May 10, 1864.

JOHN ROBINSON M'CLEAN, President,
in the Chair.

No. 1,112.—“On the Distillation of Coal, the Utilization of the Resulting Products, and the Manufacture of Coke.” By M. PERNOLET, of Paris.

By what means the products of the distillation of coal may be utilized, and the price of coke reduced, are questions which have long engaged the attention of economists and of men of science. But the Author believes, that, on the Continent, by recent improvements in the method of charring, and in the arrangement of the ovens, these questions have been at last practically solved. Of these improvements, as well as of the best processes now in use for the manufacture of coke, a description will be given in this Paper.

In the improved system, the method of charring is founded, principally, on the theory of keeping the coal from all contact with the atmosphere during its distillation, of performing that process very slowly, and of collecting and turning to account all its products, while the coke shall retain all the solidity, lustre, and density which are its distinguishing characteristics, when manufactured in the best manner by the ordinary means. It is a system which has been sanctioned by abundant experience, both in Belgium and in France, where it is actively pursued at ten different establishments, employing more than four hundred ovens of the largest dimensions, each capable of receiving from 5 tons to 7 tons of coal at one charge; and it possesses the important additional recommendation, of realizing all the above advantages, simply by the aid of some inexpensive modifications in the ovens at present in general use, especially in England, where the form of the roof is hemispherically vaulted. In fact, one peculiar merit in these improvements, deserving the careful attention of Engineers and manufacturers is, that the economy both of the apparatus and working is so great, that the value of the supplementary products obtained in the first year is sufficient to cover, more than three times, the expense incurred in altering the ordinary furnaces.

Before entering into a detailed description of the apparatus, and in order that a just estimate may be formed of the reduction in the price of coke which must result from its employment, it will be necessary to state, that the supplementary products due to the im-

proved arrangements are, a larger yield of coke, and all the tar, the ammoniacal liquors, and the gas, which would be obtained from the same coals, if distilled in the retorts of a gas manufactory.

The increase in the yield of coke depends partly on the kind of coal, and partly on the way in which the charring was done before the introduction of the improvements. In the great coke works at St. Etienne, where ovens with hemispherically vaulted tops are used, the yield of coke has been advanced from 58·8 per cent. to 69·3 per cent., and in the 'Fonderies et Forges d'Alais,' from 54·6 per cent. to 69·5 per cent. In general, it may be said, that the increase in the yield, from the rich and partially rich coals, is from 10 per cent. to 15 per cent. Consequently, in distilling the same quantity of these coals, there will be a return of coke exceeding by one-sixth, on an average, that which was obtained from the old ovens before their alteration. As to the tar, the proportion collected depends on the nature of the coal, and on the care taken, both in the distillation of the coal, and in the condensation of its volatile products. This proportion has averaged upwards of 2·53 per cent. at the 'Forges d'Alais,' 3 per cent. at Elonges, 3·25 per cent. at St. Etienne, and has reached as high as 5 per cent. from the ovens of the Paris Gas Lighting Company, where only very bituminous coals are employed. Taking, therefore, the average of these manufactories, the amount of tar obtained from the bulk of coal distilled may be reckoned at 3 per cent. The proportion of ammoniacal liquors depends, not only on the conditions mentioned for the coke and tar, but also on the quantity of moisture contained in the coal. At the works of the Paris Gas Lighting Company, where unwashed coal is used, for every 100 parts of coal distilled, there is not obtained much more than 6 parts of ammoniacal liquors; while at Elonges, at Produits, and at St. Etienne, where the distillation is principally from washed coal, the quantity of liquor collected amounts to 10 per cent. or 12 per cent. But in other respects, the useful substances contained do not appear to have any relation to the amount of water collected; and the aggregate of resulting ammoniacal substances shows but little variation for the different coals which have hitherto been tried. Provided the condensation be properly attended to, this quantity may be stated at a weight of not less than 10 lbs., and sometimes of as much as 13 lbs., of sulphate of ammonia per ton of coal distilled.

The gas obtained has not been computed at any ovens except those of the Paris Gas Lighting Company. There it is found, that, by charging the ovens to a height of 2 feet 4 inches, and distilling 6 tons per oven in 72 hours, from 10,000 cubic feet to 11,500 cubic feet of purified gas are generally obtained from a ton of coal, yielding from 69 per cent. to 70 per cent. of coke, fit for delivery to the railway companies. The density of this gas, is to

that of common air, as 40 to 100; and its illuminating power is equal to that obtained from the same coals distilled in retorts, in the ordinary manner of gas manufactories. So that, the weight of purified gas is about 15 per cent. or 16 per cent. of the coal distilled.

Where coke is manufactured for metallurgical purposes, as at Elonges, at Produits, at St. Etienne, and at Alais, it is not usual to collect the gas given off, but it is conducted beneath the ovens, to be there consumed, in maintaining the necessary temperature for distillation. Provided that the coal is rich, as at St. Etienne, or partially rich, as at Alais, this gas will be found sufficient for the purpose (precaution being taken to avoid the risk of explosion); but, generally, it is desirable to force the heat, in order to obtain at once a firmer coke and a tar richer in benzine. This is effected without any increased expense, by burning in addition, in the fire-grate, either the small rubbish which is not good enough to be sold as coke (and which, at St. Etienne, forms from $2\frac{1}{2}$ per cent. to 3 per cent. of the weight of coal distilled), or the residue from the washing, which is of equally small value, and amounts, at Produits, to about 10 per cent. of the volume of coal distilled.

At Paris, where the heating of the ovens is entirely performed with gas-coke from the retorts, from 22 per cent. to 23 per cent. of the weight of coal distilled is burnt; but as this coke contains, probably, not less than 12 per cent. or 15 per cent. of cinder, the consumption stated, represents about 20 per cent. of pure coke, that is to say of carbon. This statement will give an accurate idea of the maximum amount of heat required for the ovens still in use by the Paris Company, which are large and cylindrically vaulted, 23 feet 4 inches long, by 6 feet 8 inches wide, and are provided, at both ends, with openings, the full size of the furnace, closed with cast-iron doors; this arrangement, however, is not the most advantageous, and is avoided in the ovens of the 'Société de Carbonization.'

It follows, that by the improvements in the manufacture of coke, there can be extracted from 1,000 tons of pit coal:—1st, from 650 tons to 700 tons of good coke, instead of the 500 tons, or 600 tons generally obtained in England; 2nd, from 25 tons to 40 tons of tar; 3rd, compounds of ammonia, equivalent to, at least, 5 tons of sulphate of ammonia.

Therefore at the actual prices of these different products, in those parts of the United Kingdom where they are lowest, viz., 7 shillings, or 8 shillings per ton for the coke; from 20 shillings to 30 shillings per ton for the tar; and £14 or £15 per ton for the sulphate of ammonia, the total net value of the supplementary products which the improved ovens extract from 1,000 tons of coal, is more than £100, or about 2s. 3d. per ton.

If it be considered that, at Newcastle and Wigan, in order to procure one ton of coke, worth about 8 shillings, it is not at all uncommon to use 2 tons of rich coal, and, that the nature of this coal is such as to permit of the extraction of all the supplementary products, it will be seen, that the adoption of these ovens would effect a saving of more than 4s. per ton of coke manufactured, and consequently would reduce its price more than 50 per cent.

This reduction might be carried still further, if all the gas, or even part of it, were made use of, as there is every facility for doing, particularly in those metal works which have both coke ovens and gas apparatus, and also in those small gas factories where cannel coal is generally used. The latter item of expense might be entirely got rid of by the alteration of some of the ordinary ovens, for the employment of the gas would effect so great an economy, as to constitute an advantage, equal or even superior to that which could be obtained from the supplementary products estimated at higher values. Because since, on the one hand, the gas produced by the improved ovens is capable of supplying all the heat required for the distillation of the coal, and, on the other hand, this heat can be produced by 20 parts of carbon to 100 parts of coal distilled, it follows that the process of heating would not consume more than 500 lbs. of the most ordinary coal, to transform into coke a ton of coal, yielding, in these ovens, from 10,000 cubic feet to 11,500 cubic feet of gas, at an average expense of 1s. at the highest, or at about one penny per 1,000 cubic feet, or at less than the thirty-sixth part of the lowest price of gas employed in Newcastle, for the town supply.

The reduction in the price of coke, effected by the use of the improved ovens, will generally be, at least, from 4s. per ton to 4s. 6d. per ton, and it may amount to 8 shillings or 9 shillings per ton. But it is important to make a more profitable use of the gas, than that to which it is applied in most of the establishments referred to; for it is frequently burnt, when the most ordinary description of fuel would afford all the heat required, and when this large supply of gas might be greatly increased in value by reserving it for special purposes, not limited to the lighting of towns, but extended to heating steam boilers, or stoves, or the air of blast furnaces, or to evaporating and distilling liquids, puddling cast iron, reducing mineral oxides, and to many other uses, of which some have yet to be and no doubt will be discovered. On this point, it may be remarked, that M. Berthelot has proved, that one of the elements of illuminating gas may be transformed into alcohol, and that hitherto this manufacture has only been stopped, by the expense of evaporating the dilute sulphuric acid, which is present in large quantities. The gas of the improved ovens being able to furnish, at once, both a source of alcohol at a

low price, and a fuel eminently fitted to evaporate it, may, perhaps, help to introduce this manufacture into the field of commerce.

As regards the use of gas in blast furnaces for the manufacture of cast iron, an application of it by the 'C^{ie}. des Forges de Franche Comté' has been recently made, by which, it is said, a purer iron has been obtained, with a saving of 40 per cent. of the fuel usually necessary; and it is also stated, that, after several weeks' experience, twenty improved ovens, yielding on an average 20 tons of coke per diem, would keep one blast furnace supplied both with coke and gas.

In the foregoing remarks the employment of the richer, more bituminous sorts of coal, has been implied, and these are, in fact, the best adapted for obtaining the products of distillation. But, though the saving would not be so considerable, the improved ovens may be profitably used for the poorer coals, and even for the anthracites, provided that some of the richer kinds be used with them, as is done at the 'Forges du Creuzot.' In such cases, the economy would consist chiefly in the smaller quantity of the superior coal required, but of course, the products would be proportionately less abundant, in consequence of the small amount of tar, hydrate of ammonia, or gas furnished by the poorer part of the mixture. There would, however, result an important reduction in the price of coke, not only on account of the saving effected in the distillation of the rich coal, but because the poorer kinds, when thus mixed with the richer, instead of being charred alone, would yield three times as much coke as when used singly; in fact by means of this mixture, it is easy to transform into good coke, such coals as are usually considered incapable of being charred, or, at least, of yielding coke in pieces of an available size.

Thus, at Stoke, in Staffordshire, at the works of the Shelton Bar Iron Company, two sorts of coal are used; one flaring, but poor, which has hitherto only been charred in the open air and in large pieces, and the other, partially rich, which is charred in the ordinary ovens,—all the poor, and comparatively small coal (in pieces less than 6 inches thick) being rejected. Yet, by mixing it with the partially rich kind found in that neighbourhood, and by charring the whole in the improved ovens, the poorer coal might be used with facility, and at least 65 per cent. of good coke would be obtained, instead of the 45 per cent. or 50 per cent. produced by the rich coal, when charred by itself in the ovens in actual use.

In certain cases, also, tar, or dry pitch may be used with coals which have little or no bitumen, and which are, at the same time, too brittle to be put into blast furnaces in their crude state. By the admixture of from 8 per cent. to 10 per cent. of the above substances, these coals would be supplied with all the bitumen in which they are naturally deficient, and would then become profitable for

use in blast furnaces; for, if only the small, cheap coal were consumed, the cost of the mixture would not exceed the value of ordinary coking coal. Still, the agglomerating matters, being much more expensive than the small coal with which they are combined, it is always important to economize them; and the best way of economizing them is to exclude the air, and thus prevent them from burning, and to collect the products of distillation, and to contribute to their formation during the process. These recommendations constitute the leading characteristics of the new system.

DESCRIPTION OF THE IMPROVED COKE-OVEN.

The alterations consist:—1st. In raising the floor about a foot, and so arranging it that it can be heated from below by means of a fire-grate and flues; 2nd. In making a new opening in the roof, in which is fixed a pipe for the reception and conveyance of the volatile products; 3rd. In so arranging the openings of the old ovens that they can, by means of movable plates of metal and clay, be hermetically closed during the distillation; and 4th. In the addition of a chimney to the masonry, for the purpose of securing the circulation of the products.

In Plate 9, Fig. 1, the coke-oven most in use in England is shown unaltered; and in Figs. 2 and 3 the same oven is represented as altered with the above improvements. S S S is the floor, raised about a foot; underneath it is the fire-grate F, provided with flues A A and A". I is the opening in the roof. T is the pipe intended to receive the volatile products. P and C are the two usual openings. Fig. 2 shows the same openings, with the addition of the movable plates.

Figs. 2 and 4 show the chimney added to the masonry, X and Y. The dimensions of this chimney, as ascertained by experience, should be 50 feet in height, and the inside area should be not less than $3\frac{1}{2}$ feet square, for a group of sixteen ovens. The sectional area of the main flue should not be less than three fourths of that of the chimney. The oven is represented as arranged for being charged from above, by means of wagons running upon rails, R R, Fig. 2. This plan is the most convenient and the most expeditious. The wagons are brought up in succession over the opening C', and are then emptied into a movable iron funnel, which must be large enough to receive the whole charge at once; and as the coal falls on the floor, a workman, stationed at P, spreads it equally. In this way, a charge of more than 5 tons can be introduced in fifteen minutes, or twenty minutes, a most desirable rapidity to preserve the heat of the oven when the charge is being renewed. Should it, however, not be deemed

advisable to arrange the ovens for receiving the coal in this manner, the coal may be conveyed through the door, P, in the way most usual in England; but the latter mode is not only slower, but more fatiguing to the workman, on account of the greater height of the floor.

When the charge has been equally distributed, the door is closed, fastened with a screw, and closely luted with loam; and, until the coking is nearly completed, no further attention is required, beyond seeing that the joints allow neither the air to enter, nor the gas to escape, and that the heat is sufficient, and is equally distributed over every part of the floor. The first of these objects is effected by the simple re-application of loam, wherever there are signs of its being wanted; the second, by the maintenance of a due supply of gas to the fire, through the blast pipe, and by a free draught of air through the centre pipe, or round the edge of the blast pipe, and by a proper distribution of the flames in the flues.

To try whether the distillation is finished, the valve O, Fig. 2, is closed; the communication between the pipes T and T' being thus intercepted, if the charring is incomplete, the gas which is still given off, not having the means of escape, strains the joints of the apertures, cracks the surrounding luting, and, by escaping in the form of smoke, proves the necessity of continuing the process. In this case, the valve is merely reopened, and the gas again passes off by the outlet pipe. If, on the other hand, upon the closing of the valve, there is no escape of gas, the aperture, C, is opened, and a temporary fire-brick wall, separating the charge from the door of the oven, is taken down. It is important not to open the door before cutting off the communication between the pipes T and T', otherwise the external air would get into the pipe T', and become mixed with the gases which are circulating there as they proceed from the other ovens. This arrangement is more fully shown at T' T' T' T', Fig. 4. The door once open, the coke is removed with a rake, or shovel in the ordinary manner. While this is being done, the cast-iron cover at C' is kept shut, to avoid the risk of igniting the coke, by the draft of air which it would create if open.

When the charge has been completely withdrawn, and the cover opened, the oven is recharged. Both at this time, and while the coke is being withdrawn, the gas brought from the other ovens, by the great common flue, and collected by the small common flue, M M M, Figs. 2, 3, and 4, is allowed to pass continually into the fireplace; so that the floor is kept hot, and the gas begins to show itself above the opening only a few minutes after the closing of the door. The covering is immediately put on and luted, and the communication is reopened between the interior of the oven and the great common flue, by raising the valve.

Should it appear that, one side of the oven is insufficiently heated
[1863-64. N.S.] 2 G

and the other too much, the registers K K, must be advanced, or withdrawn by means of a hook; or if the supply of gas is too small, the cock Z, Fig. 3, must be opened rather more.

The products of the distillation are drawn off by the draught of the chimney, together with the condensation of the liquid, and the cooling of the gaseous products tends to create a vacuum, which assists the current in the direction shown by the arrows, Fig. 4. The products circulate thus in the great general flue, penetrate into the condensing apparatus Q, Q, Q, Fig. 4 (where they deposit most of the tar and ammoniacal liquor), and return to the ovens by the small general flue, whence the gas, purified and dried, passes to each fire by the pipe H H, Figs. 2 and 3.

The chief uses of the fire-grate are to heat the ovens, when they are set to work afresh, and to raise the temperature of an oven which is not so hot as the others. In this case, the small, unmarketable coke, unavoidably made with the larger, is found to be a sufficiently good fuel. Lastly, in the event of part or the whole of the gas being utilized elsewhere, the fire-grate will be indispensable, for receiving whatever fuel is to be burnt as a substitute.

The products of the distillation pass through the passages marked by the arrows, and rise to the gallery, whence they escape into the atmosphere. The time occupied in charring varies, with the arrangement of the oven, the nature of the coal, and the density desired for the coke. At St. Etienne, it is upwards of 72 hours, for rich coal, but the ovens there used differ from that which has just been described, the form of the vaulting being more elliptical. At the foundry of Torteron, where the rather poor, but very flaring coals of Commentry are used, and where the system of the 'Société de Carbonization' has been applied to the Belgian ovens, the time occupied is only 24 hours.

The condensing apparatus may be modified according to circumstances. The plan to be adopted will depend upon whether the water supply is scarce, or plentiful. With an abundance of water, the cooling surfaces, and consequently also the cost for iron work, may be diminished.

The cost of altering an oven can be estimated from the elements already afforded in the foregoing statements and in the drawing. The following is a calculation of the expenses actually incurred at St. Etienne. For each oven altered, there were used

	£.	s.
About 6 tons of fire-bricks	3	0
" 2½ " cast iron, in different shapes . .	12	10
Common iron, bricks, labour, &c.	4	10
Total	20	0

Exclusive of the value of the gas, the supplementary products gained represent a value of more than 2s. 3d. per ton of pit coal distilled; and if it be considered, that in an oven of the size of that on which the above calculation is based, not less than 500 tons are charred yearly, it will be seen that only four months' work would be required to refund the expenses incurred, since a profit of £60 per annum upon each furnace would accrue from the more perfect results expected by these inexpensive but most important improvements in the system and apparatus.

The Paper is illustrated by a drawing from which Plate 9 has been compiled.

Fig: 2.

OVEN OF THE "SOCIÉTÉ DE CARBONISATION"

Fig: 3.

Fig: 1.

ORDINARY OVEN.

Fig: 4.

GENERAL PLAN.