No. 912.—“On the Management of Engine Furnaces, with a view to the Prevention of the Waste and Nuisance from Smoke.”¹ By CHARLES WYE WILLIAMS, Assoc. Inst. C.E.

THIS subject has occupied so much public attention, that it is brought before the Institution, under the conviction, that the avoidance of the evils of waste, and smoke, is within easy reach; and also with the view of removing that mystery, which has so long been allowed to obscure one of the simplest, and best-understood operations of nature.

The subject may be considered under two heads,—chemical, and mechanical. The first is fully treated in the Author's work, on “The Combustion of Coal;”² the second embraces the practical application of the principles there detailed. A few words may, however, be necessary on the chemistry of combustion, introductory to the mechanical details. The generation of smoke, with the waste it occasions, involves the question of perfect, or imperfect combustion; that is, the combustion of all, or of a portion only of the two constituents of the gas from the coal,—hydrogen, and carbon. In perfect combustion, both of them combine with the oxygen of the air. In imperfect combustion, the hydrogen first enters into this union, producing the intense heat which raises the myriads of atoms of the carbon to that high temperature of incandescence, which results in the effect, called flame. Flame, then, is not combustion; it is but the preliminary state, as to temperature, of the carbon, which qualifies it for entering, in its turn, into chemical union with the oxygen. If the due quantity is supplied, the carbon will combine with it, and form carbonic acid gas. If, however, the supply is insufficient, more, or less of the carbon will remain uncombined, and, losing its high temperature, will be deposited in the black, pulverulent form, called smoke.

Hence it is manifest, that the air and the gas, must first be brought together and mixed, before this chemical union can

¹ The discussion upon this, in conjunction with the preceding Paper, extended over portions of two evenings, but an abstract of the whole is given consecutively.

² “On the Combustion of Coal.” By C. W. Williams. 8vo. Weale.

take place. Now, to effect this mechanical mixture, with the required rapidity, involves all that art, or human aid can do, in producing perfect combustion, and a practical illustration is afforded in the common Argand gas-burner; the only difference being, that whilst in the burner, the gas is brought to the air, through numerous small orifices,—in the furnace, the air must be brought to the gas by numerous small orifices, and in divided streams. In its operation and effect, this process is analogous to that produced on water by the rose of the watering-pot, or the artificial jet d'eau; in this case, the largest area of surface for mutual contact, must be present, on the instant, between the gas and the air. This is so self-evident, that it would appear unnecessary to add anything further. There are, however, other points for consideration, when looking to the practical application of these chemical details:—first, the place, most suitable for introducing the air; and secondly, the quantity that should be admitted.

Of the first, it may be stated, that it is a matter of perfect indifference, in what part of the furnace, or even of the flue, it may be introduced, provided the all-important condition be attended to,—that this mechanical admixture be effected, before the temperature of the gas has been reduced below that of kindling, or accension, as Dr. Ure expresses it. This temperature, according to Davy, should not be below 800° Faht., since, under that point, ignition will not take place; such, in fact, is the basis of protection in the safety-lamp. One of the most conclusive illustrations of perfect combustion effected on the Argand principle, was exhibited in the following experiment. Having removed the centre bar of the grate, which was 4 feet in length, the vacant space was covered by an iron plate bent in the shape of the letter A. (Fig. 1). This plate stood 9 inches above the bars on which it rested, (as shown in the diagram,) thus leaving 3 inches above the bed of the coal, which was 6 inches thick. Along the top, and upper part of the plate, were five ranges of half-inch holes, through which the air, rising from the ash-pit, issued through numerous orifices, into the very body of the gas, as it rose, on being generated from the coal. The immediate mixture and combustion which took place exhibited a remarkable, and even brilliant effect, the appearance being that of numerous streams of flame,

Fig. 1.

rather than of air, issuing from the orifices. Had it been possible to adopt such a mode in practice, nothing more could be desired: the combustion was as perfect as in the Argand burner, and the pyrometric temperature in the flue corresponded with the perfect character of the flame. While, however, the part of the plate above the fuel remained wholly unaffected by the heat, cool air alone passing through it, the lower portion was liable to be burned by the adhesion of clinkers. Had the plate been made of platinum, it was believed, that it would have proved to be the most effective furnace gas-burner that could be used for bituminous coal. It was this successful application of the Argand principle that led to the introduction of the air at the door end. Previous to this experiment, the general impression had been that some interval of time, was required to raise the temperature of the gas to that of ignition. The event, however, proved, that when once lighted, in the same manner as a gas-light, the communication of heat from the successive atoms of the gas entering into combustion, satisfied all that was required as to temperature.

In practice, the air has been introduced at all parts of the furnace, and in marine, and land flue-boilers, its admission by the air-distributor behind the bridge, effected all that could be desired. The adoption, however, within the last few years, of the tubular plan, rendered a new arrangement necessary, as regarded the place for the introduction of the air. In boilers on

the tubular principle, the run, that is, the distance between the bridge and the tubes, being so short, and the time so restricted, rendered it impossible, where large furnaces were employed, to effect the triple purpose of generating the gas, mixing it with the air, and completing the combustion, within the few feet allowed, and the fraction of a second of time, which was there available. The only alternative then was, to introduce the air at the door end, thus adding as it were, the length of the furnace to the length of the run.

To effect this, in tubular boilers, it became necessary to enlarge the area of the door end, as shown in Figs. 2 and 3. By

Fig. 2.

Old System of Plain Fire-door.

Fig. 3.

New System of Pierced Fire-door.

this means sufficient surface was obtained to introduce the Argand principle of numerous orifices. The great difficulty lay in adapting this principle to the boilers, as they come from the engineers' manufactories, with the usual contracted door-

ways; and another obstacle to be overcome, was the habit of firemen, to heap the fuel in front, near the door, and to leave the back end of the bars uncovered, a practice which must defeat all efforts at regulating the quantity of air supplied to the gas.

The second condition is, to supply the proper quantity of air, and in this respect, serious errors have been committed. It has been stated by 'authority,' that, "for boilers of the usual construction, the opening for the admission of air should be, 1 square inch to every foot of grate-bar."

Now, this proportion must have arisen from some error in calculation, or some serious oversight: probably, from a mistaken estimate of the speed at which the air enters. Numerous experiments, and long practice show, that the above proportions do not supply one-fourth of the necessary quantity. Instead, then, of 1 square inch, no less than from 4 to 6 square inches for each square foot of grate-bar, are required for bituminous coal, and from 2 to 4 square inches for anthracite coal: these to be regulated, by practice, and for each boiler, according to the amount of draught of the chimney, and the quality of the coal. The proportion of 1 inch is not more than is necessary for a large laboratory gas-burner, much less for a body of fuel, in the most active state, of 12 inches square, and from 6 inches to 8 inches thick.

To demonstrate, practically, the great volume of air which the gas from each ton of coals absolutely, and chemically requires, let a square tube be imagined, the internal area of which is 12 inches square; each lineal foot of the tube will, of course, represent 1 cubic foot. Since the gas evolved by each ton of coals, is about 10,000 cubic feet, the air required for its combustion will be 100,000 cubic feet: the tube, therefore, would require to be 100,000 feet long, or, nearly 20 miles. Thus, if even the air travelled at the railway speed of 20 miles an hour, the last cubic foot of that supply would not reach the furnace, until the end of one hour.

Much has been said as to the importance of skilful firemen; no one, however, has shown, in what that skill should consist. If skill is required, on the part of the man, whose duty consists in throwing the coal through the doorway, it may safely be asserted, that there is something radically wrong in some other

quarter. All that the duty of the fireman really demands, is, that he should break the large lumps, and keep the bars well, and uniformly covered. If, however, the back end, or sides of a furnace, are left uncovered, the air will enter there, in masses, and with accelerated rapidity, instead of passing through the perforated air-distributors, thus rendering nugatory all attempts to regulate, or control its admission. It must ever be borne in mind, that the air will not be dictated to, as to the direction it should take, but that it will escape by the hottest, and shortest run to the shaft. As well, then, may it be attempted to regulate the supply of water to a canal, by means of a sluice, while the lock-gate itself is left open, as to regulate the admission of the air, through any given apertures, while the much larger, and better means of admission, through the uncovered bars of the furnace remain open.

As to the use of self-acting valves, this subject has been anxiously considered. The practical result is, that the generation of the gas is, from numerous circumstances, so irregular, that the supply of air must, necessarily, be equally irregular. Moreover, no correct inferences, as to the operation of any valve, can be drawn from the mere appearance, or colour of the products escaping by the chimney. The rise, or fall of the temperature, within the working part of the flue, supplies the only reliable test; and this can only be ascertained by the aid of a pyrometer. A simple pyrometer has, accordingly, been used with perfect success, during the last ten years, without having undergone any change. It is the invention of Mr. Henry Houldsworth, of Manchester, and it was described by him at the Meeting of the British Association, in the year 1842. (Fig. 4.) Without such a test, no furnace experiments are of any value, as regards the process of combustion. In fact, they only lead observers aside from the main object,—the measure, or quantity of heat, developed, and practically applied, in the generation of steam.

In conclusion, it may be stated, that so complicated have been the expedients for the management of furnaces, and the prevention of the smoke nuisance, and such an air of mystery has been thrown over the whole, that the public are seriously embarrassed, and require some authoritative reference, or guide, on the subject. The constitution, and position of the Institution

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 woodcuts, (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