On the Utilisation of the Water of Condensation from Steam Pipes and Cylinders.

By Mr Peter Fyfe.

(SEE PLATE II.)

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The subject of the utilisation of the water of condensation in its practical aspect came before me towards the end of 1886, in connection with the treatment and washing of the city's infected clothing at the wash-house, Belvidere.

For the years 1885 and 1886, I observed that each article of clothing under treatment took in the former 3·9 lbs. of coal, and in the latter 4·3 lbs. of coal, which for 325,128 articles in the one and 281,456 articles in the other, meant a consumption of 481 and 454 waggons of coal respectively.

I got the drying stove reconstituted and divided, and, for the purpose of saving all the hot water of condensation, designed a "return steam trap," which I will have the honour of explaining to the Institute.

The improvements instituted at Belvidere effected in the following year a saving of 1·33 lbs. of coal per article over the year 1885, 1·73 lbs. of coal per article over the year 1886, and last year this rate of saving per article was very slightly increased.

When our Secretary, therefore, asked me about a month ago if I would undertake to submit a short paper to this Society, I thought it would not be time altogether wasted if I ventured to lay before you a few considerations on steam raising and the utilisation of its heat when spent as steam, and also introduce to your notice a new apparatus, which I designed, in order to stop the waste which was being caused by the hot condensed water continually passing away into the drains and sewers.

I am afraid, from what I have seen in several of our manufactories and workshops, that not only is an enormous amount of the practical thermal value of the steam raised in them lost when it finds its way skyward through the exhaust pipe, but that a serious loss is also experienced daily, through the water of condensation from the various pipes and cylinders finding its way earthward by way of the drains.

In the earlier days of steam, the products of manufacture under steam treatment commanded such prices as handsomely repaid the manufacturer for his outlays, and he could afford for a long time to ignore the constant drain upon his oncost through such losses as were caused by *direct exhaust*, *imperfect combustion*, and *hot water waste*.

But now, except where the manufacturer has the good luck to possess a monopoly, none of these items of waste must be lost sight of.

Competition is the mother of improvement in applied mechanics, and real improvement is the mother of economy.

To have any chance now in making the sale of his products pay, the average manufacturer has to guard well every outlet in his factory which may be a useless drain upon his resources.

It is well enough known that the steam engine cannot produce in work one-fourth of the practical thermal value of the coal burned in his furnace. So also when the steam is applied for heating and drying purposes, a waste is caused if the condensed water is permitted to flow away through cocks or atmospheric traps.

Before considering the amount of this waste, I would like to take you through the old story for a few minutes of the quantity of fuel which must be consumed in order to obtain the heat necessary to evaporate water to a pressure of one atmosphere.

One pound of water at 32° Fahr. requires 180·9 units of heat to raise its temperature to 212° = the boiling point. As you are aware, however, a much larger increment of heat must be taken up by the water before steam can be formed from it. This amounts to 966 units of heat which, entering into the steam, is not sensible to the thermometer, and has therefore been termed latent. The total heat units therefore taken up by steam from water at 32° = 1146·9. I will, however, put the ordinary temperature of unheated feed-water at 40°, so that 8 units of heat less will suffice.

A cubic foot of water, therefore, will absorb 10,730 heat units from 40° to 212°, and 60,267 heat units more to evaporate it to steam of 1 atmosphere. Thus a total of 70,997 heat units passes from the fuel into the steam formed from this quantity of water at 40°.

Now let us put the theoretical calorific value of 1 lb. of coal at 12,000 heat units. In an average boiler, 1 lb. of coal, it is allowed, will communicate 7000 of its heat units to the water, so that 70,997 ÷ 7000 = 10 lbs. of coal to evaporate 1 cubic foot of water at 40°. This is equivalent to 6·23 lbs. of water per lb. of fuel.

To convert steam at the absolute pressure of 15 lbs. per square inch to steam at any moderate pressure, requires a further small increment of heat. Regnault's formula is, $h = 1082 + (\cdot 305 \times t)$ in which h is the units of heat necessary per lb. of steam of any pressure, the water being 32° Fahr., and t is the temperature of the steam required.

Working this out we find that the units of heat required for water at 40° to steam at 40 lbs. pressure above the atmosphere are 1161·5, so that for all practical purposes we may at present disregard the difference from the units required for steam of 15 lbs., absolute pressure.

Having now got the expenditure of coal to evaporate 1 cubic foot of water into steam, let us see how it may be expended in turn through radiation from steam pipes and cylinder.

The amount of heat which radiates from hot surfaces into the surrounding atmosphere is directly as the difference between the hot surfaces and the temperature of the atmosphere. From small pipes under 12″ diameter, the radiation per square foot of surface exposed is not constant. It varies in an arithmetical ratio inversely as the square of the diameter.

So that we see small pipes radiate more per superficial unit of surface than larger ones up to 12″ diameter. Above this diameter it has been found that radiation is directly as the surface exposed.

In investigating the amount of condensation in cubic feet of steam, which takes place in steam pipes, there are two facts which must be discovered—

1.—The units of heat radiated per hour.

2.—The latent heat per cubic foot of the steam in the pipes.

When these are found, the former divided by the latter gives the condensation per hour of steam in cubic feet. All large drying stoves when heated by steam have to be brought up to a required temperature *gradually*, so that for the first 40 or 60 minutes the same formula which applies to uncovered steam pipes in a factory, exposed to the surrounding atmosphere, applies during the first hour or so to them, so far as their power of condensing steam is concerned.

So for the first hour, let us see what our drying stove at Belvidere is capable of condensing—

Let L = The length of piping in feet, = 4401 feet.
,, l = The diameter of pipes in inches, = 2·25 inches.
,, T = The temperature of steam in pipes, = 269° (25 lbs. pres.).
,, t = The temperature of air, = 40° at start.
,, h = No. of heat units radiated per hour.
,, c = Cubic feet of steam at T condensed per hour.
,, H = Latent heat per cubic foot of steam, = 88·14.
,, x = Exponent for draught of air in stove, = 1·2 (calm).

h will be found by the formula.

I. $h = \frac{\text{L}l}{3404{\cdot}8}\left[450 + (12 - l)^2\right](\tau - t)^x$. Or, in figures,

$$h = \frac{4401 \times 2{\cdot}25}{3404{\cdot}8}\left[450 + (12 - 2{\cdot}25)^2\right](269 - 40)^{1{\cdot}2}.$$

II. Then $C = \frac{h}{H}$.

The working out of this formula is as follows :—

	$269 - 40 = 229$ = log.	2·3598355
Multiply by exponent $x = 1·2$	-	1·2
		47196710
		2·3598355
	$(269 - 40)\ 1·2 =$	+ 2·83180260
	$(12 - 2·25) \div 450 = 545 =$	+ 2·7363965
	$2·25 \times 4401 = 9902 =$	+ 3·9957229
		9·5639220
Coefficient 3404·8	- - =	— 3·5320916
Total units of heat lost = h = 1,076,090 =		6·0318304
The latent heat of steam = H = 88·14 log.		— 1·9451730
		4·0866574

and 4·0866574 being the logarithm of 12,284 c = 12,284 cubic feet of steam at 25 lbs. pressure above the atmosphere, condensed during the first hour ; or, 1 yard of $2\frac{1}{4}''$ pipe condenses 8·37 cubic feet of steam per hour.

This is equal to 19·4 cubic feet of water at 212° or 18·6 cubic feet at 40°.

So that if all this water of condensation passes away from this system of pipes into the drains, 12 per cent. of 18·6 × 10 = 186 lbs. of coal are lost in the first hour of each day, = 22·68 lbs., or over 3 tons per annum. For the other eight hours of the day, I take the following to be a fair estimate of the work of the steam when 3000 articles of clothing are being treated. I found by the anemometer that about 4000 cubic feet of air at 130° Fahr. escapes from the stove per minute. Now the steam has to do two duties in the stove after the first hour. First, it has to evaporate about 5 grains of moisture from the damp clothes per cubic foot of air discharged ; and, second, it has to heat to 130° 4000 cubic feet of air per minute, drawn from the underground passages where it was found to be 85° of temperature.

So I find in eight hours 224 lbs. of coal are consumed for the first, and 1800 lbs. of coal for the second duty. In all, 2024 lbs. of coal per day to do this work, supposing the stove is kept full of clothes.

Now, as 2024 lbs. of coal will evaporate 202 cubic feet of water from 40° Fahr., 202 cubic feet may be taken as the daily flow of condensed water from the whole of the stove.

If this all passes into the drains (which it used to do at Belvidere) instead of being returned to the boiler at 180°, 140 heat units are lost for each lb. of water so wasted, which is equivalent to 251 lbs. of coal daily thrown away by such a proceeding, or about 34 tons per annum. To this add the 3 tons which are lost during the first hours of the days, and a grand total on this stove of 37 tons of fuel are cast away yearly into the common sewer.

Now, 37 tons at 7s = £16 19s, which does not look much, but when it is remembered that at a cost of something like twice that sum, a set of suitable traps and pipes to put the hot water back into the boiler can be erected in ordinary circumstances, the saving is seen to yield 50 per cent. on the outlay, which may be reckoned a first-class investment.

In the case of steam cylinders and pipes which do not carry their steam for heating purposes, but in order to produce force or obtain horse-power from it, a much greater waste is experienced than what I have recorded above, by letting the water of condensation *under considerable pressure* escape, the cause of this being that the water under such pressure in the pipes is almost of the same temperature as the steam, and only wants a place to expand, in order to fly into steam. Say we have water in the steam pipes or cylinders under a pressure of 40 lbs. above the atmosphere, and it finds its way to any atmospheric steam trap, and gets vent from it in the usual way, what would we see? We would just see what is to be seen daily in such traps, viz., a constant fizzle of steam and water coming from it—not, mark you, because the traps are really passing any live steam out of the pipes, but because the water they are passing into a tank, or into the drains from high pressure pipes, at once expands into steam on being set free from the pressure inside.

Now the sensible temperature of steam at 40 lbs. above atmosphere is 287°, and water compressed in a pipe, and in contact with such steam, will be of the same temperature. Let this water away through a trap or cock into the drain and you at once lose 1161·5 heat units per lb. of water so let off, or 10·34 lbs. of coal for every cubic foot of such water lost.

When one comes to consider the number of cubic feet of such high temperature water which yearly must flow away in a large factory, it does seem surprising that manufacturers and engineers do not pay more attention to the matter.

Percentage of Fuel gained by Feeding the Boiler with Hot Water.

Temp. of Feed.	32°	40°	50°	60°	70°	80°	100°	120°	140°	160°	180°	200°
32°	0	— 1	— 1·5	— 2	— 3·4	— 4·4	— 6·5	— 9	— 11	— 13	— 16	— 19
40°	+ 1	0	— 0·5	— 1	— 2·4	— 3·4	— 5·5	— 8	— 10	— 12	— 15	— 18
50°	+ 1·5	+ 0·5	00	— 0·5	— 2	— 3	— 4	— 7	— 9	— 11	— 14	— 17
60°	+ 2	+ 1	+ 0·5	00	— 1·4	— 2·4	— 3·5	— 6	— 8	— 10	— 14	— 16
70°	+ 3·4	+ 2·4	+ 2	+ 1·4	00	— 1	— 3	— 5	— 7	— 9	— 13	— 15
80°	+ 4·4	+ 3·4	+ 3	+ 2·4	+ 1	00	— 2	— 4	— 6	— 8	— 12	— 14
90°	+ 5·4	+ 4·4	+ 4	+ 3·4	+ 2	+ 1	— 1	— 3	— 5	— 7	— 13	— 15
100°	+ 6·5	+ 5·5	+ 5	+ 4·4	+ 3	+ 2	00	— 2	— 4	— 6	— 9·5	— 12
110°	+ 7·6	+ 6·6	+ 6	+ 5·6	+ 4·2	+ 3·2	+ 1	— 1	— 3	— 5	— 8	— 11
120°	+ 8·7	+ 7·7	+ 7	÷ 6·7	+ 5·3	÷ 4·3	+ 2·2	00	— 2	— 4	— 7	— 10
130°	+ 9·8	+ 8·8	+ 8·3	+ 7·8	+ 6·4	+ 5·4	+ 3·3	+ 1	— 1	— 3	— 6	— 9
140°	+ 11	+ 10	+ 9	+ 9	+ 8	+ 7	+ 4·5	+ 2	00	— 2	— 5	— 8
150°	+ 12	+ 11	+ 10	+ 10	+ 9	+ 8	+ 5·5	+ 3	+ 1	— 1	— 3	— 7
160°	+ 13	+ 12	+ 11	+ 11	+ 10	+ 9	+ 6·5	+ 4	+ 2	00	— 2	— 6
170°	+ 15	+ 14	+ 12	+ 12	+ 12	+ 11	+ 8	+ 6	+ 4	+ 2	— 1	— 4
180°	+ 16	+ 15	+ 14	+ 14	+ 13	+ 12	+ 9	+ 7	+ 5	+ 3	00	— 3
190°	+ 17	+ 16	+ 15	+ 15	+ 14	+ 13	+ 10	+ 8	+ 6	+ 4	+ 1	— 2
200°	+ 19	+ 18	+ 17	+ 17	+ 16	+ 15	+ 12	+ 10	+ 8	+ 6	+ 3	00
212°	+ 20	+ 19	+ 18	+ 18	+ 17	+ 16	+ 14	+ 11	+ 9	+ 7	+ 4	+ 1

The principle involved in the "return steam trap" (see Plate II.) is, so far as I know, a new one. It consists in utilising the steam pressure in the trap, both for stopping the discharge of the condensed water, and for starting its flow. The operation of valve closing and valve opening in this apparatus is not therefore obtained as in ordinary "float" traps and "pot" traps by the difference of weight caused by the float or pot being immersed in water or otherwise. In the well-known "pot" trap the floating power of the pan when emptied of its water is all that can be depended upon for closing the valve; and its excess of weight when full over its floating potentiality when empty, must open the valve. This being the case, the outlet valve must be necessarily of the smallest dimensions, something like in ordinary sizes $\frac{1}{4}$ inch diameter. Hence a very small quantity of sedimental matter coming into the trap from the steam pipe or cylinder is sufficient to render it inoperative.

All traps also which depend upon the difference of expansion in the metals of which they are composed, under variation of temperature, or through the movement got on a flexible disc of metal, being acted upon by the expansion of highly volatile liquids, such as ether or alcohol, are open to the same objection. These latter are also open to the objection that an equilibrium becomes established, and water and steam flow through them in constant driblets. They may also at any time, when the condensed water comes to them in any great volume, allow it to back into the pipes and be carried away with the steam.

In the trap which is illustrated in the figure (see Plate II.) the water and steam enter E at the bottom into a small chamber distinct from the trap chamber proper, which is shown at A, B. This serves the double purpose of retaining pieces of solid matter and sediment which invariably find their way into all traps, and also prevents the ball or float being vibrated by the ebullition caused when the steam has immediate access to the main chamber.

The water rises in this chamber and flows over the top of the partition at X into A, B. At this time the balanced strong copper float, L, is lying at the bottom. In this position it admits, through the three-way cock, I, steam into the small chamber, D, which is fitted at the bottom with a flexible disc, H. This disc bears on the top of the outlet valve, G, and so long as the steam is kept in the chamber, D, the valve is kept closed so that no water can escape.

This action continues until the water reaches the top of chamber, D. At this point the steam is cut off from D, and a communication is opened between D and the outer air through the small pipe, Y. This relieves the pressure in D, and the steam at once forces the accumulated water almost full bore up through the valve seat, F, into the chamber, C, and out through W to a distance or height corresponding to the pressure of the steam in the trap.

As the float falls in the trap, the communication is closed between D and the open air, and opened between D and the chamber, A, B, when the steam pressing on the flexible disc closes the valve until the water accumulates again, when the action described is repeated.

It might be thought that the pressure of the steam in D would simply counteract the pressure on the under side of the valve, G, but this has from experience been found not to be the case.

So long as no obstruction exists in the valve, no water nor steam escapes until the ball has risen cutting off the connection.

When the valve is, from any small obstruction, leaking water continuously, a small rod having an eccentric motion, which passes through the hole, Z, in the head of the valve, is turned by a handle situated at the side of the trap; this lifts the valve and permits a full blow through, which at once relieves the valve.

M is a small air valve to let the air off which always accumulates in steam pipes and cylinders. Here, then, we have a steam trap actuated mainly by the steam itself, discharging its water at any temperature desired, to any place consistent with the pressure behind it.

In order to have the *full* benefit from such traps, it is necessary to conduct their water back to a similar apparatus of somewhat larger dimensions, placed 10 or 12 feet above the boilers. This apparatus is shown in Plate II., Fig. 2. It consists of a chest arranged in a similar manner. The steam cock communicating with the chamber, D, is placed on the outside of the apparatus, and the float lever, K, which works on a pin, P, inside the trap communicates its motion to the lever, which is forked so as to allow a considerable play on the float. Before it begins to operate on the cock, I, when the float, L, is at the bottom of the apparatus, the outside lever, S, with the back balance weight on it has tilted the lever of the valve, so that the steam from the boiler is admitted to D, thus keeping the valve, G, closed. As the water rises in the trap, the outside lever, S, is gradually brought over the vertical position by the pins, PP, on the lever, L, and falls to the right (see Fig 3, Plate II.), opening the communication between the boiler and the chamber of the trap, and closing it between the boiler and the chamber, D.

The water is then forced out through the valve, G, and by force of gravity runs into the boiler through a small check valve placed on the delivery pipe.

Thus the alternating action is kept up, and all the water accumulating in the various traps, by being connected to this apparatus, is fed into the boilers at whatever temperature and pressure it may have on arriving at this second trap.

Considering that much waste of fuel attends our present system, I have been tempted to lay before you this paper, and the apparatus I have designed. I have been for some years so dissociated from engineering proper, and so engrossed in matters relating to the public health, that I may have overlooked some better designs for the same purpose.

The discussion of this paper was set down for the 21st January, 1890, but no one responding to the President's invitation, he said that Mr Fyfe had brought forward a very good paper with respect to an important matter—the utilisation of condensed water from steam pipes and cylinders, which was usually allowed to go to waste. Mr Fyfe had carried out this in a very efficient manner; and had clearly described it in the paper he had read, and therefore, he deserved a hearty vote of thanks from the meeting for bringing the subject before them.

UTILIZATION OF THE WATER OF CONDENSATION FROM STEAM-PIPES AND CYLINDERS. By Mr. PETER FYFE.