CARBONISATION OF COAL AND RECOVERY OF BY-PRODUCTS.

By B. Wilson Haigh, *M.L.A.* (*Bihar*), *M.I.Chem.E.*

No excuse is needed for the inclusion of this subject in the symposium 'Coal in India', for the subject is one of tremendous importance in the industrial life of the country and especially the Province of Bihar.

What is meant by Carbonisation.

When coal is heated in the absence of air so as to expel part or nearly the whole of the original volatile matter of the coal, it is decomposed and the process is termed destructive distillation. With coking coals, however, the particles fuse together, coalescing to form a coherent mass which is called coke. The carbon residuum of the original coal has become cemented with a binding ingredient formed or liberated during the heating. Coals with a high binding power are called strongly coking coals, those with a low binding power are feebly coking; there are also non-coking coals which have no binding power at all such as anthracite. When the coal is heated to temperatures varying from about 400°–700°C. the operation is generally known as Low Temperature Carbonisation. When the temperature to which the coal is subjected is between say 900° and 1300°C. this is called High Temperature Carbonisation and this is the one which is practised in India. There is also Medium Temperature Carbonisation carried on at a temperature of about 800°C., little practised as yet but about which more will be said later. If non-coking coals are so heated as to drive off most of the volatile matter and afterwards allowed to cool, the residue appears to have the same form as the original coal, so that if the coal is first crushed, nothing but a black powder remains after heating.

High Temperature Carbonisation.

This may be conducted in beehive ovens which are firebrick chambers shaped like a beehive. The heat retained in the structure commences the distillation, the gases given off from the coal mix with air which is allowed to enter above the door and combustion takes place—the heat reflected from the dome carries on the carbonisation—the products of combustion pass out at the top of the oven. Very good coke can be produced in this way and also in the 'Country oven' which is a long narrow rectangular chamber where the heat is also produced by the combustion of the evolved gases. This process is slow, the carbonising time varying from say 48–72 hours but nowadays furnace and foundry cokes are chiefly made in the by-product oven.

This is the source of most of the coke used in the iron and steel industries today. In the beehive oven process the only product is coke but, as is implied

VOL. VI—No. 3. [Published August 19th, 1940.

in the name, the by-product oven is the source of by-products—coal gas, coal tar, ammonia, benzole, naphthalene and some others.

Some idea of the magnitude of the coking industry may be gained from the Report of the Chief Inspector of Mines in India for year ending December 31st, 1937. He gives the figure of 1,848,521 tons coal despatched from Jharia alone to coke factories and 88,540 tons of hard coke despatched from Jharia. 786,126 tons of soft coke were also despatched from Jharia, mostly made, not in ovens, but by the 'heap' method. There are vast deposits of first class iron ore in Bihar. The best coking coals are also mined in Bihar so that with one exception the large coke factories are situated at the collieries in Bihar or the Steel Works of Tatas' also in that province. The iron ore is so pure that coke of a higher ash content than is generally used in steel manufacture in other countries can be used in India. The lowest ash in Indian-made coke is about 15% and it is often used up to 22 or 23%, and even then sometimes less than 18 cwts. of coke per ton of pig iron is used in the blast furnaces.

The by-product coking industry is of comparatively recent growth, the first by-product coking plant in Great Britain was installed in 1881 by Henry Simon working in conjunction with Francois Carves, a distinguished French engineer, and the first plant in India was built by the same firm (Simon-Carves, Ltd.) at Giridih in 1909. Since then enormous strides have been made and in 1940 it is anticipated that at Tatas' Works in Jamshedpur they will be able to manufacture over 3,500 tons of coke per day or 1,300,000 tons per annum. This plant will be the largest single coking plant in the British Empire with a maximum capacity of 5,400 tons of coal per day.

Described in non-technical language a coke oven is a long rectangular chamber built of firebrick, or silica bricks. Ten metres (33 feet) used to be the standard length with a height of 2½ metres, but the modern tendency is to build larger ovens and the latest type in India measure 44 feet 5 inches long by 14 feet 7 inches high by 17½ inches mean width. These ovens each take a charge of 20 tons of coal and are capable of carbonising this in 15 hours, the normal operating time is 18 hours. On either side of the chamber are flues heated by gas and underneath is a sole flue similarly heated. The gas used for heating is generally that produced in the process which is normal coal gas. Its composition varies. The following figures are typical:—

	Per cent.
Carbon dioxide	0·7– 2·0
Benzol, etc.	0·6– 1·5
Heavy Hydrocarbons and Tar	1·0– 5·0
Carbon Monoxide	5·0–10·0
Methane	24·0–36·0
Hydrogen	50·0–59·0
Nitrogen	1·0– 6·0
Hydrogen Sulphide	0·1– 1·0

The quantity of gas evolved from 1 ton of coal varies of course but an average figure is 10,000 cu. ft. per ton having a heating value of 450–500 British Thermal Units (net) per cubic foot. This is called 'rich gas' and is a very valuable heating agent. Sometimes all the coke oven gas is used for heating purposes as at a steel works or it may be sold for domestic lighting and heating in cities or towns.

In that case the ovens have to be heated by 'lean gas' either blast furnace or producer gas and under those circumstances a special type of oven is available called the Compound Oven. These are of course of the regenerative type where the air for combustion is strongly pre-heated. The products of combustion are passed through a chequer work of firebrick which becomes heated to a red heat and after half an hour, air for combustion is passed through the regenerator. There are two sets of these and they are used alternately every half hour. During one period they are heated by the products of combustion and during the other period air is passed through to be heated. Where 'lean' gas is used the gas is also pre-heated in a similar way before combustion through a separate regenerator.

The coal is charged into an oven through suitable openings in the top, the charge is levelled by a long arm operated electrically passing over the charge and the doors and charge holes are made gas-tight.

The leveller is attached to the ram or coke pushing machine which discharges the coke into a car in which it is quenched by water or on to a coke bench of cast iron plates where it is cooled in the same way. The products of distillation escape through the ascension pipe controlled by a valve into a collecting main which is constantly flushed either by tar or liquor to remove the dust which is carried in the gas stream.

The gas is pulled away from the collecting main by means of an exhauster and forced through the different pieces of apparatus where the by-products are removed, back to the return main where it is burnt in the heating flues or supplied for other uses. In the most modern types of ovens as much as 60% of the gas may be 'spare' and available for uses other than heating the ovens. The cycle is continuous and there is rarely any gas-holder provided for gas storage and when for any reason the cycle has to be interrupted the whole of the gas has to be by-passed and the crude gas blown away into the air—an operation in which there is an element of danger and which needs great care.

Oven Construction.

Nowadays ovens are built on a reinforced concrete decking supported by reinforced columns carried on a reinforced concrete raft. This is necessary owing to the larger modern ovens being so much heavier. Brickwork arches which were formerly used could not support the great weight of the modern superstructure.

In the construction of the ovens refractory material of the highest grade has to be used and it is a fortunate circumstance that there are ample supplies of first class fireclay and silica materials within easy reach of where they are required. The manufacture of refractories has progressed in Bengal and Bihar to a remarkable degree. It is now acknowledged that the special shapes in fireclay, semi-silica and silica which are required in coke oven construction can be manufactured of as fine a quality, with as great precision and with as small a tolerance as in any other country.

It must never be forgotten that the most important product from coke ovens is coke and it is the duty of the coke works manager to produce the best possible product from the coal at his disposal. If he uses different coals careful blending is called for and a variation in the coking time may often make considerable difference to the resultant coke.

If the blast furnace manager is to get the best results, what he aims at is to reduce coke consumption to the minimum so as to get the lowest coke consumption per ton of pig iron. To do this he must have coke of regular quality, sufficiently hard to stand the burden of the furnace (that is why soft spongy coke is useless for the purpose). On the other hand it must not be too hard or lacking in porosity otherwise it would pass down the furnace into the slag at the bottom without performing its function, which is to reduce the oxides of iron to the metallic state. That is why the 'Jhama Coke', a natural coke produced by the carbonisation of certain Jharia coal seams *in situ* is useless for blast furnace work. It is so hard and non-porous because it has been coked under such great compression of the overlying strata. Coke is also used in foundries for melting iron and brass to make castings. It is used in sugar factories, aerating gas factories for producing CO_2 and in smithies for blacksmiths' use.

Coke also contains sulphur and phosphorus and a portion of these finds their way into the pig iron during the blast furnace operations; when in excess both have a deleterious effect on the pig iron. Fortunately Jharia coals are very low in sulphur—the best contain only about 0·5% which is negligible. Giridih coke is particularly low in phosphorus and so is suitable for the manufacture of ferro-manganese.

Nothing has been written about gasworks practice which is also a branch of high temperature carbonisation. This is conducted in nests of fireclay retorts and the chief product is not coke but illuminating gas and the retorts are heated by burning coke, the balance being sold as gas coke for domestic use.

Tar and ammonia are also recovered and the gas is stored in large gas-holders and distributed through a system of mains and metered to the various consumers for commercial or domestic heating, cooking and lighting. As is well known, some Calcutta streets are lighted by coal gas.

Low Temperature Carbonisation.

In this system the coking temperatures range from about 550° to 700°C. or a little higher. The main objects of thus restricting the temperatures are:

(1) to obtain maximum yields of liquid products, and (2) to produce free burning semi-cokes containing proportions of volatile matter ranging from 8% up to about 20%. The yield of rich gas in L.T. systems will range from 2,000 to 7,000 cu. ft. per ton of coal and its calorific value may be from 700 to 1,000 B.Th.U's. per cubic foot.

Generally speaking, the gas and oils from the L.T. process are mostly of the paraffin series of hydrocarbons whilst high temperature carbonisation yields aromatic hydrocarbons of the benzene series.

The chief product of the Low Temperature process is a smokeless fuel and several successful fuels have been marketed in England, notably Coalite, but it can only be regarded as a luxury fuel for it is sold at a high price somewhere round 45 shillings per ton, higher than that of best house coal. A vast number of experiments have been done during the last 30 years, many systems have been tried on a semi-commercial and commercial scale, hundreds of patents have been taken out, millions of pounds of capital have been expended most of which has yielded no return to shareholders, and where profit has been made it has only been due to the 'fancy' price which the producers have been able to obtain for their smokeless fuel. The main fillip to this industry comes from the patriotic people who deplore the smoky atmosphere of England's cities and towns and who try to do their bit to reduce it and the resultant fogs, by burning a smokeless fuel.

The British Government have tried to help by grants-in-aid and by purchase of the Low Temperature oils for use in the Navy but even with these adventitious aids the prospects are not favourable.

There is much loose talk and often ill-informed newspaper correspondence in Calcutta and elsewhere asking why large-scale Low Temperature plants are not established in the coalfields to recover the valuable by-products (dyes, etc.) which are now being lost. The Bihar Government are making experiments with this system but they are instigated by those who have a rather limited knowledge of the subject and are, in the opinion of the writer, likely to meet with little success.

The capital cost of such plants is high. Where is the profit to come from to pay the interest,—after providing for the overhead charges and working costs,—let alone any dividend ? Where is the market for the semi-coke at a price that will pay ?

Other products are Low Temperature tar of which 10–18 gallons may be recovered from a ton of coal but as it is not suitable for road tar, where is the market for it ?

Sulphate of ammonia is also recoverable but probably not at a profit. Sulphuric acid has to be manufactured or bought and some coke plants have already ceased to recover this by-product as it cannot compete with synthetic ammonia. Motor spirit is another recoverable by-product but has to pay an excise duty of 10as. per gallon (now 12as.). Even on a large scale it would cost 4 or 5 times as much to manufacture as petrol, so again how could it be sold to compete with petrol and yield a profit? These facts should be known before Governments or investors sink money in projects which under present conditions have little hope of success. There are many difficulties in the way, both technical and other, and probably no other technical process has yielded so many disappointments.

Medium Temperature Carbonisation.

This is a process which lies in between the high and low and may be conducted at temperatures round about 800°C.

Its main object is the production of a smokeless domestic fuel.

There are now more coke plants in India than are required to produce the hard coke required for the iron and steel industries and coke oven owners may now be compelled to turn their attention to the domestic coke market.

The adaptation of coke ovens for the production of a free burning reactive coke has been proved to be possible notably in France and less in Great Britain and the time is soon coming when close attention will have to be given to the subject in Bihar. Soft coke as made in heaps or mounds is sold very cheaply as there is no capital expenditure involved in its manufacture but generally speaking it is a very low grade fuel though the Soft Coke Cess Committee are trying to improve it and push its sale which is increasing fairly rapidly (786,126 tons were sold in 1937 and over 900,000 tons in 1938).

If, however, a demand for a clean readily ignitable fuel at a higher price than soft coke can be created and developed there must be a great potential market in India. No doubt the difficulties are many, a very highly developed marketing organisation would need to be established and the fuel would probably have to be delivered in jute bags by lorry from house to house on a cash basis.

It may develop into a profitable distributing agency if properly organised and managed.

The by-products produced at 800°C. are of a character similar to those obtained in normal high temperature carbonisation and are thus more valuable than the paraffinic bodies obtained by carbonisation at low temperatures.