCE OF INCREASE IN THE RATE OF CIRCULATION THROUGH THE TUBES OF WATER-TUBE BOILERS."

By MR. GEO. HALLIDAY (Member).

READ AT 58, ROMFORD ROAD, STRATFORD,
MONDAY, DECEMBER 11TH, 1899.

CHAIRMAN.
Mr. T. F. AUKLAND (Companion).

Former experiments were made to see whether molecular change of the water was the cause of the increased absorption of heat by water at the boiling point, as set forth in a previous paper. We found that at the boiling point there was rather less absorption of heat than at lower temperatures. This was the condition of things when the effects of more rapid motion of the water were eliminated. An attempt was also made to find whether there was a constant increase of absorption of heat by the water as the speed of the water through the tubes increased. It was found that the absorption of heat did rise with an increase of velocity up to a certain point, but after that point in the velocity was reached the absorption fell off, and continued to fall off as the speed of the water through the tube continued to increase. This point in the speed of the water where the maximum rate of absorption of heat occurred was not constant. It varied under the influence of various factors. The speed at which the maximum effect took place rose as the quantity of heat supplied to the tube increased. So did the quantity of heat absorbed, rise. The quantity of heat absorbed rose also with the quantity of heat supplied to the outside of the tube.

In these experiments we only dealt with water. We did not deal with water and steam. Steam was not evaporating from the moving water when the results were noted. That being so it would not be fair to conclude that water while giving off steam behaved in the same way as water did under changes of velocity. Water while evaporating steam might behave quite differently to water alive without steam. Water when evaporating steam does not run through the tube as water but as water and steam, and therefore the effect of the presence of the steam may change entirely the conditions. What was sought in the following experiments was to apply heat to the outside of a tube through which water was flowing and note the quantity of steam given off while the water was moving at different velocities. The quantity of heat was also varied and the quantity of steam given off under the different conditions were noted. First of all it may be premised that the accepted view is that the evaporation increases with the rapidity of circulation of water through tubes; that is, the faster the water runs through tubes it is believed the quicker is the evaporation of steam. Professor Perry even says the water ought to be forced through the tubes with a pump, and John Elder designed a boiler on this principle. This is the universal view with one exception. "The Engineer" has held that this is not true. It has always held that circulation is an evil, after a certain point. It says: "So long as the surface is wetted; so long as the circu-

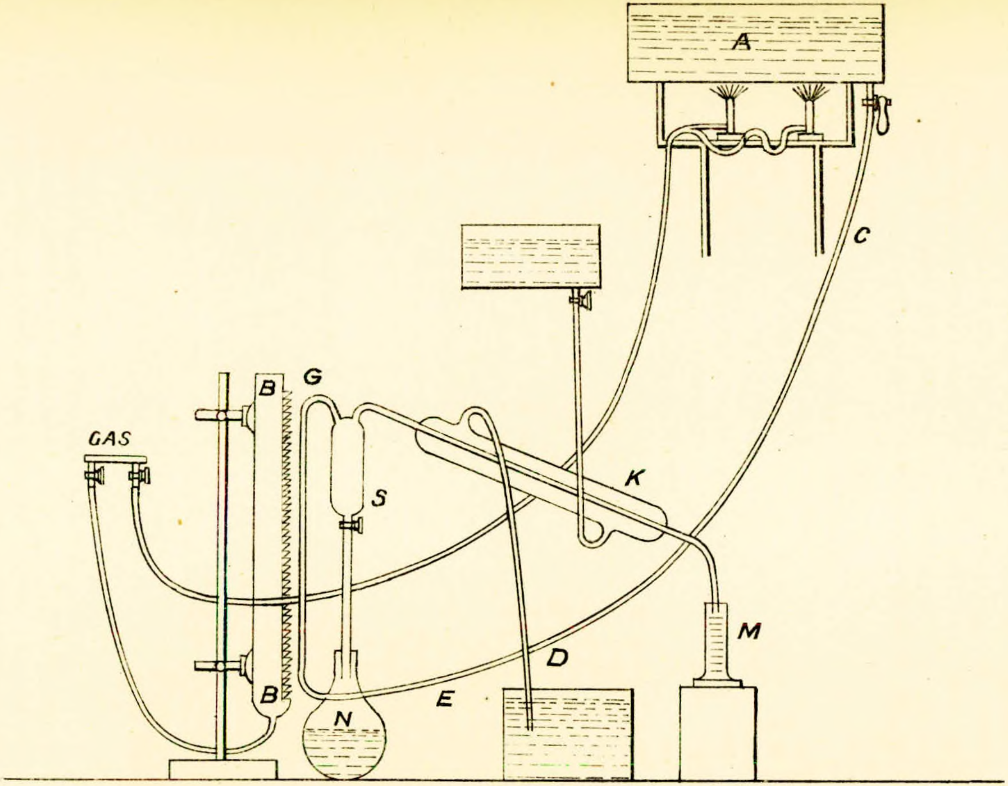

FIG. I.

lation is sufficient to provide a wetted surface that is enough. Anything beyond that is injurious." I do not know that any experimental proof has been given to demonstrate this. My belief is that it is a conclusion drawn by engineering instinct led up to by watching the action of water on hot surfaces. However that may be, the statement was made that circulation after a certain rate has been reached, is injurious.

The experiments were made with the apparatus shown in Fig. 1. Water was heated to boiling point in the tank A and allowed to run through the india-rubber tube CD to the copper tube EG. As the water flowed up the copper tube it was heated by means of a Fletcher burner FB and steam was generated. Steam and water flowed into the separator S which has two necks at the top, and a small tap at the bottom. Steam and water flow from the copper tube by one neck at the top of the separator; the water is drained off at the bottom and the steam escapes out at the other neck at the top into a condenser K. The steam is condensed in the condenser and falls into the measure M. The steam generated is thus measured as water in M. The water which flows through the tube without being evaporated is measured from N. The sum of the two gives a measure of the circulation.

First, the flame of the Fletcher burner was kept constant; that is, the heat supplied was kept constant. Under this condition it was sought to determine the influence of the rate of circulation. The rate at which the water moved through the tube was varied. It was sought to determine whether the amount of evaporation remained constant with the heat supplied or varied with the velocity of the fluid through the tube.

The second question was whether the evaporation increased with the speed of the water and steam through the tube or in what way the evaporation was affected by the velocity of the water and steam through the tube.

First, then, the tank supplying the water was heated to the boiling point, until it gave off steam freely. Then the Fletcher burner was lit and the flames allowed to play on the copper tube. Then the water from the tank was turned on and allowed to run. After the water had gone through the heated part of the tube, steam and water together flowed through the separator S into the flask N. After that, the cold water was turned on at the cold water tank and made to flow through the condenser K. By that time the whole apparatus was in full working order.

The period settled for each experiment was four minutes. At the end of four minutes the water in N was measured and the condensed steam in M measured also. The sum of the two gave the quantity of water run through the tube for four minutes, and that in M the quantity of steam evaporated for four minutes. After the first four minutes 14 cubic centimetres of water were found in the measure M. This meant that 14 cubic centimetres of water had been evaporated during the same time that 175 cubic centimetres of water had run through the tube without having been evaporated. This quantity, 175 cubic centimetres, was found at the end of the first experiment in the flask N. The total water which had flowed through the heated copper tube was thus 189 cubic centimetres.

When these had been measured, the water in each measure was poured away and the apparatus got ready for a second experiment. The flame and the gas supplied to the Fletcher burner were left the same as before. This flame was kept the same through the full set of experiments. To start with, the water and steam were allowed to run right through the separator S. As soon as the time to start began the water and steam were shut off in the separator by means of the small tap at the bottom, and the flask N cleared out. When placed below the separator the water was run into it again, but a little water was always left in the bottom of the separator to prevent steam blowing through.

The steam then flowed through the second branch at the top of the separator got condensed and flowed into the measure M. At the end of the four minutes the condensed steam was measured in M and the water in N. The result of the second experiment was that at the end of four minutes 18 cubic centimetres of steam had been condensed and 140 cubic centimetres of water had run into the flask N. The total quantity of water which had flowed through the copper tube was thus 158 cubic centimetres.

The results of the sets of experiments were as follows:—

Time.	Water evaporated in c.c,	Water not evaporated in c.c.	Total water flowing.
8.40 to 8.44	14	175	189
8.47 „ 8.51	18	140	158
8.55 „ 8.59	19	110	129
9.2 „ 9.6	$21\frac{1}{2}$	100	$121\frac{1}{2}$
9.9 „ 9.13	23	80	103
9.16 „ 9.20	24	70	94
9.22 „ 9.26	$23\frac{1}{2}$	70	$93\frac{1}{2}$
9.28 „ 9.32	12	750	762
9.37 „ 9.41	14	650	664
9.42 „ 9.46	15	560	575
9.47 „ 9.51	18	360	378
9.57 „ 10.1	22	100	122
10.2 „ 10.6	23	70	93
10.8 „ 10.12	$24\frac{1}{2}$	30	$54\frac{1}{2}$

Here, then, are two sets of results:—

Velocity of water.	Water evaporated.
$93\frac{1}{2}$	$23\frac{1}{2}$
94	24
103	23
$121\frac{1}{2}$	$21\frac{1}{2}$
129	19
158	18
189	14

In the second set we have:—

Velocity of water.	Water evaporated.
$54\frac{1}{2}$	$24\frac{1}{2}$
93	23
122	22
378	18
575	15
664	14
762	12

The curve A represents the first set and the curve B the second set. The curves below in Fig. 2 show the variation of the evaporation in consequence of the variation of the velocity of the water and steam through the tube.

In these experiments there is the bare surface of the separator S and the uncovered surface of G, and so there will be condensation of steam from this cause. The quantity of steam condensed in the condenser and measured in M will not give the total quantity of water evaporated. But since the duration of each experiment is the same, namely, four minutes, and the temperature of the steam and water about the same each time, the radiation and condensation of the steam will be about the same each time. It may thus be taken that the quantity of steam condensed in consequence of the naked surface of the separator and tube leading to it, the loss in each case will be about the same. The quantity of water evaporated in the above experiments should, correctly, be increased each time by very nearly a constant quantity. But, approximately, we obtain comparative results, and since we merely wish to determine the effects of speed and the quantity of heat supplied to the tube on the evaporation in the tube the results may be looked on as supplying an indication of the behaviour of the water under the different influences.

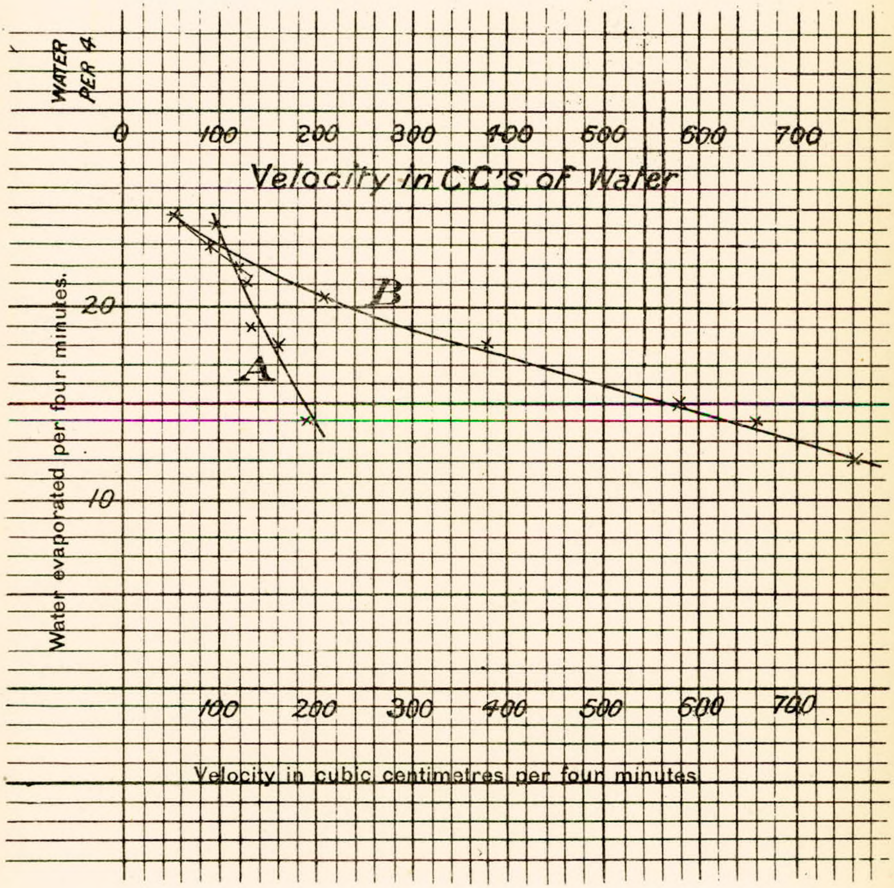
WATER
PER 4
0
100
200
300
400
500
600
700
Velocity in CC's of Water
B
A
20
10
Water evaporated per four minutes.
100
200
300
400
500
600
700
Velocity in cubic centimetres per four minutes.

FIG. 2.

The following are the results of another set:—

Time.		Water evaporated in c.c.		Water not evaporated in c.c.		Total water flowing.
6.40 to 6.44	..	27½	..	33	..	60½
6.45 „ 6.49	..	27	..	32	..	59
6.50 „ 6.54	..	27½	..	33	..	60½
6.55 „ 6.59	..	28	..	37	..	65
7.0 „ 7.4	..	27½	..	35	..	63½
7·5 „ 7·9	..	27	..	36	..	63
7.10 „ 7.14	..	27	..	40	..	67
7.15 „ 7.19	..	26	..	54	..	80
7.20 „ 7.24	..	26	..	56	..	82
7.28 „ 7.32	..	20	..	200	..	220
7.34 „ 7.38	..	12½	..	465	..	477½
7.39 „ 7.43	..	4	..	880	..	884

In the above set an attempt was made to evaporate all the water in the tube so that nothing else would come through but steam. As there were only india-rubber joints between the heating tube and the separator and the tube got quite red hot this was found impossible. It will be noticed, however, how constant the quantity of steam is which is evaporated. From 6.44 to 7.24, and from a rate of circulation of 59 cubic centimetres per four minutes, to 82 cubic centimetres per four minutes.

The following curve C, Fig. 3, shows the manner in which the evaporation falls with the velocity.

In the next set of results more heat was used at the Fletcher burner. Care was taken to begin with a large velocity and then gradually work down. The object was to see whether the very slowest rates of motion were followed by the greatest evaporations, or whether it was best to have some velocity. The results appeared to show that there was a maximum evaporation at a certain speed of the water. That, at very slow speeds, the evaporation was a certain amount, at higher speeds it was greater and there was a maximum. The figures and curve D show how the evaporation varied with the speed.

Time.		Water Evaporation		Water not Evaporated.		Total Water flushing.
7.47 to 7.51	..	12	..	830	..	842
7.52 „ 7.56	..	16	..	665	..	681
7.58 „ 8.2	..	31	..	190	..	221
8.3 „ 8.7	..	34½	..	110	..	144½
8.8 „ 8.12	..	36	..	62	..	98
8.13 „ 8·17	.	38	..	28½	..	66½
8.21 „ 8.25	..	30	..	10	..	40

The fire from the burners was then turned full on and no attempt was made to see whether there was a velocity which gave a maximum evaporation.

The result is given below and the curve representing the results by E, Fig. 3.

Time.		Water Evaporator.		Water not Evaporated.		Total Water Flowing.
8.24 to 8.42	..	40	..	36	..	76
8.29 „ 8.33	..	36	..	123	..	156
8.34 „ 8.38	..	35	..	170	..	205
8.39 „ 8.43	..	22½	..	635	..	657½
8.44 „ 8.48½	..	11½	..	1080	.	1091

The three curves C, D, and E, Fig. 3, show the effects of variation of the quantity of heat and also the velocity of the water through the tube. The curves appear to show that the fall off of evaporation in each case is at the same rate because the curves are nearly parallel. An addition of heat appears simply to raise the curve, that is, to increase the amount of evaporation. The curves also appear to show that a velocity which gives an evaporation about equal in quantity to the water not evaporated, gives the best result.

The above results were obtained by experimenting with the same copper tube throughout. The next experiments were with a copper tube of larger diameter of bore. The time of each experiment was, as before, four minutes. The period noted for the water to run through the tube was four minutes. The water was brought to the boiling point in the tank first, so that the flame had to deal with boiling water. The steam was separated from the water in the same way as it

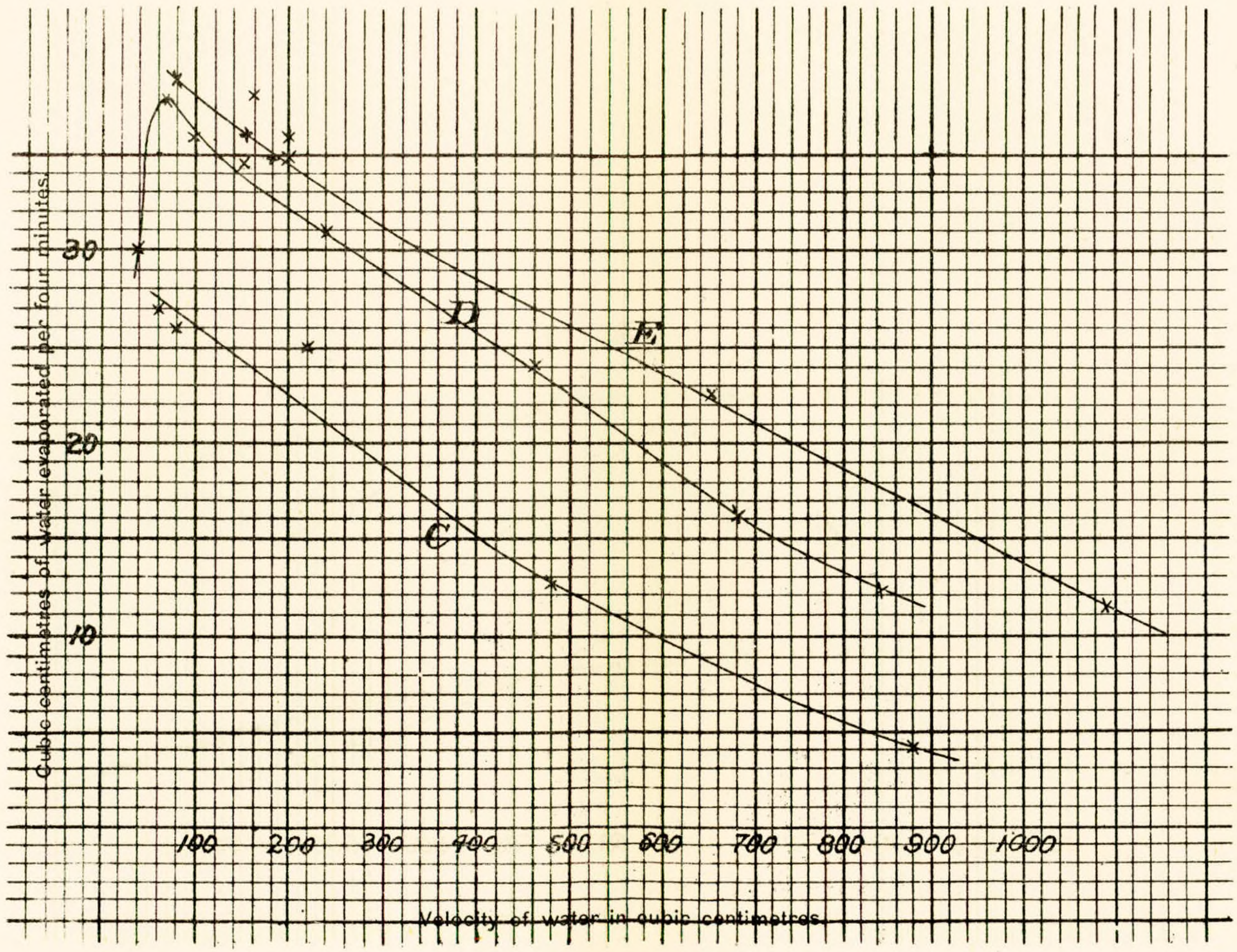
Cubic centimetres of water evaporated per four minutes.
30
20
10
D
E
C
100
200
300
400
500
600
700
800
900
1000
Velocity of water in cubic centimetres.

FIG. 3.

was separated in the former experiments. The totals in the fourth column represent the velocity of the water, and the second column the evaporation.

Here follow the results of experiments :—

Time.	Evaporation c.c's.	Water Not Evaporated.	Total.
7.39 to 7.41	20	155	175
7.45 ,, 7.49	30	41	71
7.51 ,, 7.55	26	104	130
7.57 ,, 8.1	25	130	155
8.5 ,, 8.9	16	600	616
8.12 ,, 8.16	20	420	440
8.17 ,, 8.21	23	285	308
8.22 ,, 8.26	27	170	197
8.27 ,, 8.31	31	75	106
8.32 ,, 8.36	32	36	68
8.37 ,, 8.49	29	8	37
8.42 ,, 8.46	10	2	12
8.47 ,, 8 51	35·5	5	40·5
8.52 ,, 8.56	26	80	106
8.57 ,, 9.1	18	460	478
9.2 ,, 9.6	15	690	705
9.7 ,, 9.11	7·5	1000	1007·5

Arranging these in the order of velocity we have :—

Velocity.	Evaporation.
12	10
37	29
40·5	35·5
68	32
71	30
106	26
106	31
130	26
155	25
175	20
197	27
308	23
440	20
478	18
616	16
705	15
1007·5	7·5

The manner in which the evaporation changes with the change of velocity is shown in Fig. 4.

It will be noticed that when the velocity is very small the evaporation is small. In these two cases the quantity of water supplied was insufficient and the effect was simply to heat the pipe. The highest evaporation was when the velocity was 40·5. In that case the evaporation was 35·5. Really all the water supplied was evaporated, and the greatest effect took place then. In the case where the velocity was 68 the evaporation was 32. In this case the quantity of water evaporated was about equal to the quantity not evaporated, yet there is a considerable fall of evaporation from the maximum. The general direction of the curve is plainly marked, and shows a general falling off with an increase in the velocity of the water through the tube.

The author wishes to acknowledge the kind assistance given him by the Experimental Committee.

DISCUSSION

HELD AT 58, ROMFORD ROAD, STRATFORD

ON MONDAY, DECEMBER 11TH, 1899.

CHAIRMAN:

MR. T. F. AUKLAND (Companion).

Mr. Alderman KIDD (Member) asked Mr. Halliday if he would explain how some of the extraordinary differences recorded in the paper came about, because this apparatus was not like the boiler of a steamship, and while it might be all very well as a matter of theory, it would be interesting to know exactly the conditions which gave these widely different results. According to one of the tables included in the paper, when 76 cubic centimetres of water were flowing through the tube, 40 centimetres were evaporated, but

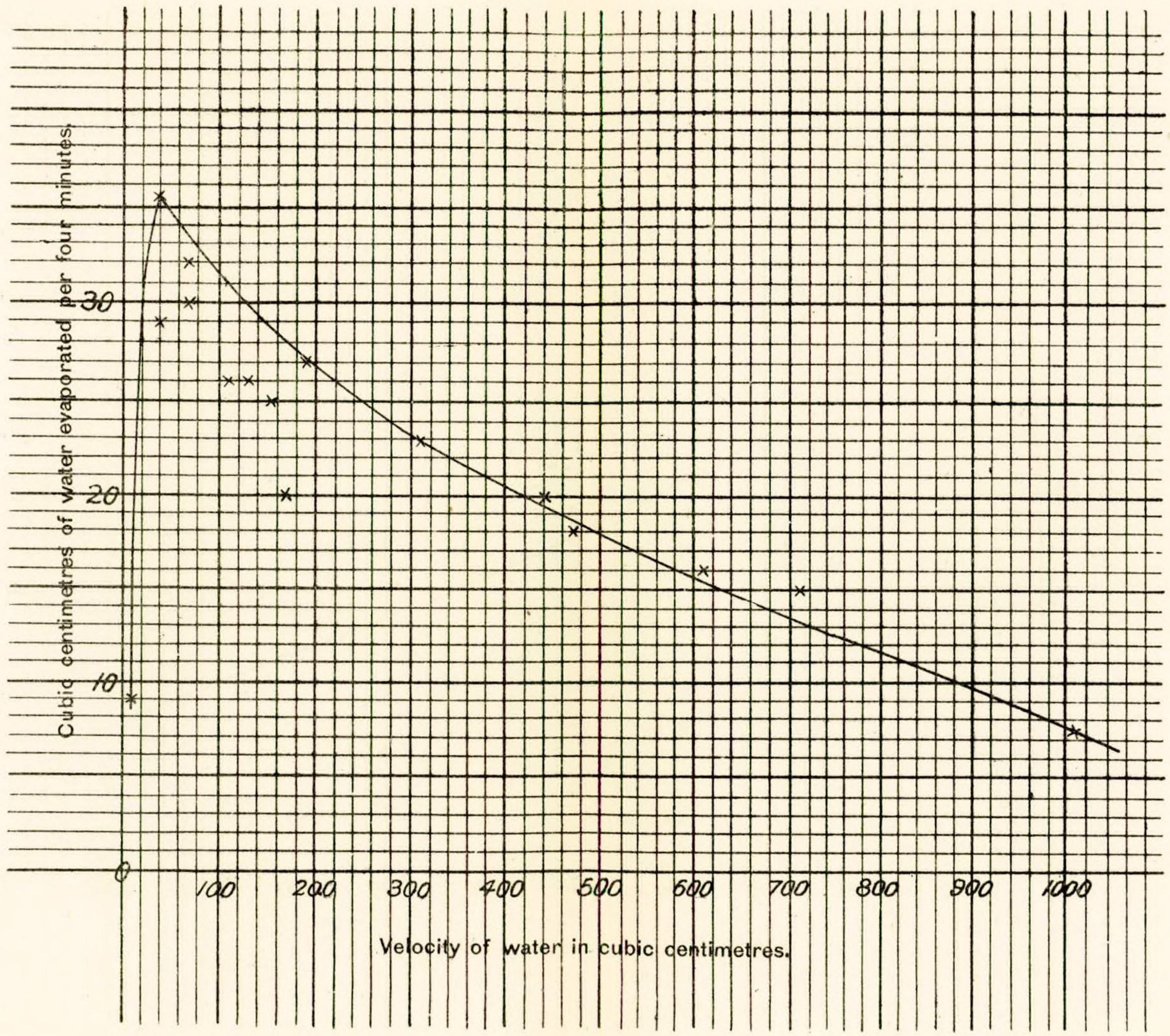
Cubic centimetres of water evaporated per four minutes.
0
10
20
30
100
200
300
400
500
600
700
800
900
1000
Velocity of water in cubic centimetres.

FIG. 4.

when 1091 centimetres of water were flowing only $11\frac{1}{2}$ centimetres were evaporated! How did the author account for this great difference? What was the explanation?

Mr. HALLIDAY said he could only reply that the figures given were the results of experiments that were carried out. The experiment was tried of allowing the large quantity of 1091 centimetres of water to flow through the tube when the evaporation was only $11\frac{1}{2}$ centimetres, but when the flow of water was slower and only 76 cubic centimetres of water were allowed to go through the tube, the evaporation rose to 40 centimetres. He had his theory as to the cause, but for the present it was perhaps sufficient to say that the figures represented the facts. It was simply a matter of observation. The facts existed, and there was no getting over them.

Mr. Alderman KIDD: May we ask this further question. Was there any pressure used to force this water through the tube?

Mr. HALLIDAY: No; only gravitation.

Mr. Alderman KIDD said it was possible to force cold water through tubes of this kind so speedily that there would be practically no evaporation at all. This experiment did not represent what went on inside a steamer's boiler, because in the boiler there was no pressure behind the water to force circulation.

Mr. HALLIDAY: My paper only deals with one particular point—the effect of circulation upon evaporation in water tube boilers. You may have a boiler so constructed that the circulation will be very rapid, while in another boiler the circulation through the tubes will be sluggish. My experiments go to show that the evaporation from the boiler which has a sluggish circulation will be better than the evaporation from the one which has a high rate of circulation. The effect of the results of these experiments is to advise people to so construct water tube boilers that the circulation through the tubes will be slow and not fast.

Mr. Alderman KIDD: In an ordinary boiler the circulation is controlled by the evaporation. Is that so?

Mr. HALLIDAY: No, because you can have circulation of the water before there is any evaporation at all.

Mr. Alderman KIDD: I should contend that before you get circulation you must have evaporation, but the principal point I make is that I cannot see how it is possible, with a flow of 1,091 centimetres of water through the tube to evaporate only $11\frac{1}{2}$ centimetres, without you have pressure to force the water through.

Mr. W. LAWRIE (Member) said he thought he must take the same exception to Mr. Halliday's experiments as had been taken by Mr. Alderman Kidd, for it would be seen from the diagram given with the paper that there was a head of water to assist the circulation. The tank A was some two feet above the tube, which gave a very appreciable head of water, and the pressure of the water must assist the circulation. They could see that the circulation could be very easily checked, or assisted. Under no conditions that he knew of on board ship was the water heated in the same manner as that adopted by Mr. Halliday, and altogether he very much questioned the practical value of the experiments described in the paper. No doubt the figures given by Mr. Halliday were absolutely correct, but they would be much more useful and valuable if the apparatus employed were altered so as to reproduce to a greater extent the conditions obtained on board ship. The nearer the conditions of the steamer's boiler could be approached in these experiments, the more satisfactory would be the results from an engineer's point of view.

Mr. McLAREN (Member) said that, as a member of the Experimental Committee, which had been engaged in these experiments, he must, of course, admit that there was a pressure of water to assist the circulation, and that it was possible to force the circulation at will. After discussing the matter with Mr. Lawrie, he was inclined to think that they ought to try the experiment of having the water tank on a level with the tube, and he believed that Mr. Halliday would be induced to try this method at the next opportunity, if only to see the difference it would make. He certainly hoped that these experiments would be continued, and that an effort would be made, as Mr. Lawrie had suggested, to approach, as nearly as possible, the actual working conditions of a boiler on board ship. At the same time, the experiments which Mr. Halliday had undertaken were not directed to any question of consumption, or the use made of the heat obtained. They were on the question of evaporation, as it was affected by circulation, and the results showed that the greater the flow of water the less was the evaporation, the less the flow the greater the evaporation.

Mr. Alderman KIDD: I would also like to suggest that if Mr. Halliday takes up these experiments again, he should take the water on a dead level, and let it circulate by itself. He will get much more practical results in that way.

Mr. SHEARER (Member) said he quite coincided with the views to which Mr. Lawrie had given expression on the subject.

Mr. LAWRIE: I think we all appreciate Mr. Halliday's tenacity of purpose in trying to get at the bottom of this subject, and I can quite believe that he sees himself that this apparatus can be improved, but it will cost money, and in carrying out experiments like this his hands are to a great extent tied. I think that if the Members of this Institute gave proper assistance there is no doubt that Mr. Halliday could work out most useful results; and it would be to the credit and advantage of the Institute if he had the opportunity.

Mr. HALLIDAY said that some Members had taken exception to his experiments because they had not been carried out with an apparatus that was like an ordinary boiler. But the difficulty with an ordinary boiler was, not that they could not see through it, but that they could not control the circulation. In an ordinary boiler the circulation was increased by increasing the fire, but he wanted to vary the circulation with the same fire, in order to observe the effect of speed of circulation upon the evaporation. An ordinary boiler would not, therefore, suit his purpose. Another difficulty was that with an ordinary boiler there was no proper means of measuring the circulation. In the apparatus which he used for his experiments, instead of having a tank to produce a pressure—a head of water—he could have used a pump and varied the rate at which he pumped in the water. The question was, however, did this element of pressure very much affect the particular point that he was investigating—the effect of circulation upon evaporation? Was it very material for this purpose how the circulation was brought about? His object was to get a number of comparative results to show the evaporation with different rates of circulation.

Mr. Alderman KIDD: I concede at once that more circulation does not mean more evaporation, but I do think that any experiments made with this machine or any other in connection with this Institute, ought to be made with the object of benefiting the marine engineer by increasing his knowledge, and if the experiments were brought down to the conditions of ordinary working in a marine boiler, we should get far more valuable and useful results.

Mr. HALLIDAY: I only say this—Do not make a water tube boiler which gives rapid circulation, because it is not a good one.

The CHAIRMAN said he had been requested by the Hon. Secretary to remind the meeting that these practical experiments, arranged by the Experimental Committee, were carried on every Friday evening, at the Institute premises, and that the attendance and assistance of Members was invited.

Mr. J. R. RUTHVEN proposed, and Mr. LAWRIE seconded, a vote of thanks to Mr. Halliday for his paper.

At the instance of Mr. Alderman KIDD, a hearty vote of thanks to Mr. Aukland for presiding was carried by acclamation.

The CHAIRMAN, in the course of his response, said that during the discussion a very good suggestion had been thrown out. It had been suggested that further apparatus should be provided for experimental work in connection with the Institute, and he desired to say that he should be very happy to subscribe towards any fund that might be established for defraying the cost. He thought that experiments of the kind were very valuable, and that it was for the benefit of the engineering profession at large that they should be continued, and even extended.