16TH MAY, 1889.

DON'S PATENT SMOKE PREVENTER AND FUEL ECONOMISER.

By G. A. KEY.

In bringing under your notice this evening Don's Patent Smoke Preventer and Fuel Economiser, it is not so much with the view of simply describing this patented appliance as with the object of laying before you some remarkable results on coal consumption obtained by its use, and to endeavour to explain the reasons why these results must necessarily follow the application of the principle involved in it.

When it is mentioned that the quantity of coal consumed in Great Britain alone for manufacturing industries during last year was over 50,000,000 tons, any new facts brought to light that may have the effect of causing an economy in the consumption of coal must be of great interest to engineers; and if, in addition to economy, smoke can be prevented, they will have a greater interest, and one, also, that the public at large can quickly appreciate.

From the first introduction of the steam boiler as a generator of steam for industrial purposes, up to the present time, no advance has been made in the method of burning the fuel. The land boiler and marine boiler furnaces (as far as their arrangement for the burning of the coal is concerned) are practically the same to-day as they were fifty years ago, and yet every point onward, after the generation of the steam, has advanced in a wonderful degree during that time. The steam boiler itself, and the steam engine, are very different to-day to what they were fifty years ago. Compare the engines and boilers of one of our latest mail steamers, working on the triple expansion principle, with boilers carrying steam pressures of 160lbs. to the square inch, with the mail steamers that traded here thirty years ago, with their cumbersome, slow speed engines and boilers carrying only steam pressures of 15lbs. per square inch, and then the wonderful progress will be apparent, but yet the coal was handled and consumed in the older vessel precisely as it is now in the new.

Combustion being purely a chemical action may account for the reason why engineers have failed so far to make any practical improvements in its application to the burning of coal in furnaces.

The theory of combustion is, however, well understood by scientific men. Great minds, such as those of Lavoisier and Laplace, Dulong, Favre and Silbermann, Joule, Thomsen, Tyndall, Rankine and others, have devoted much time and labour to ascertain by experimental research the heat obtained by combustion and the laws that govern it, and have conclusively demonstrated the exact quantity of heat that can be obtained from coal and other fuels under perfect combustion.

Mention may here be made to one practical engineer who investigated the subject thoroughly, and whose writings on it are even now the standard—that is, the late Charles Wye Williams, for many years Director and Engineer to the City of Dublin Steam Packet Company, and in this paper references will be made to his work to explain the theory, and an endeavour will be made to show where he and others have failed to apply in practice the conditions necessary to fulfil it.

Before entering into the question of prevention of smoke and proper combustion, it may be well to first describe the invention, the subject of this paper, and the results so far obtained by its use.

Plate VI. shows the appliance and its application to an ordinary land or marine boiler furnace. It may generally be described as an air-injector so arranged that it draws the air from the atmosphere, and delivers it into the furnace *above* the fuel. More particularly the part D is an annular air-injector, complete in itself, which delivers the air into a bent pipe, FF. The lower limb of that pipe is arranged at such an angle, and with a specially shaped distributing exit, that the air is directed to reach with force every point of the fire, both in length and breadth.

The points in it which come specially into play are :—The quantity of air delivered, the velocity at which it is delivered, the time when it is used, and the equal and forcible distribution of the air over every point of the fuel surface.

In the appliance now illustrated, which is a size suitable for an ordinary-sized furnace, having a grate bar surface of 18 square feet, or 6 feet long by 3 feet broad ; the size of the opening for the admission of the air is $1\frac{1}{2}$ inches in diameter, equal to an area of 1·767 square inches.

The action of the injector is such that the current of air passing through it is equal to sustaining a column of mercury of 14 inches, or about a velocity of 39,660 feet per minute, so that 480 cubic feet of air can be delivered on to the fuel every minute.

It will thus be seen that, if the current of air follows the lines of the distributing exit, the velocity being so great, the air will strike every point of the fuel with immense force ; in fact, the atoms of air will be projected on to the fire like a shower of inconceivably small bullets shot from a gun.

Before trying to show how such an effect may meet the recognised theory of combustion, it may be advisable to first give the practical results obtained by its use on a very exhaustive trial made recently by a number of well-known members of this Institution.

The report on that trial is as follows :—

Sydney, 27th March, 1889.

Sir,

We, the undersigned, have much pleasure in submitting the results obtained by us on two exhaustive trials made to test the merits of your Patent Smoke Preventer and Fuel Economiser.

Some time ago a number of us submitted reports on the action of the same invention during a two days' trials conducted on board the steamer "Mermaid." The results then obtained were highly satisfactory as to smoke prevention and economy of fuel ; but as the size of the vessel was comparatively small, and the boiler had only one furnace, an opinion was expressed that a trial on a much larger scale would be advisable, as from the use of a larger quantity of coal errors of observation would be practically eliminated and the test be more reliable.

The trials now reported on were conducted on the passenger paddle-wheel steamer "Narrabeen," a vessel 160 feet long by 24 feet beam and 10 feet deep, having compound engines of 450 indicated horse-power, supplied by two through tubular boilers 8 feet diameter by 19 feet long, with four corrugated steel furnaces 3 feet diameter by 7 feet 6 inches long, with a total grate bar surface of 66 square feet.

The trials extended over two days, the 22nd and 23rd inst.; six hours continuous steaming on each day; the first day being with the apparatus applied, and the second day without it.

We first note that the instruments used differed greatly from the original one tried on board the "Mermaid," presenting features that commended themselves to us at once, although embodying the same principle in working. The chief differences being an annular opening for the steam—a smaller instrument discharging the air with greater velocity, and in its working using very much less steam and producing a great deal less noise. The noise made by the original instrument was decidedly objectionable, but in this case it was of no practical moment.

On the trials, observations of steam pressure vacuum, revolutions, temperature, measuring of water, etc., all as per appended tables, were taken every fifteen minutes; the coal weighed and firing watched in the continuous presence of two or more of our number.

Manipulation.—This is so simple that on the day of test the apparatus was worked by the firemen themselves without assistance.

Smoke prevention.—This is effected in such a way as to thoroughly fulfil every condition of all Smoke Acts.

Economy.—The accompanying table of observations gives the results of the two days trial, from which it will be seen that, by using the apparatus, a nett saving of 11·25 per cent. of coal was obtained.

General.—We are perfectly satisfied that these trials were carried out impartially and that the results obtained are so satisfactory that we can with confidence recommend its adoption both for smoke prevention and economy of fuel.

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When there are such well-known names to you all as those appended to that report, no one in this Institution will doubt for an instant the correctness of these results—that an economy of $11\frac{1}{4}$ per cent. of coal was obtained, accompanied by perfect prevention of smoke. This trial, as you will see, was on a vessel of considerable size, and was the outcome of a previous trial conducted by the same gentlemen on a vessel of much smaller dimensions. In that trial similar economical results were obtained, but as it is a well recognised fact that none of the thousand and one inventions that have been brought forward during the last fifty years or more as "smoke consumers" were ever accompanied by economy, men such as these were ever in doubt of their own observations and desired this trial on a large scale to confirm, or otherwise, what they had obtained before.

On a trial such as the one now referred too, errors of observation were practically impossible. Being a vessel travelling in smooth water, on calm days and at exactly the same draft of water, the work required to drive the vessel was absolutely the same on each day. In other words the loads on the engines were equal.

Maintaining equal revolutions, with the same opening of throttle valve and link, and with equal temperatures of feed water and condensing water, the quantity of steam necessary to drive the engines, equal revolutions would be the same. These were maintained, or nearly so, any differences being calculated and allowed for in the final result. The only point, therefore, on which there might be a doubt was the weight of coal in the fire at the start and finish on each day, the actual coal consumed being weighed to a pound. To prevent doubts as to any possible errors on that point, the fire was made up before starting to measure, on the day without the appliance; then on the day with it, so that it was plainly visible to all the observers that it was a heavier fire, and at the finish a less one than on the day with it; therefore, if there was a discrepancy, it was against the appliance, so no favour was granted, but the reverse. In conducting the trial, the method was to run first for over half an hour, so that the fires were in good condition, with steam at full pressure and maintainable with the extreme revolutions and then with a clean stokehole to weigh down the coal and start the time at the first firing. In addition to these two trials referred to, the author, in conjunction with Mr. Norman Selfe, had three day's trial on the same vessel (the P.S. "Narrabeen") during the previous week, and the results then obtained were even more favourable. At present preparations are being made to have a very accurate series of evaporative tests at the Sydney University, the results of which may be added as an appendix to this, or brought before you in another paper on an early date. A series of evaporative tests were roughly made by the author some months ago with results confirmatory of those now obtained in actual practice, but the apparatus employed for measuring feed water and taking the other necessary observations was not sufficiently accurate to warrant the figures being given for publication. It may be specially mentioned that in these trials no alteration whatever was made in any way with the furnaces bars, doors, or bridges; nothing was done in any shape to the boiler, but to simply apply the apparatus.

This is mentioned as we have often heard of economy being obtained by smoke consuming patents, but on investigation by competent judges it has been found that the economy was not from the apparatus employed, but by altering some wasteful condition existing prior to its application, such as shortening a too long fire-grate, lowering the bridges, and more careful instructions to the firemen when and how to fire, &c.

Having now described the appliance, and given the results obtained, let us consider whether the effect of the shower of air forcibly driven on to the top of the fire can meet the theoretical requirements of smoke prevention, together with economy.

The immense volumes of smoke that issue from the chimneys of our steamers and factory stacks are naturally looked upon as an enormous waste of coal, and when any one produces by any appliance the effect of preventing smoke, and tells us that economy of coal is the result, we are very naturally led to the conclusion that it must be so. Now, if we look carefully into the question, we will find that this need not be so, but that smoke may be prevented without any appreciable economy. Now, what is smoke? The common definition is that it is particles of coal passing away unburnt, but that is a fallacy. Smoke does not proceed from the solid or carbonaceous portion of the coal. For instance, Anthracite coal does not smoke, and the best Welsh coal but little, and yet they contain a greater per centage of solid carbon than the ordinary bituminous coal. Coal, as you are well aware, is composed chiefly of carbon and hydrogen.

In the natural state of coal the two are united and solid. Their respective modes of entering into combustion are, however, essentially different.

The bituminous, or hydrogenous portion is convertible to the purposes of heat in the gaseous state alone, while the carbonaceous portion is combustible only in the solid state.

When a fresh charge of coal is thrown on a furnace in an active state and (that is the time when you observe smoke) gas is evolved from the fresh coal, and, until the whole gas contained in it is given off, the coal remains black at a comparatively low temperature; in fact, heat is given off in turns, first by the gaseous portion, and then by the solid.

As before mentioned, it is at the time of firing, and for a few minutes afterwards, that smoke is observed; it follows, therefore, that the smoke we see is solely a product from this gaseous portion of the coal, the chief constituent of which is a gas—carburetted hydrogen, the ordinary gas we use for lighting. Before the characteristics of combustible gases were known it was natural that all coloured vapours rising from heated bodies should be called smoke.

Carburetted hydrogen gas is composed of hydrogen and carbon in the proportion of two atoms of hydrogen to one of carbon. Hydrogen is a gas, and carbon a solid, and yet when chemically united in these proportions, the result is this invisible carburetted hydrogen gas.

When this gas is decomposed into its constituents the atoms of carbon become invisible. When heat is applied, in the presence of air, to this gas, decomposition takes place; the heat generated by the work of decomposition showing itself to the eye as flame. The hydrogen, on liberation, having a greater affinity for oxygen than carbon, unites at once with oxygen of the air, forming water, vapour or steam, and the carbon is set free to pass up the chimney along with the watery vapour in the visible shape of soot, which acts as colouring matter to the cloud of watery vapour. But if at the moment of decomposition sufficient heat be present, together with oxygen, then the carbon will unite with this oxygen in either one or two proportions, forming carbonic oxide or carbonic acid, both invisible gases, and as such it will pass away unseen, and we have prevention of smoke.

To get the oxygen for the carbon, however, there must be sufficient air present to first supply the hydrogen with its quantity of oxygen, and a surplus to supply the carbon with what is required to form either carbonic oxide or carbonic acid. If the carbon pass away in the visible for its relative weight to the watery vapour is as but 6 to 286. It is, therefore, apparent that smoke takes away a very insignificant proportion of carbon, so that by *its* prevention *only* little or no economy can be gained. It is the wonderful colouring properties of this soot, or lamp black, that deceives the eye. A very little of our cloud of smoke is therefore available as a source of heat, however much of a practical nuisance it may be, and is.

As we have seen, all that is necessary for the prevention of smoke is the presence of sufficient volume of air, when the gaseous portion of the coal is being decomposed, to combine with the hydrogen and sufficient over to give the necessary supply to the carbon, and at a time whilst the temperature is high enough for the ignition of the gas. By the use of Don's instrument sufficient air is delivered to effect this, as you will see practically on board the steamer "Narrabeen" on Saturday next. We thus see that all the benefit that may be got by preventing smoke only is a bagatelle outside of the nuisance, which it is in its sanitary aspects. Yet, as a large economy is obtained by the use of this appliance we must look for some other reason why such economy should exist.

Heat is the element we seek to obtain from the combustion of coal for the purposes of steam raising. To obtain economy of coal we must, therefore, obtain economy of heat; economy in this sense means obtaining greater heat from like quantities of coal. Now, by the use of Don's appliance, we gain greater heat in the following manner:—

As previously stated, heat is obtained from the gaseous and carbonaceous portions of the coal in rotation. In ordinary practice, when we have a bright clear fire radiating great heat to the furnace crown, we have then to supply fresh fuel, the result of which is the immediate lowering of the temperature by preventing radiation from the clear fire, and no heat can be got from the solid portion of the freshly put on coal until its gaseous portion is all evolved. To get heat from this gaseous portion it must be in combustion, by both its hydrogen and carbon combining chemically with the oxygen supplied by the air.

If that can be done instantly the new coal is thrown on the fire, we shall then get the effect of combustion in the shape of clear but heat-giving flame. To get this chemical union instantly has in the past been the difficulty. Time is essential for that union, and under the ordinary conditions of the furnace, the gases, as evolved, travel away from the furnace before the union takes place, sometimes a portion may combine and ignite in the combustion chamber, or later in the tubes or flues, and even as late as the chimney top, and it is not until the greater portion of this valuable gas is given off and lost that the later portions, being given off more slowly, have sufficient air around them to unite. It is well known to chemists of late years that pressure greatly hastens chemical union, and if the pressure be intense enough it is practically instantaneous, and that is the great point we gain by this appliance. The pressure and great volume of air forced directly on to the coal drives the atoms of oxygen forcibly into contact with the atoms of hydrogen and carbon at the instant they are set free or (all chemical unions take better effect at that time than any other—what is called the nascent condition) with the result of visible flame giving heat in the furnace, thereby taking the place of radiated heat from the clear fire, and maintaining a steady heat in the furnace first by the flame from the gases, and then from the solid portions instead of the great lowering of temperature every time fresh fuel is added. This question of time in obtaining the chemical union has been the stumbling block in all previous attempts to get perfect combustion in ordinary furnace practice. Professor Daniell, writing to Wye Williams whilst he was investigating combustion, says:—"Any method of ensuring the complete combustion of fuel, consisting partly of the volatile hydro-carbons, *must be founded upon the principle of producing an intimate mixture with them of atmospheric air, in excess,* in that part of the furnace to which they naturally rise. In the common construction of furnaces this is scarcely possible, as *the oxygen of the air,* which passes through the fire bars, is mostly expended upon the solid part of the ignited fuel with which it first comes in contact." Wye Williams himself, after explaining all the essential conditions for perfect combustion, especially dwelling on this question of time required for chemical union, concludes thus:—"That, as we cannot *force* the gas and air to mingle with sufficient rapidity under the ordinary circumstances of the furnace, our views should be directed to the effecting such modifications of that furnace as will aid nature in those arrangements which are essential to combustion, rather than in obstructing them."

All the devices tried in the past for the prevention of smoke, and by which the public have been led astray, such as hollow bars, supplemental flues, calorific plates, Venetian doors, etc., etc., have all missed the point of sending in to the furnace the required quantity of air and *directing it to its work,* but nearly all have had some partial effect in igniting more or less of the gas in the combustion chamber or flues, thereby partially preventing smoke, but as economisers of fuel have been practically worthless.

This subject of combustion being one of great interest to engineers, is the author's excuse for taking up your time so long in describing this appliance, and his regret is that the time at his disposal since being asked to write the paper has been so short that he feels he has not put the matter before you as well as he might have done.

In conclusion, he might say that from the first time he saw this appliance at work he was satisfied that a new principle in practical combustion had been attained, and he feels confident that in the near future the manufacturing and shipping worlds will utilise it to their commercial benefit, and, at the same time, giving the public in densely-populated cities the benefit they so much need—an atmosphere free from smoke.