

CARBONISATION OF COAL.

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The history of carbonisation of coal goes back about two hundred and fifty years but progress was slow until a hundred and fifty years ago when William Murdoch first used gas for public lighting. From that time a great industry has developed and gas supply is one of the most important public utility undertakings in modern life.

Until recent years the carbonisation of coal was considered as 'destructive distillation' but with the increased importance of the by-products—coke, tar, etc.—this phrase is falling out of use. During the past two decades a large amount of scientific work has been carried out to determine the best conditions and type of plant employed.

It is generally accepted that coal is the product of the decomposition, under great pressure, of vegetable matter. During this process, the carbon content increases and the hydrogen and oxygen contents decrease. The percentage of volatile matter decreases until at the stage when the hardest coal, anthracite, is formed, the proportion is only about one-sixth as compared with that of lignite, which may be considered as a midway product in the formation of anthracite from the original vegetable matter.

The question of finding the most suitable coal is of vital importance to the Gas Engineer and is influenced by several factors. These factors also determine the kind of plant in which the carbonisation is to be carried out. Practically all coal is carbonised in one of the following types of plant:—

- (1) Horizontal Retorts.
- (2) Vertical Retorts.
- (3) Coke Ovens.
- (4) Chamber Ovens.

If the main product required is Town Gas, either of the first two is generally used. If hard coke for metallurgical work is the main product, coal is carbonised in the third type of plant. The fourth system, Chamber Ovens, is a combination of the two. In addition to these types there is another system coming into use for the production of light oils, benzols, etc., by the carbonisation of coal at low temperature but the amount of coal so carbonised is very small at present.

Horizontal retorts are usually made of fireclay and the dimensions are 20 feet × 22 inches × 16 inches, the section being a rough \sqcap shape. The general practice is for the retorts to be set in a 'bed' of four tiers of two retorts.

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At each end of the retort a cast iron mouthpiece is fitted from which the gas as generated is carried off through iron pipes to a hydraulic main fixed on top of the bed. The pipe from the mouthpiece is sealed, usually about $\frac{1}{2}$ " in liquor in the hydraulic main. The mouthpieces are fitted with doors which are hermetically sealed by means of an eccentric lever. When the doors are opened for charging with coal or pushing out coke the seal prevents air being drawn in and mixing with the gas. The 'beds' are heated by producer gas generated from coke and each bed is a separate unit with its own furnace. The temperature of carbonisation reached is 1250°C . When a retort is emptied of coke produced from the previous charge of coal another charge is put in by means of the stoking machine and the doors are closed as quickly as possible. With Indian coal the average weight of the charge is $10\frac{1}{2}$ cwts. and the period of carbonisation is 10-11 hours. By the end of that period all the gas is driven off together with all tar vapour, etc. and only coke remains. The gas, tar vapours, etc. are drawn through the condensing plant, where the tar condenses out, by means of 'exhausters', and then passed through the washing and scrubbing plant to remove cyanide products and ammonia and finally through large cast iron chambers (purifiers) containing ferrous oxide to remove sulphuretted hydrogen.

In vertical retorts the coal gravitates through the retorts and the residual coke is extracted at the bottom. In the majority of vertical retort installations the process is continuous although there are a few where the charge of coal is dropped in and left until the carbonisation is completed when the coke is released into wagons by opening the bottom door. In the continuous process, coal enters at the top and coke extracted from the bottom. This process ensures a regular quality of gas produced. The heating of the retorts is by producer gas and usually is so regulated that the top 5 or 6 feet of the retort is comparatively cool, the centre section is heated to a temperature of 1300°C . and the bottom section of the usual 25 feet length of retort is progressively cooler than the middle section. Near the bottom a controlled supply of steam is admitted which, meeting the incandescent coke, combines with the carbon forming 'water gas', which may increase the yield per ton of coal by 30%, this latter figure depending, of course, upon the quality of gas required. A further effect of admitting steam is that the water gas scours the plastic coal and washes out many gaseous hydrocarbons which otherwise would be decomposed if left in contact with the hot sides of the retorts.

In India the bituminous coals used for gas manufacture are not of a very wide choice. All coals, of course, will produce gas but the most suitable are of a limited quantity in this country. A Gas Engineer firstly requires a coal that will give a large volume of gas after purification but also he must have a coal which will produce a good saleable coke and a fair yield of tar. The moisture content of the coal should be very low because when coal is brought into the retorts the first substances to be distilled are the free water and light oils. If the water content is high, too much weak virgin ammoniacal liquor is

produced which reduces the efficiency or increases the cost of the production of ammonium sulphate.

A proximate analysis of good gas coal in India is—

Moisture	1.5%	} dry basis
Ash	11.0%	
Volatile Matter	34.5%	
Fixed Carbon	54.5%	

with the calorific value over 13,000 B.Th.U.s. per lb.

The ash content is at least twice as high as that of good English gas coals and the fusion point of the ash is low. This latter factor has a bad effect upon the producers which supply the beds with gas for heating and it is necessary to adopt special grates to prevent heavy clinker forming. Also, the quantity and quality of the ash renders its use almost impossible in carburetted water-gas plants, which are frequently used in Europe as auxiliary to coal gas plants and exclusively used in some parts of the U.S.A. and Canada.

Another unfortunate feature of a good Indian gas coal is that in most cases when it is plastic during carbonisation the mass swells considerably. This has in the past prevented the installation of vertical retort plants in India and has led to the loss of export trade to gas undertakings on the China coast. Two years ago, however, the Hongkong Gas Company working with the contractors who erected their vertical plant solved the problem of Indian coal 'sticking' in the vertical retorts and now have recommenced importing. The Shanghai Gas Company also find they can now use Indian coal and, as supplies of Japanese coal are no longer available, may use it in preference to Australian coal which, although easier to carbonise, is dearer to purchase.

One obnoxious impurity, sulphuretted hydrogen, to be found in crude gas is produced from pyrites in coal and in this respect Indian gas coals are superior in most respects to European coals. The 'free pyrites' is usually well below 0.5% and the percentage of H_2S in crude gas is below 1%. This small proportion is easily extracted. The small amount of pyrites present reduces the danger of spontaneous combustion when stored. At my works Indian gas coal is stored under cover to a depth of 15 feet and no case of fire has occurred.

In carbonisation the 'decomposition point' of coal varies with different kinds of coal. When coal is first heated in a closed retort or chamber occluded gases are first given off. These gases are mainly paraffin hydrocarbons and are given off at temperatures between 150–200°C. Water vapour and light condensable oils are given off up to about 400°C. and during this range sulphur compounds and oxides of carbon are evolved. From 400°C. large volumes of gas which are rich in hydrocarbons are produced. These hydrocarbons combine with the lighter oils, benzene, toluene, etc. and form 'gas tar'. Above 1000°C. only gas containing a large percentage of hydrogen is evolved. The

original nitrogen in the coal, plus some of which may have leaked in during the process, combines with the hydrogen and forms ammonia. It can be assumed that the maximum combination occurs when the retort is at a temperature of about 1000°C ., and if the carbonisation of coal is carried to the extreme, say several hours at 1300°C ., the total quantity of ammonia produced is not greatly increased. If the gas is not extracted from the retorts, the ammonia would be decomposed before the retort reached 1000°C . and it has to be remembered that during carbonisation, when the temperature is rising to say 1250°C ., the gases evolved are being continuously extracted by the exhauster. There is no doubt the presence of other gases prevents or retards the decomposition of ammonia. Some of the original nitrogen in the coal combines with the hydrogen and the carbon of the incandescent coke to form hydrocyanic acid and also a little free cyanogen. HCN does not form below 900° and it is believed that at the higher temperatures some of the ammonia is decomposed by the incandescent coke to produce this impurity which has to be removed.

The proportion of carbon dioxide in the gas produced would be about 1% if the coal were distilled in a hermetically sealed chamber. In practice such conditions cannot prevail and air and waste gases from the exterior of the retorts enter through the pores or cracks in the fireclay retorts, the interior of the retort being kept at about 2/10ths of an inch vacuum. The oxygen so entering combines with carbon of the incandescent coke or gaseous compounds and carbon dioxide is formed. It is the aim of a Gas Engineer to keep the percentage of this 'inert' constituent of the gas as low as possible.

Where coal gas is supplied to consumers the quality is governed in most countries by Acts and the undertaking is severely penalised if the calorific value falls below the standard defined or if sulphuretted hydrogen is present. The general standard for the United Kingdom is 450 B.Th.Us. per cubic foot of gas. The problem that has to be met is to obtain the highest yield of gas per ton of coal whilst keeping the quality of the gas supplied above the standard calorific value. All good gas coals if distilled in a perfect atmosphere in the retort, that is the gas is extracted as generated without either pressure or vacuum, would produce gas at the temperatures prevailing too rich with a corresponding low volume. In horizontal retorts the gas during the first three hours of carbonisation would contain such a high percentage of hydrocarbons that the usual burners of consumers' appliances could not supply sufficient air for combustion and long smoky luminous flames would result. On the other hand the gas produced during the last three hours of carbonisation would be of low calorific value as the hydrogen proportion rapidly increases. To obtain a satisfactory mean and to produce a gas of consistent quality the charging of retorts is spread over the period of carbonisation. In India where the retorts are set in four tiers it is the practice to 'charge' the retorts of each tier in turn spreading the whole operation to cover the 10-11 hours of carbonisation. This means that gas generated in each 'bed' is being generated from

coal in four different stages of carbonisation with the result that the gas is well mixed before passing through the condensers, washing plant, etc. to the holders for distribution to the town. To avoid waste through the porous retort material it is usual to keep a slight vacuum—about $\frac{2}{10}$ inch water gauge—inside the retorts. This is controlled by a water-sealed governor fixed on the foul main between the hydraulic mains and the condensing plant. Should any variation in the quality of gas produced as indicated by the recording calorimeters occur the attendant can immediately restore conditions to normal by altering the 'pull' on the retorts by adjusting this governor. If the calorific value of the gas is too high a little extra vacuum will remedy this and *vice versa*.

In both systems of carbonisation—horizontal and vertical retorts—the most economical working is obtained by removing the hydrocarbons away from the incandescent coke or sides of the hot retorts before decomposition (or degradation) has proceeded too far. It is a matter of experience to determine with each installation and each coal or blending of coal which conditions give the best results. The decomposition of the hydrocarbons lowers the quality of the gas and also adversely affects the tar. When the decomposition occurs some of the liberated carbon is carried forward by the gas and deposits in the condensed tar increasing the percentage of 'free carbon'.

It is not possible to say which system of carbonisation is best as every installation has to be considered in relation to local demand for gas and type of coke and also the kind and cost of coal available for carbonisation.

