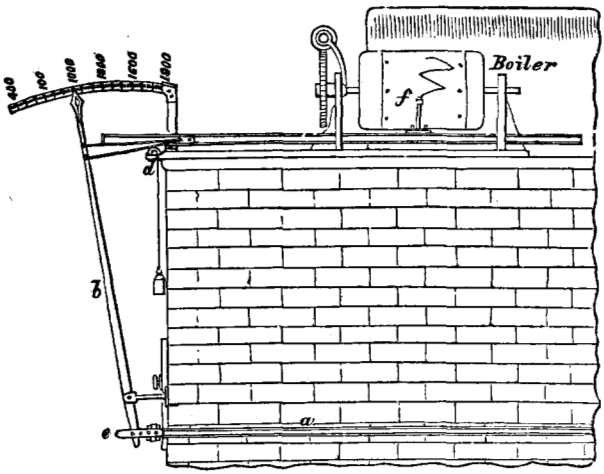
Fig. 4.



of Civil Engineers pointing to it, as the most appropriate, and legitimate body for the exercise of such a function, this Paper is submitted to them by the Author. The process of nature, in the combustion of coal, and coal-gas, chemically considered, is now so thoroughly understood, and is so simple, and so capable of physical demonstration, that, if the subject were inquired into by the Members of the Institution, the result would be well received by the community, and would satisfy the sphere of usefulness the Institution is so peculiarly qualified to fulfil. Such a proceeding would have this good effect, that it would, at once, become the means of detecting the fallacies, and even absurdities, which have too long been suffered to prevail.

The Paper is illustrated by diagrams, from which the wood-cuts, (Figs. 1 to 4,) presented by the Author, are compiled.

Mr. C. W. Williams explained, by means of a diagram, the several divisions of the process, leading to the combustion of the gas in furnaces. The first division gave the mere relative gross bulk of gas and air, required for combustion. The second showed the mechanical mixture of the gas and air, such mixture, or contact of atoms, being essential to the subsequent chemical union. The third exhibited the several constituents of gas and air:—the former being hydrogen and carbon; the

latter, oxygen and nitrogen; ten volumes of air being absolutely essential to the combustion of one volume of gas. The fourth division showed the proportions, in which those constituents combined. The great amount of caloric evolved during the combustion of the hydrogen, was the direct cause, by which the temperature of the atoms of carbon was raised to that of white heat, producing the luminosity of flame. This process might be illustrated, by reference to the mode of producing the intense heat and luminosity required for the oxy-hydrogen microscope. In the latter, the piece of lime, or carbon, on which the heat was projected, was instantly raised to the temperature of extreme luminosity, neither the lime, nor the carbon, however, suffering rapid combustion. In the former case, the carbon of the gas was raised, by the same means, (the combustion of the hydrogen,) to the high temperature, but it could not suffer combustion until it was brought into contact, in its turn, with its equivalent of the oxygen of the air. If, however, that supply of air was not provided, before the carbon lost its high temperature, it returned to its previous, and natural state of a black substance, and gave the black character to the products, called smoke.

The first important condition, therefore, to insure perfect combustion, was to provide the requisite quantity of air. Authorities differed as to the area which should be allowed for the passage of the air into a furnace, and some had even considered, that half a square inch of aperture, for each square foot of furnace-grate, was sufficient for the combustion of the fuel. He had found, however, that for practical purposes, the proper proportion of area for admission was from 4 to 6 square inches for each foot of grate, according to the extent of draught and the nature of the coal. This serious difference had, no doubt, arisen from an erroneous calculation of the rate of the current of air entering. For, if half a square inch of area was all that was allowed, the air must have a velocity ten times greater than it could be shown to have ever attained. Thus, supposing a furnace to be 4 feet by 2 feet 6 inches, equal to 10 square feet of bar-surface, this would effect a combustion of 2 cwt. of coal per hour, and require for the gas alone, a supply of 10,000 cubic feet per hour, or, for 20 cwt. of the coal, 100,000 cubic feet. The following comparison of velocities of the air entering

for the supply of the gas, gave some idea of the cause of under-rating the required area of admission:—

Air aperture per square foot of grate.	Velocity of draught per second.	Quantity of air per hour.	Quantity for each ton of coal.
6 square inches	at 5 feet per second	7,500 cubic feet	75,000
6 ,, ,,	at 10 ,, ,,	15,000 ,, ,,	150,000

If the area were reduced, therefore, to half a square inch, it would require a velocity of 80 feet per second, to provide for the admission, within the given time, of the necessary quantity. Now it resulted from close observation, by means of an aerometer, that the velocity of the entering current was from 8 feet to 10 feet per second, if the draught was good, and from 5 feet to 8 feet, when it was but moderate. It should also be recollected, that by admitting the air through numerous thin films, or divisions, its velocity was necessarily reduced, by mere friction through so many half-inch orifices.

Mr. F. BRAITHWAITE said, that smoke was the result of imperfect combustion, the finer particles of the fuel, as well as its bituminous, oily and fatty constituents passing off unconsumed, in consequence of the imperfect combination of the oxygen and hydrogen. The application of the mechanical principle to the prevention of smoke was by no means novel, as Brunton had introduced, many years ago, a revolving feeder for gradually supplying the fuel: the systems differed but little from each other, they were expensive, and, in many cases, commercially impracticable. The temperature required for furnaces varied considerably. Brewers and distillers, for example, evaporated at 212°, while a much greater heat was necessary for tallow melters. In Prussia, a plan had been adopted of arresting the smoke by means of pierced diaphragms.

Dr. ARNOTT said, that his attention had been principally directed, in connection with this subject, to the domestic fireplace, in which the nuisance of smoke was prevented, by causing the supply of fresh fuel always to rise into the grate, from a charged receptacle immediately beneath the fire, so that the smoke, or vapour generated was compelled to ascend through the ignited mass, and was thus consumed. The setting of the grate was, moreover, modified, in order to attain other useful ends.

Mr. FRASER demurred to the observation in Mr. Williams' Paper, that skill was not required in a stoker: his own opinion was, that this class of men could not be too highly educated. So also, with respect to the manner of feeding the furnace, he preferred that the coal, when first thrown in, should be heaped up near the fire-door, and be afterwards pushed back, when partially carbonized: by this method, the dense smoke was consumed. He was also in favour of admitting all the air through the bars, as it was more equal in its action, than when it was made to pass over the fire. Mechanical apparatus was often condemned, because it broke down through negligence and misuse; but the fault was not in the machine, but in employing men who would be just as careless with furnaces with fixed bars. He had sixteen sets of Juckes' apparatus in action: they required no manipulation, and the supply of fuel was always equal. He had been convinced, by experiment, that 12 per cent. in the weight of the fuel was economized, by the use of apparatus with moving bars, when they were properly attended to. He had arrived at this result, from an examination of the quantity of water evaporated, under the two systems, by a given weight of fuel, and this was the true test of the relative degree of combustion which had been effected.[1]

Mr. G. F. WILSON, through the SECRETARY, said, that his experience was greatly in favour of mechanical apparatus. At Price's Candle Manufactories, three methods were employed, with success. The first was introduced about seven years ago, and the more recent between three and four years, so that there had been sufficient time to judge of their merits. All three, Juckes', Hazeldine's, and Hall's, were upon the same principle,—a continuous supply of fuel at the front of the fire, by means of moveable bars carrying the coal forward. In these furnaces, as in those of the common form, the air was admitted only between the fire-bars, which were always kept covered with fuel.

The objections urged against these machines, were their first

[1] Since the foregoing remarks were made, Truman, Hanbury, Buxton, and Co., have fixed two large mechanical furnaces in Cornish boilers, having the respective areas of 31 feet and 38 feet. The firm, after an experience of ten years, entertain the highest opinion of the merits of this plan, which they have publicly expressed.—A. F., 1857.

cost and their liability to derangement. The first objection applied with greater force to Juckes' apparatus than to either of the others. With respect to the second objection, the furnaces, when first constructed, were imperfect, and consequently, did not afford a fair test; but they had since been properly fitted up, and made of greater strength, and his decided opinion, based upon the experience of twenty-one furnaces, was, that the liability of smoke-consuming apparatus to derangement did not constitute any serious drawback to their use, so far, certainly, as Hazeldine's and Hall's apparatus were concerned, the mechanism of which, especially of the former, was very simple. The engine furnaces, both at Vauxhall and at Battersea, had been long fed by smoke-consuming apparatus.

The practical advantages of these machines more than compensated for the extra first cost and expenses of repairs, for all the furnaces he had named, were absolute smoke-consumers; they worked well, with cheap small coal, and were not subject to the rush of cold air, which, in coaling and stoking common furnaces, must waste heat, and must be more, or less injurious to the boiler. The continual movement of the apparatus insured, moreover, a gentle and continuous stoking, which kept the bars free from clinker. On the whole, he preferred Hazeldine's apparatus, on account of its being the cheapest and the simplest, but in a number of new furnaces now in course of erection in the north, it was thought more prudent to have an equal number of Hazeldine's and Juckes', as the nature of the coal which might be eventually used, could not at once be decided on.

Mr. J. G. MARSHALL said, that this subject had been recently forced on the attention of mill-owners, and the result of his experience was, that the prevention of smoke was best secured, by constantly feeding the surface of the fire with small quantities of fuel. This was well effected by Brunton's grate, but it was troublesome to manage, and it did not accommodate itself to all forms of boilers.

Mr. HAWKSHAW said, that he was one of those who had contended, for many years past, that smoke could be easily and advantageously consumed, by adopting the plan of large grates, with a free admission of air and ample boiler power. Mr. Houldsworth had done great service by the introduction of his

system, and the invention of the metal-rod pyrometer. The question of self-acting apparatus was not one which was necessarily mixed up with that of the prevention of smoke; the difference in the expenditure of fuel would decide, whether this system, or manual labour, was to be preferred. In discussing this subject, it should be recollected, that 'Parliamentary' smoke was confined to the black visible particles emitted from the chimney, but that in a scientific point of view, the question assumed a much wider aspect.

Mr. MUIR, through the SECRETARY, said, that too much stress had been laid on the chemical part of the subject, and that the question had been unnecessarily complicated by the assertion, that it was impossible to burn smoke. All that the public cared about was, that by some means, the black, or brown visible smoke should be prevented from forming, or be consumed, after formation, of the possibility of which there could be no doubt. In the analogy sought to be established between the furnace of Mr. Williams and an Argand burner, it was forgotten, that in the one case, the flame was produced in a cool atmosphere which preserved the parts from being burned, whilst in the other, the atmosphere into which the jets of air were admitted, was hot enough to fuse brick, or iron. The best plan, probably, was to admit the air by perforations in the brick-work, at points not exposed to the greatest heat of the furnace; but it might also be admitted by the fire-door, or through a split-bridge, and in either case, the smoke would be burned as effectually as though a thousand jets of air had been employed.

Practically, the consumption of smoke could be effected by supplying the coal in small quantities as in the apparatus of Juckes, Hazeldine, Hall, and others, or by the double-furnace boilers of Galloway, Rose, M'Gavin, and others, or by admitting air to the ordinary furnace. The first system was suitable only where fuel tolerably free from clinker was to be obtained. The 'breeches' boilers were objected to, on account of the small depth over the flues, and the weakness of that portion where the furnaces joined, rendering them more liable to explosion from want of water in case of neglect. With the ordinary boilers, the admission of air invariably reduced the evaporative power, or caused waste of fuel, unless there was a sharp draught and spare boiler power: when these latter requisites, however,

were secured, the air might be admitted in any way that might be found most convenient. Such was the opinion he had formed, after examining many hundred furnaces, and all the patents he could hear of. All the so-called systems of Williams, Stevens &c., were no systems at all, but mere modifications of one and the same principle.—the admission of air, otherwise than through the bars. That principle was excellent when there was sufficient boiler power and draught, but when these conditions were absent, no plans for the admission of air, whether hot, or cold, would satisfactorily effect the purpose. The most creditable mechanism for the admission of air that he had seen, was that of Mr. Prideaux, but its neatness was its only recommendation, as it could not improve the draught, nor could it burn the smoke better than would be done by merely leaving the furnace-door ajar. The doors of Mr. Prideaux were, moreover, too delicate in their construction, to resist the wear and tear of a furnace. Alternate firing of the 'breeches' boiler was the best plan; that, with boiler power, draught, and a little air, might supersede the expensive apparatus of Juckes, Hazeldine, and others, in ordinary cases. Under special circumstances, other means might be used, and such means were in existence for every conceivable form of furnace.

Mr. C. W. WILLIAMS said, that the mode of admission of the air adopted by Mr. Prideaux, was identical in principle and effect, with the method he himself had introduced. Mr. Prideaux, in his book, stated, that "the door of the furnace should be double, and the air should pass into the furnace, through a series of perforations in the inner plate. By this arrangement, the important features of heating the air and subdividing it into minute jets were secured." The great object to be effected was, the division of the air, on its admission to the furnace, so that no more atoms were brought into contact with the atoms of the gas, at any one moment, than were required for their successive union and combustion. If this were the case, combustion and heat would be generated, continuously, as the gas and air came into contact. If, however, the air entered in a body, or even in a film, in larger quantities than could be taken up by the gas, before the temperature was lowered, a refrigerating effect must be the consequence, smoke would be formed and fuel would be wasted. The introduction of sight-holes and of pyro-

meters which he had proposed, was only for the purpose of experiments in testing the temperature, and this was all that Mr. Houldsworth had in view.

He objected to the term 'burning smoke,' inasmuch as the smoke did not exist, until the gases had left the furnace; this was easily demonstrated by distilling coal in a close vessel, and forcing in a small quantity of air, when a jet of gas immediately issued, which, on ignition at the orifice, was almost colourless, then merged into flame, and ultimately, became opaque smoke.

Mr. SIMPSON, jun., said, that he had recently made a tour for the purpose of seeing what had been accomplished at Manchester and the neighbouring towns, and he had found, that the manufacturers strongly objected to all mechanical apparatus. The double-furnace system was that which was most approved, but neither at Manchester, nor at Bolton, had it been attended with the desired result. It was evident, that the simplest means were the best, if they could be made to succeed; and he believed, that if greater attention was paid to the admission of air, and to the employment only of skilful stokers, the end would be better attained, than by machines.

Mr. FIELD said, that during thirty years, he had had great experience in steam-machinery, and he believed, that the best proportions of fire-grates, flues, and chimneys for marine boilers, had at length been arrived at. The systems for consuming smoke might be divided into two classes, the first consisting of those which admitted air to mix with the flame, at various parts of the furnace, and the second comprising the different mechanical apparatus for insuring regularity in the supply of the fuel. The latter appeared to have been most successful, where there was a large boiler power which did not require to be forced, and from the experience afforded by the extensive use of these machines at Price's Candle Manufactories, it was evident, that they could be kept in order. The first class also succeeded, when under proper supervision: as long as thirty years ago, Mr. Josiah Parkes had instituted experiments which established the fact, that the admission of air through the bridge-plate did, undoubtedly, destroy the smoke. But in all the cases which had come under his notice, the system had been neglected after a time, frequently because the admission of air diminished the generation of steam. Mechanical apparatus might be employed

in factories, but they could not succeed with such intense fires as were required for marine-boilers; he was convinced, however, that in steamers, smoke might be diminished, with a little loss of fuel, by the judicious admission of air and careful firing combined with ample boiler space. It was worthy of remark, that a large steam-ship did not emit, in proportion, so much smoke as a small one. He doubted the efficacy of double firing, in preventing the generation and emission of smoke, to the extent sometimes stated.

Mr. SHEARS inquired, whether the admission of air produced oxidation of the boilers.

Mr. FIELD replied, that the air, when admitted near the bridge, did, in some degree, injure the boilers.

Mr. ECKSTEIN observed, that Cutler's system, which was introduced thirty years ago, and which was the same in principle as many of those now in vogue, was well adapted for small boilers.

Mr. JERRARD said, that all furnaces necessarily threw off smoke, until the smoke-consuming apparatus became incandescent. As the carburetted hydrogen was generated within the furnace, it should be gradually mixed, as fast as it was produced, with a sufficient supply of oxygen, without which perfect combustion was impossible. In order to effect this, he deemed it essential, that the fresh air should be delivered immediately over the front coking-plate, within and close to the door of the furnace, where the fuel was deposited for coking; and also that the quantity of fresh air should be properly regulated, so as not to be in excess. It was only after these points had been carefully attended to, that any dependence could be placed on smoke-consuming apparatus. Those which he had constructed worked satisfactorily and well, if properly managed, but no furnace could be, at all times, protected from the consequences of wilful abuse.

Mr. DAVID MUSHET, through the SECRETARY, called attention to a form of furnace which had been designated the 'Palmerston furnace.'

The general principle of the invention was to apply various movements, not to the individual bars as hitherto, but to a frame which supported them. The movement carried all the bars with it, and obtained changes of position, which whilst it facilitated

the entrance of the fuel, and the stoking, simultaneously provided such extra supply of air as was required for perfect combustion. The motion usually preferred was derived from balancing the grate-frame on a more, or less, central pivot. This pivot might be on a level with the bars, or it might be placed at any convenient depth beneath that level, to obtain a series of flatter curves; and these differences, united with the equal, or unequal, position of the pivot, forward, or backward, commanded a variety of action to suit every requirement.

Mr. FAIRBAIRN, through the SECRETARY, said, that he was ready, at all times, to award to Mr. Williams the great merit of having been, for many years past, a successful labourer in the cause, and the only difference upon the subject which existed between them, was relative to the quantity of air which it was necessary to admit behind the furnace, for the more perfect combustion of the gases, as they passed from the furnace into the flues. From experiments made, some years since, upon a double-flue and double-furnace boiler, he found, that in a well-proportioned boiler, with alternate firing for the prevention of smoke, one square inch per square foot of grate surface was a fair and effective area for the admission of air, and even this opening was considered too much, after the coal acquired an increased temperature, and approached an incandescent state. The admission of large quantities of cold air immediately behind the bridge had been found to be prejudicial, and most of those who had paid attention to the subject, preferred closing the whole of the air-apertures, and regulating the quantity of air through the fire-doors, which were left open for that purpose, about three-quarters of an inch, for a few minutes after the furnace was charged. The most effective, and, probably, the most satisfactory way of dispensing with the nuisance of smoke, was to adopt the system of alternate firing and to use boilers of great power. If the boilers were of limited capacity and the furnaces had to be forced, it was almost impossible to prevent the escape of large volumes of smoke. The generative power of the boilers was an important element in this question; it should always be in excess of the motive power: proper attention, with a little more than ordinary care, was then all that would be necessary to insure the consumption of opaque smoke.

Mr. POYNTER, through the SECRETARY, stated, as an argument for the necessity for some stringent measure, with respect to the engine furnaces, in all large towns, that in the nine years, from 1845 to 1853, eight hundred and one new chimney shafts for manufactories, breweries, &c., had been erected in the metropolitan districts. Some of them might have been merely rebuilt, after destruction, but the large majority caused additional impurity in the London atmosphere. From 1845 to 1851, the greatest number built in one year, was ninety-nine; but in 1852, one hundred and eleven were constructed, and in 1853, the number rose to one hundred and twenty-three.

Mr. NICHOLAS WOOD, through the SECRETARY, mentioned two cases which came under his daily experience, where the combustion of the fuel was complete, and where smoke was entirely annihilated. The first was that of the ventilating furnaces of the coal-mines in the North, where it was essential to raise a column of air as light as possible; it was, therefore, requisite, that the furnace should be in a state of intense combustion, and that no smoke, or other extraneous matter should be produced, or mixed with the current, which might add to its weight, or density. In the earlier days of mining, this furnace, though of nearly the same form and construction as at present, was worked in a different manner. Combustion was produced by the upward passage through the coals, of a great portion of the current of air, which passed underneath the bars of the furnace, and the consequence was, that a considerable portion of the fuel was driven off as smoke. The modern arrangement was to obstruct the current of air in passing over the top of the furnace, and so direct it with great force upon the upper surface of the fire. By this means, the body of fire on the grate-bars was always kept at an intense heat, the gases from the distillation of the coal were rapidly and perfectly evolved, and no smoke was produced from the coal resting on the bars. The component parts of the coal being thus rapidly developed and immediately ignited, the whole surface of the fuel became a complete set of flaming jets of gas, and after all the gas had been expelled, a vivid mass of incandescent carbon. When fresh fuel was added, the intensity of the heat was such, that the loose particles of coal, which would, otherwise, have produced smoke, became immediately and completely distilled into gas, ignited

and passed over the fire in flushes of flame. Perfect combustion was thus attained, nothing being produced but flame and heat, and when the operation was properly managed, not a particle of visible smoke passed up the pit.

The other case was that of two ranges of coke-ovens placed opposite each other, the flues from each of which passed into one longitudinal flue; or four circular ovens placed together, the flues from each of which were taken into one of the four sides of a square chimney. It was well known to coke-burners, that the whole of that portion of the bituminous products which produced smoke, passed off within the first few hours of the process, as the smoke proceeded from the upper layers of the coal, which did not, at first, come in contact with a sufficiently high temperature to resolve the bituminous products into gas. When the process was further advanced, and when the upper layers of bituminous products had been driven off, the carbon, or coke was left, and becoming heated to the requisite temperature for decomposing the coal, it evolved the gases, which ignited and passed off as flame. This process gradually proceeded downwards into the mass of coal, the bituminous products being resolved into gas, and burnt as soon as developed, until the whole of the coal was converted into coke. To prevent any emission of smoke from the chimney, care was taken, in the case of the two ranges of ovens, that they should not all be in the same stage of coking at the same time, but that whilst one was passing off smoke, the other should be passing off flame; and by thus directing the entire current of smoke and flame into one flue, the flame from one set of ovens met and consumed the smoke from the other set.

In the ventilating furnaces, perfect and complete combustion of the coal was accomplished, no smoke being produced. In the coke-ovens, the gaseous products only were consumed, (the carbon, or coke being left for combustion by another process,) but no smoke was emitted from the chimney. From a consideration of the circumstances under which the annihilation of smoke was obtained in these two cases, and the conditions requisite for its accomplishment,—it appeared, that smoke was produced by the coals being subjected to a low degree of temperature, or heat, sufficient to expel the bituminous products, but not sufficient to distil, or resolve such pro-

ducts into their component gases, or to ignite them when evolved.

According to Sir Humphry Davy, carburetted hydrogen was fired at 800° Fahrenheit, but common gas became ignited at a lower temperature: these temperatures, however, could not be kept up, if all the air was passed through the bars of a furnace. This was evidenced by the ventilating furnaces, and would equally apply to engine furnaces. To prevent the production and emission of smoke, it was necessary to throw a strong current of air upon the fire, in order to maintain it at an intense heat, so that when fresh fuel was applied, the gases of the coal should be evolved, and be consumed by the flame. How far this principle could be applied to a common engine furnace, was a question for engineering skill and talent to determine. But if the smoke was once produced, then, as in the coking process, it could only be destroyed by bringing to bear upon it, a powerful body of flame. Too much stress had, in his opinion, been laid upon the precise quantity of air requisite to be admitted to a furnace, whilst the fundamental principle had been overlooked, that unless a decomposition of the products of the coal into its component gases was accomplished, and that such gases, (supplied of course with the requisite quantity of atmospheric air,) were ignited, smoke would, necessarily, be produced.

Mr. SIMPSON,—President,—said, that the question was of great importance at the present moment, and deserved the serious attention of all the Members of the Institution. The general result of the investigation appeared to be, that the mechanical apparatus hitherto introduced were all, more, or less troublesome and expensive, and although they might be used, with success, in large establishments, it could not be expected that they would be adopted for every furnace in small manufactories. He believed, that the prevention of smoke would eventually be accomplished by a plentiful and judicious admission of air, combined with care and skill in firing, and the method employed by Mr. Williams appeared to fulfil the required conditions.