

The next paper on the list, "On a Boiler and Condenser suitable for extending the Cornish Economy, and for preventing Boiler Explosions," was read by the author, Mr. T. Craddock. A small working engine was also placed before the members.

"In submitting to the meeting the subject of this paper, it appears desirable to call attention to the well established practical data, from which, by the Cornish system of generating and using steam, such economical results have been obtained. To this end, a very brief review of the various laws or principles immediately bearing upon the subject, seems to be essential for placing the matter in its proper light before the meeting. For this purpose, perhaps the classified mode is the preferable one.

"Firstly,—we have to do with the laws by which heat is transmitted from hotter to colder bodies, and *vice versa*. These demand in our steam boilers and condensers an extensive surface, and, as far as other circumstances will allow, that such surface be composed of thin metal. It is further necessary, if we would produce the greatest economy in the generation of steam, that the heat produced in the furnace be, to as great an extent as possible, absorbed by the water; this is best effected by a sub-division of the gases, by a slow draught, and by completely surrounding the combustible matter in the furnace by the water in the boiler.

"Secondly,—the hydrostatic laws require, in order to render high-pressure steam equally safe from explosion as low-pressure, that we diminish the sectional area of the interior surface of the boiler upon which the pressure of the steam acts, in the same ratio as we increase its pressure. If we do this, then the rending force, tending to burst the boilers, remains the same at whatever pressure the steam be generated.

"Thirdly,—the laws relating to latent and sensible heat, when considered in combination with large volumes of water, and subjected to the casualties attending the steam engine, suggests the diminishing the quantity of water necessary in steam boilers, as far as practical circumstances will permit, as one of the surest means of preventing destructive boiler explosions. The importance which attaches to the suggestion these laws present, becomes apparent when we consider the effects in case of explosion, which such an amount of sensible heat produces as that contained in the large volume of water necessitated in boilers of 60-horse power, for instance, and of the usual construction, as the sensible heat contained in so large a volume of water would, supposing the pressure of the steam to diminish from 40lbs. to 20lbs. per square inch, generate a volume of steam at 20lbs. pressure, equal to 30,000 cubic feet. Here we have a cause, equivalent to the diffusive and destructive effects exhibited in common and large boiler explosions. The boiler to which this paper refers reduces the danger from this cause nine-tenths, though the steam be generated in it at a temperature and pressure of 100lbs. per square inch. In this case, we find the sensible heat contained in the water required by such boilers would give but 3000 cubic feet of steam at 20lbs. pressure. The boiler under consideration is equally successful in diminishing the risk from explosion, arising from the rending strain due to the pressure of the steam; as on a comparison with the common boiler,—in which we suppose the steam at only 36lbs. pressure,—we find the rending force to be 5,400lbs., whilst in the tubular, even with 100lbs. pressure, the rending force amounts only to 900lbs., or but one-sixth of that given in the instance of the common boiler. The most obvious and certain conclusion to which such well established principles lead, cannot fail to shew how ill-grounded, and unscientific, must be the objections raised against high-pressure steam when generated in such boilers.

"Fourthly,—the laws relating to the expansive action of steam plainly indicate the importance of the two leading features of the matter before the meeting, namely, that of removing the atmospheric pressure from the exhaust side of the piston, on the one hand, and on the other, enabling us to make use of high-pressure steam with safety, as by the removal of the atmosphere in non-condensing engines, an economy is produced by this cause alone, equal to thirty-eight per cent., and by increasing the pressure of the steam at the commencement, we can obtain a further increased economy upon the Cornish system, equal to forty per cent.

"My boiler and condenser form part, only, of arrangements which have been practically proved to give the following advantages:—

- "An increased extent of grate surface.
- "A slow state of combustion.
- "Great extent of heating surface for the fire to act upon.
- "Increased facility for generating the quantity of steam required.
- "Water free from deposit for the use of the boiler.
- "Removal of the atmosphere from the exhaust side of the piston.
- "Insurance of safety from explosion.
- "Great facility for generating the steam under higher pressure by which the expansive principle is much extended.
- "Diminished tendency to priming.

"An effectual means of preventing the loss arising from steam blowing away at the safety valve.

"Self-adjusting means for keeping the steam at an uniform pressure, whatever the pressure desired may be.

"A continuous supply of pure water for the use of the boiler; it not requiring a *fresh* supply of more than one gallon per horse power, per day, to make good that lost by leakage.

"The engines and boilers compacted into a much less space, and not half the weight for equal power, as those in general use.

"THOMAS CRADDOCK."

Birmingham, April 26th, 1848.

The PRESIDENT enquired whether there would not be a liability in the top and bottom chambers to give way?

Mr. CRADDOCK replied, that he had had these boilers in use for five years, and he had worked them as high as 130 lbs.; but in general from 60 to 80 up to 100 lbs., and he had never detected any leakage whatever.

The PRESIDENT:—You expect a saving of fuel in this, I suppose?

Mr. CRADDOCK:—I do; but I am not at present prepared to submit the exact amount.

The PRESIDENT:—What vacuum do you get?

Mr. CRADDOCK:—I have got from 24 to 26 inches, mercury, and I do not despair of getting 28. I hope to be able very shortly to show an engine of 40-horse power, which shall not take half a horse power to drive the condenser. It will not take so much power to work the air-pump on this principle, as by the injection system. I do not propose this as a substitute for water, by any means; but I propose to carry that principle into every place where air can be obtained, so far as other practical circumstances will admit.

The PRESIDENT:—I think it requires a very ingenious mind to follow you.

Mr. M'CONNELL enquired if any trial had been made of the engine in actual work; to which

Mr. CRADDOCK replied, that it had been tested at the London Works at Smethwick, and referred to Mr. Cowper of that establishment, for the particulars of the trial.

Mr. COWPER:—Mr. Craddock brought the engine to our Works, and, as near as I can remember, the results were,—that the horse power was 22 and a fraction, indicator horse power; and the condenser took one and a half horse power to drive it. I think it may have been less, but not more, while the engine was doing the work of 22-horse power. The vacuum was $22\frac{1}{2}$, and in a very hot day in August he got as high as 25 inches.

Mr. M'CONNELL:—May I enquire the diameter of the cylinder, the stroke, and the pressure of the steam?

Mr. COWPER :—I think the high-pressure cylinder was 7 inches, and the other 13 inches.

Mr. CRADDOCK :—The other was 14 inches. The stroke of the one was 16 inches, that of the other 2 feet.

Mr. COWPER :—The pressure of steam was generally about 80 lbs.; but that varied.

Mr. CRAMPTON :—I should like to know what proportion the condensing surface bears to the heating surface of the boiler?

Mr. CRADDOCK :—I can furnish you with the substance of it. For instance, in an engine of 10-horse power the condenser would be a weight equal to 10 or 12 cwt. The larger the engine the less would be the proportionate weight; but I can say it would not exceed 12 cwt. for 10-horse power.

Mr. CRAMPTON :—We generally suppose 9 feet of heating surface to generate steam for one-horse power; and what I meant was, how many feet of cooling surface would condense this?

Mr. COWPER :—I think it was, as near as possible, 40 square feet to 41. I think Mr. Hall used, with his water condenser, 20 feet, and Mr. Craddock, with his atmospheric condenser, used twice as much.

Mr. CRADDOCK :—I use about twice as much surface for giving out the same quantity of heat; but I think I shall be able to show, that I produced treble the amount of power from the same quantity of steam.

The PRESIDENT :—Have you any idea of trying it with locomotive engines as well as stationary?

Mr. CRADDOCK :—That depends upon whether I obtain sufficient encouragement; but I think it would be found highly economical there; and hence I have an idea that some day or other it may be so applied.

Mr. BUCKLE :—Do I understand that you generate three times the quantity of steam as a common boiler does?

Mr. CRADDOCK :—Certainly no. All I contend for is, that there is a larger amount of surface for the heat to act upon; and I conclude that I get a facility for generating steam which the common system is not capable of.

Mr. M'CONNELL :—What is the proportion of the high-pressure cylinder to the low-pressure?

Mr. CRADDOCK :—Six to one.

Mr. M'CONNELL :—And the relative pressure of each when working?

Mr. CRADDOCK :—That will materially depend upon the space which there is between the two cylinders for the steam to expand in. It is a matter of experiment only.

Mr. M'CONNELL :—So far as your experience goes, what do you consider to be the relative pressure of the two cylinders?

Mr. CRADDOCK :—As four to one.

Mr. M'CONNELL :—Yes, that is the area ; but the pressure ?

Mr. CRADDOCK :—Experiment will determine that.

Mr. CRAMPTON :—I think he has to expand the steam six times when he has a pressure of 80 lbs. on the atmosphere. Is that so ?

Mr. CRADDOCK :—It is not fixed.

Mr. CRAMPTON :—The expansion of steam is only relative. The general rule is, that at a pressure of 25 lbs. the steam is expanded five times. It appears to me that, in asking questions about the relative capacities of the small and large cylinder, we should always bear in mind the pressure of steam to be worked.

The PRESIDENT :—I should like to see the engine pumping water, in order to test it.

Mr. M'CONNELL :—What is the relative consumption of your engine ?

Mr. CRADDOCK :—I have not carried my experiments so far as to form any rule : but where I derive the economy is chiefly in the expansion of the steam.

Mr. M'CONNELL :—I think it is now some four or five years ago, since you first brought it under notice, and I was then anxious to ascertain what its economy was. Now I had hoped, that having acquired more experience, we would have been favoured with statements upon the subject, and also as to what Mr. Henderson's engine did, as compared with yours. They were at work at the same place, and you had every opportunity of making the necessary experiments if you had wished it.

Mr. CRADDOCK :—I have never directly asked Mr. Henderson ; but I have many times thrown out a suggestion that it might be satisfactory to have some experiments made, and the suggestion was never acted upon.

Mr. M'CONNELL :—In dealing with this question, we have to trust entirely to practice ; and as to the economy of expanding steam to a certain extent, and that particular system of condensation, I do not think we are prepared to give a decided opinion. The best test would be, as the President has stated, that of pumping water.

Mr. BUCKLE :—Or grinding corn.

The PRESIDENT :—Or driving a locomotive engine.

Mr. CRADDOCK :—I submit whether the indicator is not a sufficiently good test.

Mr. CRAMPTON :—No question of it : but, when talking of economy, we must take into consideration, first, What does the boiler do ? how much water do we evaporate for a given surface ? When that is settled, then we may ask how much better is it than another ? There is a question whether the two cylinders are better than a single one. Evidently a loss there is in the expansion of steam from the small cylinder

to the large one, which you never can get back, and which you avoid by using a single cylinder. There may be a little more equal motion, but that is all you get. I tried them some years ago, and I found that you would lose something like 14 per cent., merely in the travelling of the steam from the small cylinder to the large one. It is, however, desirable that we should come to some settled opinion upon the subject. My impression has always been that there is a loss connected with the small cylinder. Put the same amount of steam in the large cylinder, cut it off, and you will do more work than if you first put it in the small one, and then sent it through to the large one.

The PRESIDENT :—There must be a loss. No doubt the Cornish engine does its work more economically from having only one cylinder.

Mr. CRAMPTON :—What I want to know is, If the double cylinder is so good, *why* is it so? I cannot find, by any experiments I have made, that there is any reason for it. There is, as I have said, a rather more uniform motion; and that little advantage I think we can get from a fly wheel. We must lose a certain quantity of steam in going through the passage, and the gain of the more uniform motion is more than compensated, by the greater economy in having the high-pressure steam.

The PRESIDENT :—If you throw the steam into the large cylinder, and cut it off at high pressure, at a short portion of the stroke, you have that steam to expand over the other portion of the cylinder, before it is thrown into the condenser; because this brings the high pressure and low pressure systems into action in the same cylinder, and you have as much power in that as you have in two cylinders.

Mr. M'CONNELL :—There is one subject which we have not yet considered, and that is the advantage to be gained from using the revolving air-condenser, as compared with the ordinary jet-condenser of a stationary engine. There is certainly the advantage of using the same water and having no sediment, instead of drawing it up by an air-pump and discharging it.

Mr. CRADDOCK :—In reply to Mr. Crampton and the other gentlemen, I may state, that the practice of the profession is in my favour, as regards the use of the two cylinders. Time was, however, when these engines, were tried and thrown aside. Let me call the attention of the meeting to the model before us. It is scarcely necessary to remind the members, that in so small an engine the friction is considerable when first started; yet it had worked up to its speed with the steam cut off at 1-60th of the stroke; to get the same effect in one cylinder, would cause great irregularity of motion. Another thing which I have found in the course of my experience—which has been considerable, having

been engaged ten years in this matter, seven of which have been devoted in a great measure to experimenting—is, that those experiments with respect to the relative advantages of the double and single cylinder have proved to me, that by admitting high-pressure steam direct from the boiler into the cylinder, a considerable portion of it becomes condensed by coming into contact with the comparatively cold metal of such cylinder; the water resulting therefrom being in contact with the metal of the cylinder, does, when placed in communication with the condenser, again assume the form of steam, which passing to the condenser, uselessly carries away much heat from the boiler to it, without producing mechanical effect. I suggest that a more conclusive test, than that of indicator figures, to which Mr. Crampton has alluded, will be that of two cylinders, one of which could be readily thrown out of action. Such engine being connected with the same boiler expending the steam to the same extent, and performing the same work. The steam and coal required in both cases being accurately weighed. I have made experiments which are perfectly conclusive to my own mind; and I hope shortly to be able to give you an invitation to investigate experiments which will be equally satisfactory to yours.

Mr. M'CONNELL:—There is more than the question of the two cylinders involved in this. There is another principle, and if Mr. Craddock would pay attention to that, it might afford a great deal of information. I allude to the principle of condensing by air, in contradistinction to our ordinary way of condensing by a water jet. If there is economy in that, we get this result, that we have pure water, and we all know the benefit of that in the working of a steam engine. I merely suggest this, that Mr. Craddock may bring forward at a future period the results of this principle, as well as the advantages it may afford in the generation of steam. It appears to me that the condenser is most valuable for marine purposes.

Mr. CRADDOCK:—The advantages of the condenser for marine purposes may be stated in a few words,—it would ensure us water free from deposit, thus rendering tubular boilers practicable, they enabling us to generate high-pressure steam with safety, and thus by carrying out the expansive principle, with other advantages consequent thereupon, a saving of two millions annually, in our steam navy alone, would be effected.

Mr. JACKSON:—I have for many years looked upon double cylinder engines as compound machines. From the manner in which Mr. Crampton has discussed this matter, it is evident that he could throw some additional light upon it. I therefore beg to move, “that this meeting will esteem it a favour if Mr. Crampton will prepare, and lay before the next meeting, a paper and diagrams descriptive of the

experiments made by him, on the comparative merits of the double and single cylinder systems." The motion having been seconded, was carried unanimously.

Mr. CRAMPTON assured the meeting that it would give him great pleasure to do any thing he could, to elicit information on the subject. He had made some experiments, eight or nine years ago, and he would be happy to go into the question again.