Although the retorts used at Messel and in Scotland are not really intended for bituminous coal, it is useful to refer to them since the experiences gained with them in decades of successful working is of value in the production of oil from coal.

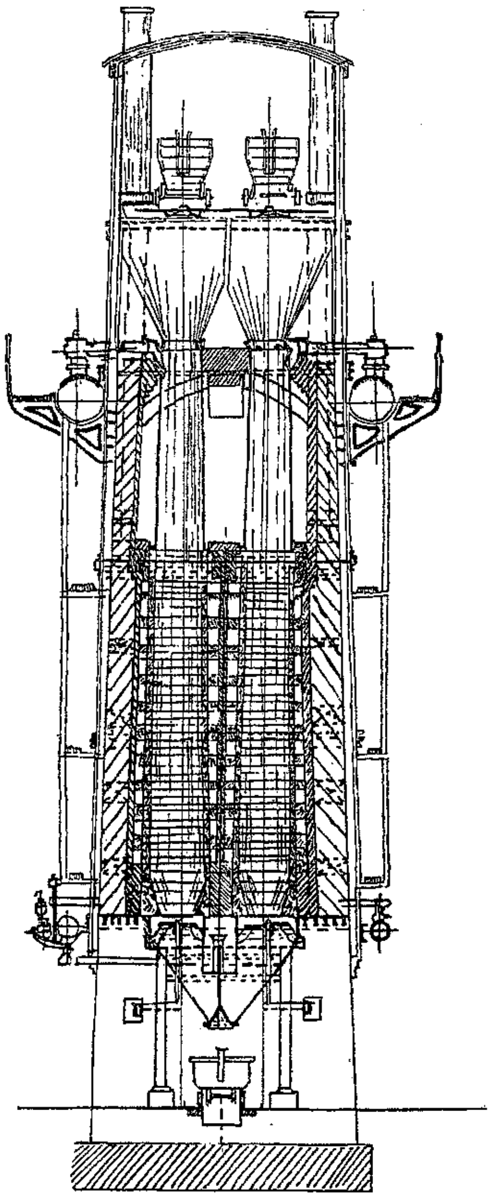


FIG. 15.

Horizontal Retorts.—The process of Del Monte-Everett (Fig. 16) is continuous. The slightly inclined tubular retort is made of cast steel. The coal is introduced at the lower end and is carried through the tube by a worm conveyor. At the upper end the semi-coke is cooled in the absence of air.

The retort is lagged with a refractory lining and is built with several others into a brickwork setting. The gas leaves at the lower end of the retort; after condensing oil and water, the gas is blown again into the upper end of the retort after having passed through a superheater. The distillation is therefore effected partly by external heating and is accelerated by a circulating current of superheated gas. The surplus gas formed in the process is taken out of circulation and utilised for the external heating of the retort. An experimental plant of this kind was in use at Chiswick, London. The plant was stated to yield exceptionally high percentages of oil, due to the circulation of gas and the consequently rapid removal of the oil from the retort.

The Carbocoal process (Figs. 17 and 18), which was developed in America from an experimental installation at Irvington into a large plant at Clinchfield, started up in 1920, is one of the few which may claim to have assumed large industrial dimensions. Horizontal retorts are used which are outside heated, somewhat on the lines of the bottom-heated Otto coke-oven. The retorts are built of firebrick and have a cross-section shaped like an inverted heart; they are 6 metres long, 2 metres wide and 1·5 metres high. Blades bolted to two shafts serve as mixing and conveying worms. The description of the plant leaves the impression that it has been built with great care and unusual technical resources. The Carbocoal process has the following peculiar features: The coal is converted into semi-coke while travelling through the horizontal retorts. The gaseous products are withdrawn at the

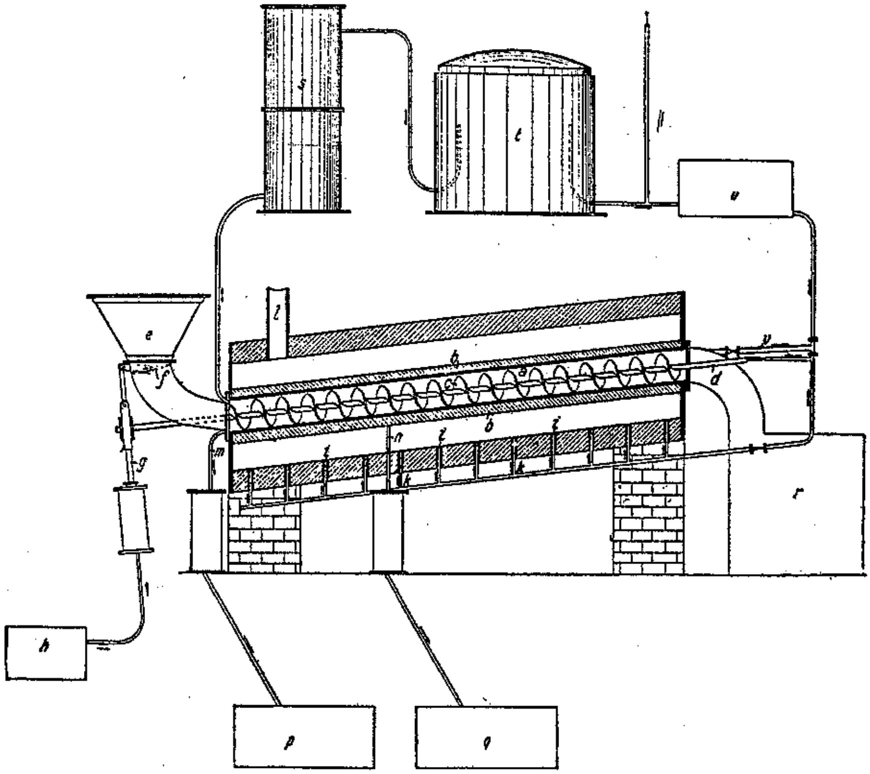


FIG. 16.

end opposite to the charging side, whilst the semi-coke drops through a vertical shaft to be ground in hammer mills and pressed into ovoid briquettes with an admixture of from 10 to 12 per cent. of liquid pitch. The briquettes cannot be utilised as smokeless fuel on account of their pitch content. They are, therefore, subsequently carbonised in high-temperature secondary retorts (Fig. 19) yielding smokeless fuel and a tar similar to coke-oven tar.

It has been repeatedly emphasised that a suitable application of semi-coke is an essential requisite for the economy of primary tar production. In the case of the Carbocoal process, there is no doubt that it can yield a primary tar, nor will it be questioned that the final product is a useful solid fuel of convenient shape. The methods by which this end is attained give rise to

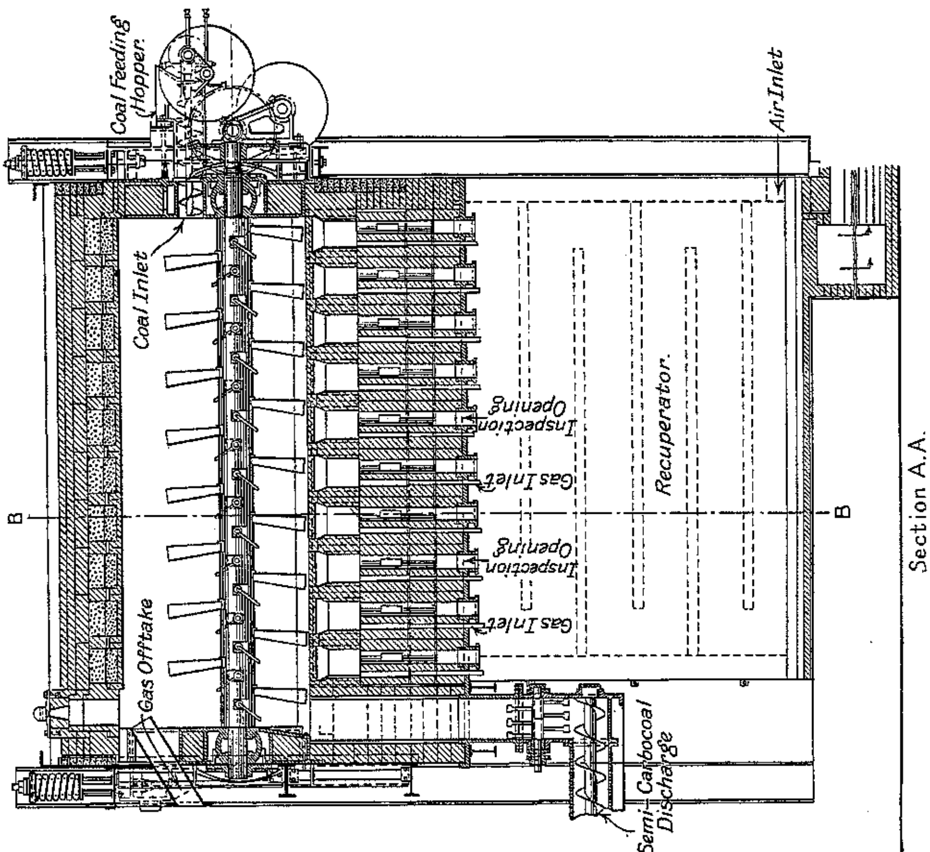


FIG. 18.

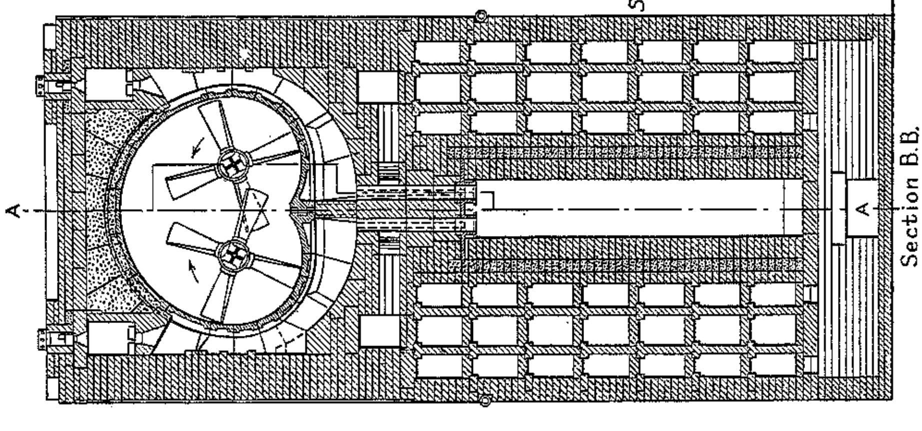


FIG. 17.

grave objections on economic grounds. The pitch required for briquetting the semi-coke cannot be obtained from the corresponding weight of coal in sufficient quantity. It must be assumed that the products of the high-temperature retort are re-introduced again and again into the pitch cycle, or else pitch must be bought from outside. In any event briquetting and repeated carbonisation are very costly, and cast considerable doubt on the commercial possibilities of the process. Early objections by various experts were confirmed by the extensive reports of Curtis and Chapman.[70] They show that many difficulties had to be overcome, and that no fewer than twenty-five different retorts were constructed, most of which were actually

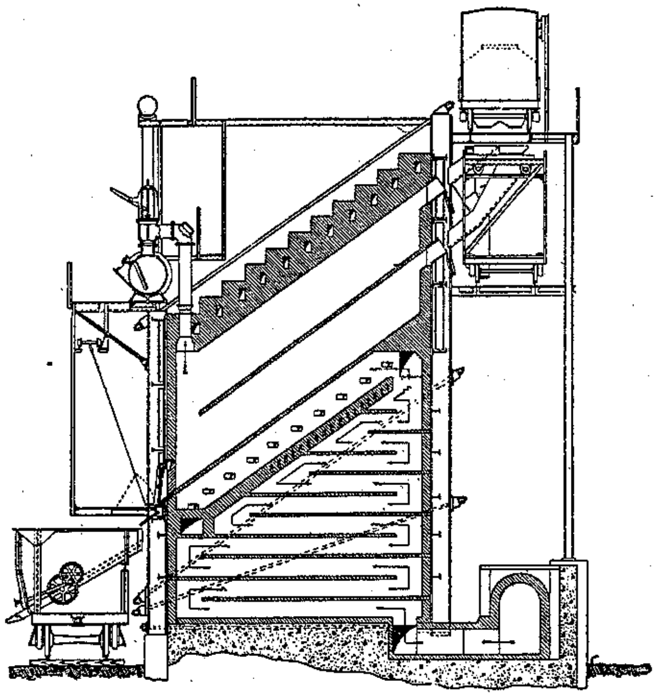


FIG. 19.

tried. The greatest difficulties caused by the conversion of the semi-coke into a smokeless fuel and its economic failure led eventually to the closing-down of the plant early in 1922. One is probably not mistaken in assuming that the plant, which was subventioned by the American Government, chiefly aimed at the production of a smokeless fuel, and that the production of oil was considered of secondary importance in America, where oil abounds. If one is at all justified to speak of the "failure" of the plant, it would chiefly relate to the production of a firm smokeless fuel, an object which is paramount in other countries where low-temperature carbonisation has to be conducted for the sake of the oil, especially if it is considered that there are other useful applications for semi-coke.

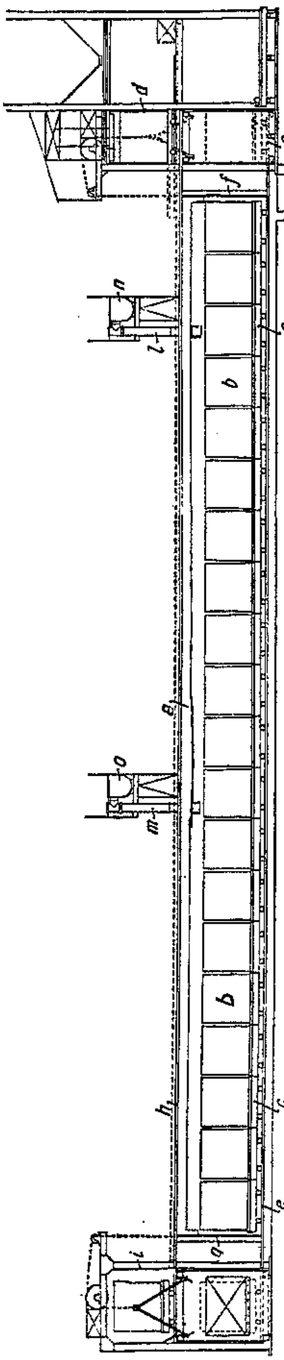


FIG. 20.

Tunnel Kilns.—It has also been proposed to effect continuous low-temperature carbonisation by means of tunnel kilns similar to those used in the ceramic industry. One essential advantage of the tunnel kiln is, that in distinction from the rotary retort, it avoids not only the disintegration and pulverisation of coal and hence the very unpleasant formation of dust, but also admits of the utilisation of small and generally poorer grades of coal. By stamping or pressing, such fuels can be shaped into briquettes of suitable size and be carried through the kiln on small trucks. Tunnel kilns occupy more ground space than rotary retorts, but have the advantage of being able to deal with smalls without creating a dust nuisance, and this may weigh heavily in their favour against rotary retorts under certain local conditions.

The Patent literature affords several proposals for the use of tunnel kilns for low-temperature carbonisation. As far as I am aware, the only large tunnel kiln actually built is that of the Westdeutsche Industriebau A.-G., at the Konstantin der Grosse Colliery at Steele-Ruhr. Figs. 20 and 21 give longitudinal and transverse sections through the kiln. The kiln is comparatively narrow and high, resembling a coke-oven in cross section and in the mode of heating. The bogey of the trucks is protected from the heat by a refractory slab on which the briquettes to be carbonised are stacked checker-work fashion. The trucks are pushed into the tunnel, one at a time through a lock, so that the train in the tunnel advances by one truck-length, whilst at the other end one truck leaves the discharge lock. The tunnel is heated through flues provided in the setting, the highest temperature being in the middle portion. The hot combustion gases pass along the horizontal flues towards the truck inlet and

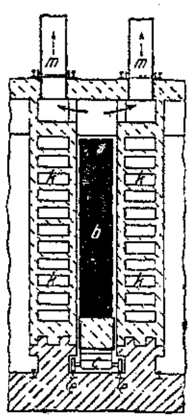


FIG. 21.

into the chimney; they are thus moved in the opposite direction to the truck. In the other half of the tunnel, air is admitted through the flues from the discharge end of the coke and is directed towards the burners of the carbonising zone. The coke blocks on the trucks are cooled whilst travelling through this half of the tunnel, and transmit, through the brickwork, part of their heat to the air, which thus becomes more and more preheated as it approaches the burners.

The products of distillation are taken by numerous pipes to a collecting main. The tar is said to be quite free of dust.

Whether an entirely unchanged primary tar can be obtained in this tunnel kiln will depend upon the mode of operation. The strong exhauster action

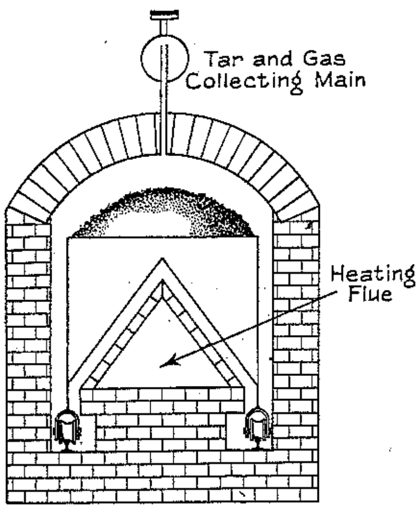


FIG. 22.

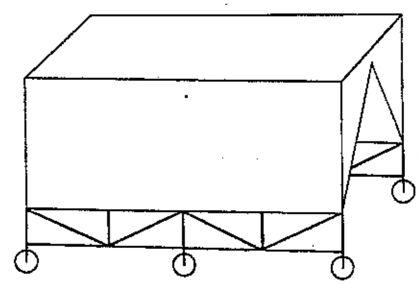


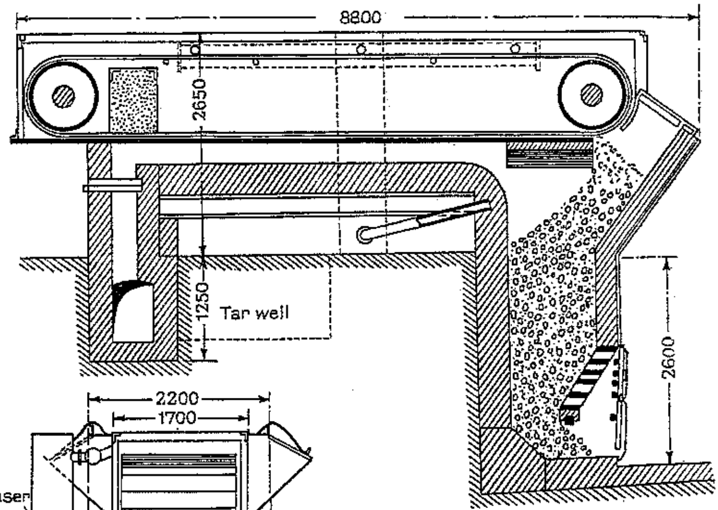
FIG. 23.

required probably keeps the tar vapours issuing from the briquettes from prolonged contact with the hot walls and thus prevents decomposition.

The "Central Channel Kiln" is a tunnel kiln designed to avoid such contact, and especially intended for primary tar production. The wagons run astride a flue which is triangular in section as shown in Figs. 22 and 23. The coal used may be smalls, lumps or briquettes, and the wagons will accordingly be built of sheet metal or of lattice work. The heat is transmitted to the wagons practically from inside. The products of distillation escape outward, and are withdrawn from the top of the outer arches. Longer carbonising periods are required with this arrangement than with tunnel kilns of the coke-oven type, but the products of distillation are less liable to secondary decomposition. In this type of truck, the semi-coke might be compressed during its formation by means of a heavy perforated plate put on the coal.

On coming out of the tunnel, the wagons are quickly discharged by lifting their side walls. The central flue is heated in its middle portion only. Here again the products of combustion pass in counter-flow to the wagons towards the smoke stack, remaining completely separated by the flue wall, from the distillation chamber in which the wagons are running. The outer walls of the tunnel need not be heated, but require good heat insulation.

FIG. 24.



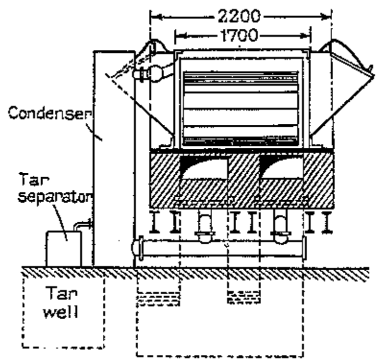


FIG. 25.

The principle of the Carthaus System will be understood from the diagram of Figs. 24 and 25. The fuel is spread in a thin layer on a belt conveyor which is drawn along the top of the cast-iron plate. This plate forms the crown of a heating flue and transmits the heat quickly to the flue. The belt conveyor runs over two pulleys, receives the fuel at one end and throws off the residue at the other end. The distillation products are withdrawn through ports provided in the casing which surround the belt conveyor. The throughput of this plant is stated to reach 18 tons of shale per 24 hours. I am not aware of any practical tests of the Carthaus System, but it represents a type of its own which might be modified into a tunnel kiln.

Rotary Retorts.—Rotary retorts have found special favour in Germany, their prototype being Fischer and Gluud's rotating drum laboratory apparatus. Whilst the drum was devised for charges of 10 to 20 kg. of coal only and had therefore to be operated intermittently, the large-scale rotary retorts were designed for continuous working. The first rotary retorts of really large dimensions were designed by Dr. Roser [71] of Messrs. Thyssen & Co., Mülheim-Ruhr, a few years ago. At present there is a plant for 100 tons throughput per day at Thyssen & Co.'s works, two units at the Graf Bismarck Colliery, and one other installation at the Hamburg Gasworks. The Thyssen rotary retorts are of surprising simplicity and capacity. The iron drums are built in one piece of 24 metres length and 2·5 metres diameter.

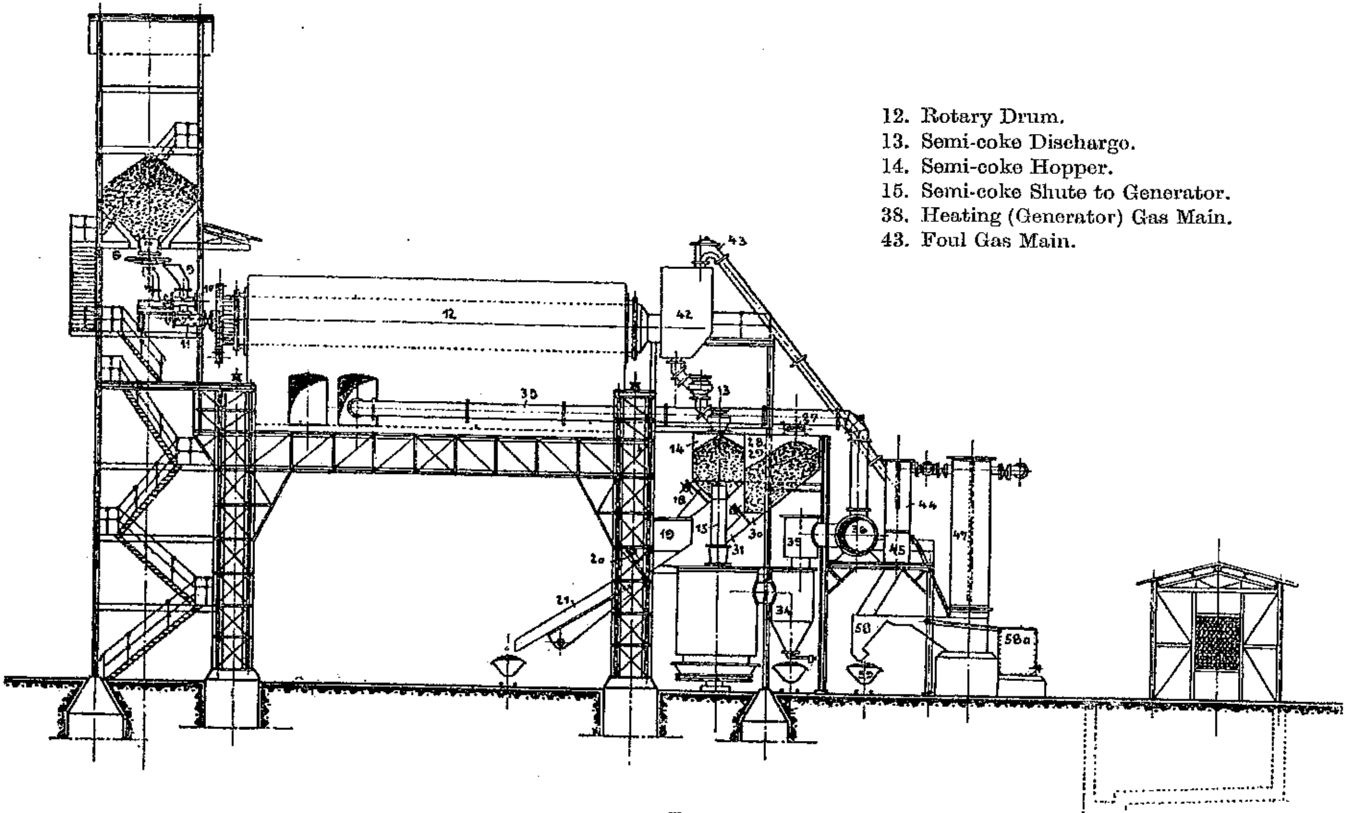
Fig. 26 illustrates a Thyssen rotary retort heated by producer gas and combined with a semi-coke gas generator; Fig. 27 is a view of the two retorts at Graf Bismarck Colliery.

The coal fed into the rotating tube at one end is carried in two hours through the 24-metre length of tube, by means of helical screw lifters riveted to the drum, and drops out at the other end in the form of a semi-coke. The iron drum runs in a chamber which is fired with producer gas, and lagged by strong brick walls against heat losses. The distillation gases leave the drum together with the tar vapours at the same end as the semi-coke. It is questionable whether this is the most suitable arrangement. I shall revert to this point in a special section on "The Influence of Retort Design." According to Messrs. Thyssen, the liquid carbonising products equal in quantity and quality those obtained by careful laboratory working with the Fischer rotating drum. The only difficulty with which the Thyssen plant has to contend is the formation of dust.

In most low-temperature retorts the escaping gases and tar vapours carry with them coal dust or, more correctly, semi-coke dust. This dust trouble is particularly pronounced in large rotary retorts, because the friable semi-coke is kept in rolling and tumbling motion, and the dust, once produced, is continuously being stirred up.

As the presence of dust in the tar interferes with the separation of the water and lowers the value generally, it is necessary to remove it before the tar is condensed. In our laboratory apparatus we used a dust separator fixed in the drum, so as to deposit the dust at the temperature of the furnace, *i.e.*, free from tar. The high boiling tar fractions were then condensed at 150° and, therefore, free from water.

The lower boiling fractions and the liquor were subsequently condensed by cooling with water, the liquor being separated from the oil in the ordinary way. It is therefore not difficult to produce a tar free of dust and water,



12. Rotary Drum.
13. Semi-coke Dischargo.
14. Semi-coke Hopper.
15. Semi-coke Shute to Generator.
38. Heating (Generator) Gas Main.
43. Foul Gas Main.

Fig. 26.

if the dust is eliminated, say, at 400° in a heated separator, the high boiling tar at 150°, and the lighter oils and liquor at ordinary temperature. The problem has also been solved in connection with works plant; heated dust eliminators are arranged as separate units, in preference to building them into the retort drums.

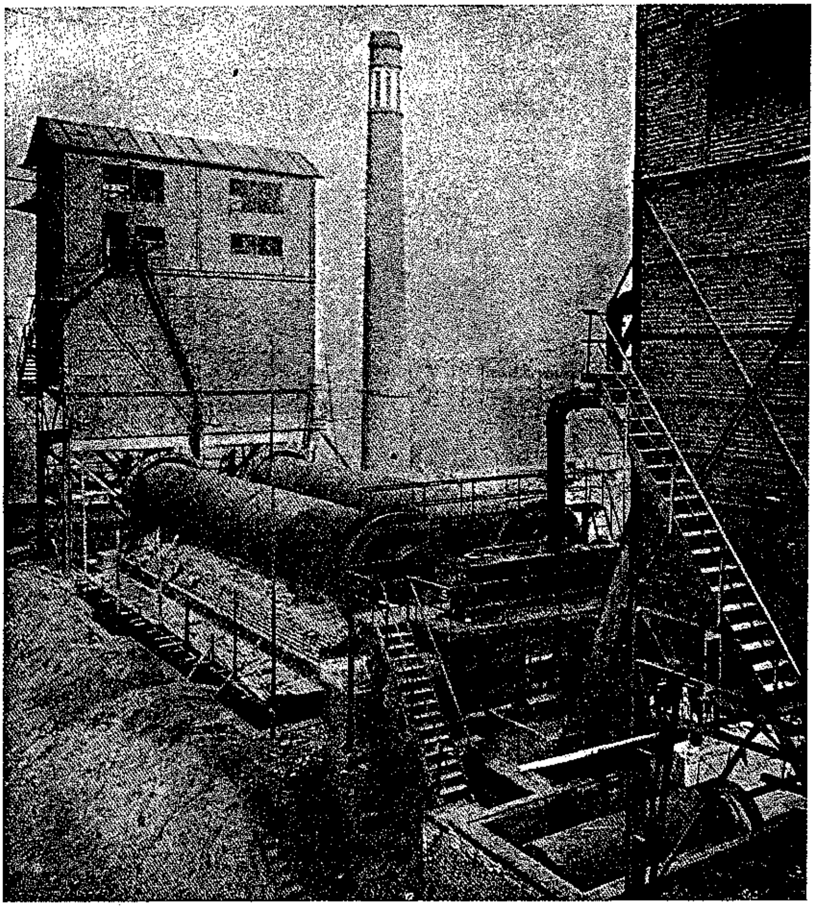


Fig. 27.

The Thyssen installations are usually provided with benzine recovery plants in which the benzine is washed out of the gas by means of oil. This benzine is a valuable motor spirit.

Fellner and Ziegler of Frankfort-on-Main have erected a rotary retort plant for the Gelsenkirchener Bergwerks-A.-G. This plant has been described in detail by Thau.[72] Figs. 28 to 31 show the essential features of this system.

Whilst the Thyssen rotary retort is mounted horizontally, that of Fellner and Ziegler is slightly inclined. They can therefore dispense with the helical screw, but they run the risk that the whole charge may slide down, as occasionally happens in rotary cement kilns. It is questionable whether this risk need be considered in the case of caking coal. The plant seems to be very well designed and carefully executed. The drum is made of riveted mild steel plates, 18 mm. thick; it has a length of 20 metres, an internal diameter of 2·5 metres, and an inclination of 5 per cent., so that one end lies 1 metre lower than the other. The retort is heated with blast furnace gas which is effective enough in spite of its low calorific value, and has the added advantage of giving a long and uniform

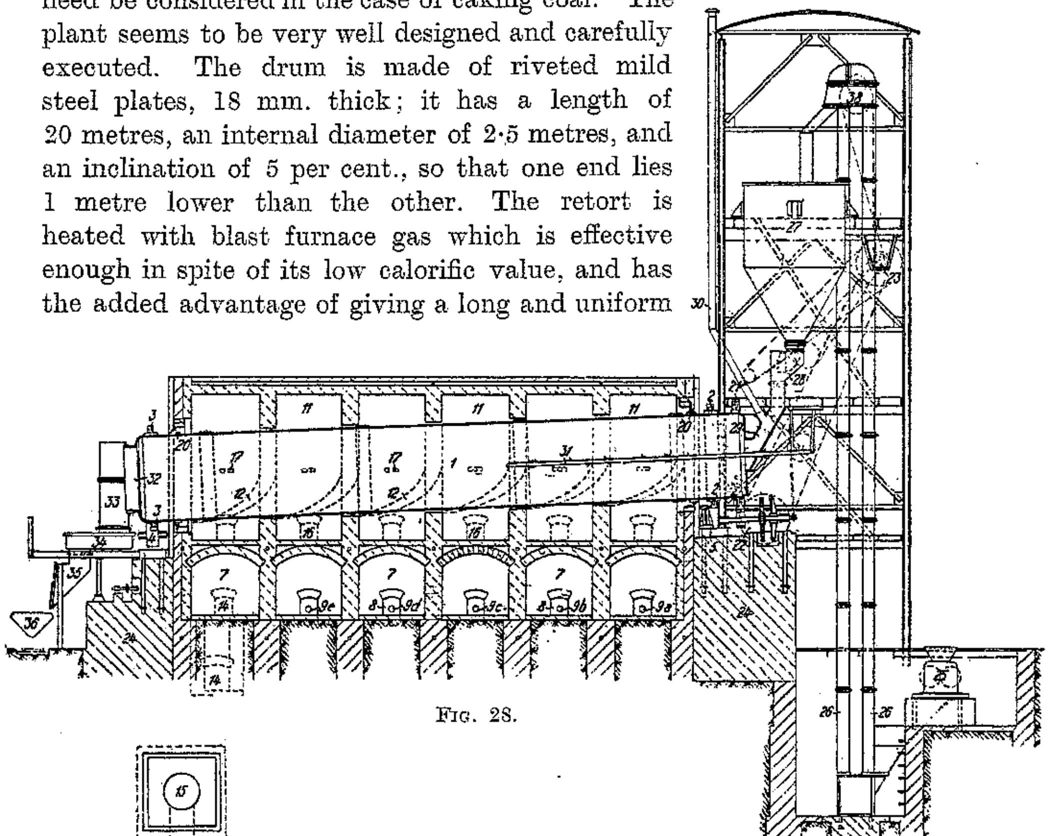


Fig. 28.

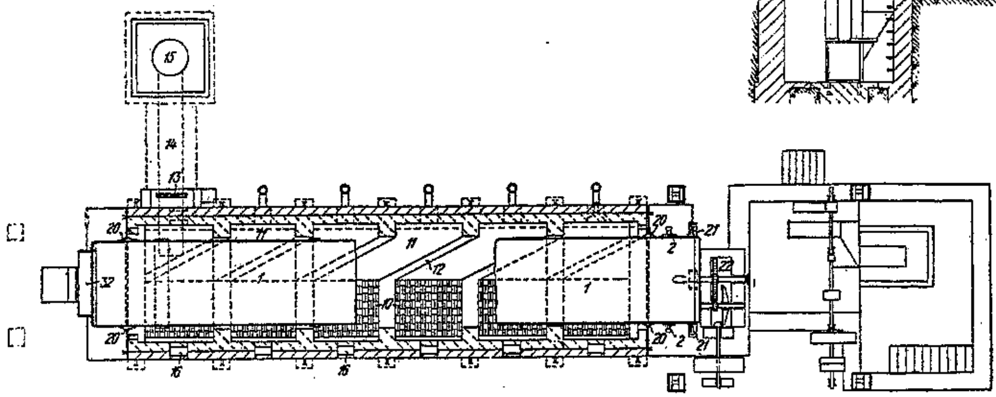


Fig. 29.

flame. The carbonising gas leaves the drum at the same end at which the coke is discharged, and after passing the dust separator, enters the condenser for the separation of the tar and water. The tar contains relatively much water and requires special treatment. This plant does not yet comply with the demand for a tar free of water and of dust. The gas, after removal of the tar, is stripped of its benzine in a special plant after the design of a benzol factory.

The Kohlenscheidungs-Gesellschaft, of Essen, is erecting on one of the Stinnes collieries an iron rotary retort which differs from the two types just described in that it consists of two concentric tubes. The coal travels first along the inner tube from one end to the other, being at the same time dried and preheated; it then drops into the outer tube, and travels back the whole distance. The advantage claimed is a better utilisation of heat, owing to the compactness and greater stability of the whole setting. The mode of firing is said to be novel. Whilst with other types the low temperature of the heating gas required is obtained by admitting a large excess of air, the combustion is in this case effected with the least possible excess of air. After this combustion, which secures the highest degree of efficiency, the temperature of the fire gases is reduced by mixing them with waste flue gases which are continually circulated through the flues. Apart from high thermal efficiency, the system offers the advantage that the temperature may very quickly be adjusted to any desired degree, and that the high gas velocities attainable ensure a superior heat transmission to the carbonising drum.

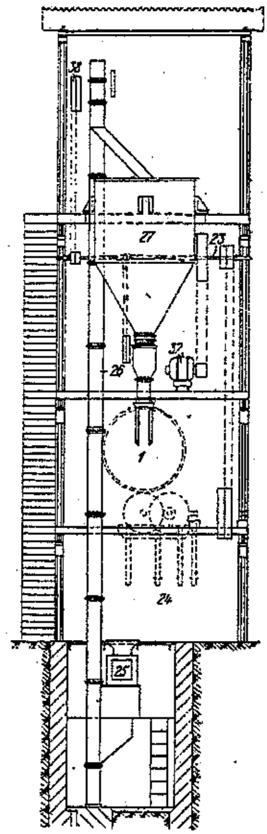


FIG. 30.

The firm of Méguin A.-G.[73] has erected an experimental vertical rotary retort at Butzbach, Hessen. In this furnace the coal is intended to be compressed during the carbonisation by centrifugal force; the tar is said to be free of dust.

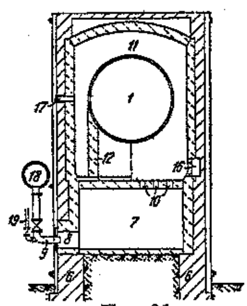


FIG. 31.

Attention has recently been paid outside Germany to externally-heated rotating retorts on a principle closely related to that of the Kohlenscheidungs-G.m.b.H.

Goodwin [74] gives the following particulars of the "Fusion" retort: The retort (Figs. 32 and 33) consists of two concentric tubes, *a* and *b*. The coal is fed into the inner tube, which it traverses from one end to the other, and then drops into the outer tube, in which it is carried back. In the inner tube is placed a loose "star" or "cross" breaker, which in rotating is carried up and falls back so that one edge of the stars or crosses gives a chipping or hammer effect to the material being treated. The products of the distillation are taken off at *o*. The retort has the advantage that it needs a gland at one end only; the other end, at which the coal drops from the one tube into the other, may be sealed.

Retorts with Inner Lining.—Thomas [75] has designed a rotary retort for continuous operation (Figs. 34 and 35). It consists of a cylinder of iron, up to 30 metres in length. It is lined inside with firebricks, which are hollowed out so as to form flues running parallel to the axis of the retort. The heating gas is fed through a gland into burners which project into the flues, the whole heating system and the burners rotating with the furnace. The fuel is introduced into the retort by a helical conveyor at the one end; at the other end the semi-coke drops into the space *h*, and thence into trucks, whilst the gases and tar vapours find an outlet through *h* and the tube *z*. It is not apparent for what purpose the furnace is lined inside, and is made to rotate. The author is under the impression that this retort is already surpassed by the much simpler German rotary retorts.

(2) *Internal Heating.*

The obvious idea to effect carbonisation by the aid of superheated steam directly forced through the layer of coal was many years ago adopted for brown coal by Ramdohr. Ramdohr called the tar which he produced in this way "steam-tar," but the process did not find favour at the time.

Franz Fischer and W. Gluud originally tried to distil coal by means of superheated steam combined with slight external heating. They abandoned these experiments (unpublished) in favour of their rotating drum with steam distillation.

Superheated Steam as Heating Agent.—Lamplough [76] constructed a device in which he effects carbonisation entirely by means of superheated steam.

The retort (Fig. 36) consists of an iron tube, tapering towards the top, and lined with bricks for the purpose of heat insulation. Superheated steam enters at the bottom and is uniformly distributed over the cross-section of the retort by means of a perforated plate. The steam passes through the coal and leaves the retort together with the distillation gases and the tar vapour. At first, the steam is only superheated sufficiently to expel primary tar, but later on it is heated to 800°, in order to facilitate the formation of ammonia.

There is no doubt that steam is the most suitable direct heat carrier, because it can be separated from the products of distillation by simple cooling, so that these products are obtained in an undiluted form. Yet such a process would probably be very expensive for a complete tar recovery. It is not sufficient merely to cool the large amount of steam necessary to 100°; the steam must be condensed to water to make the extraction of benzine possible.

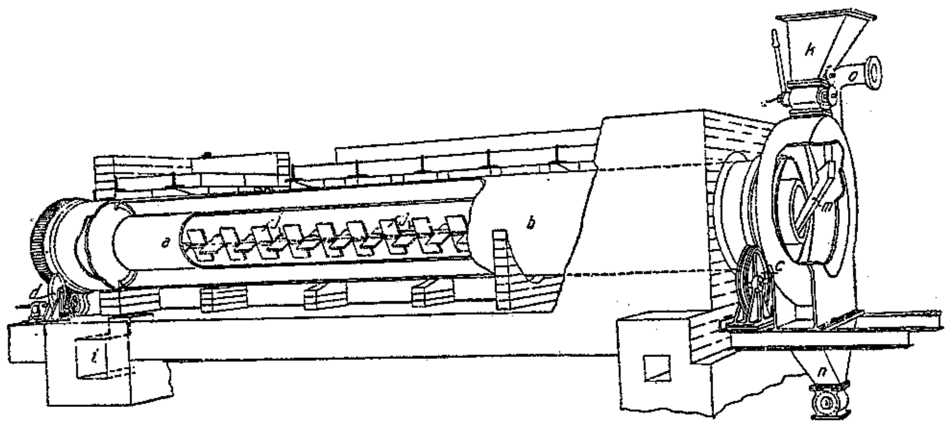


FIG. 32.

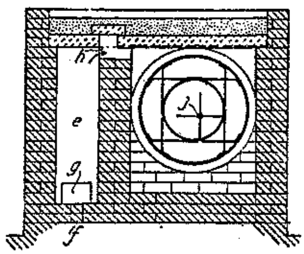


FIG. 33.

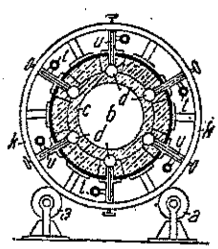


FIG. 35.

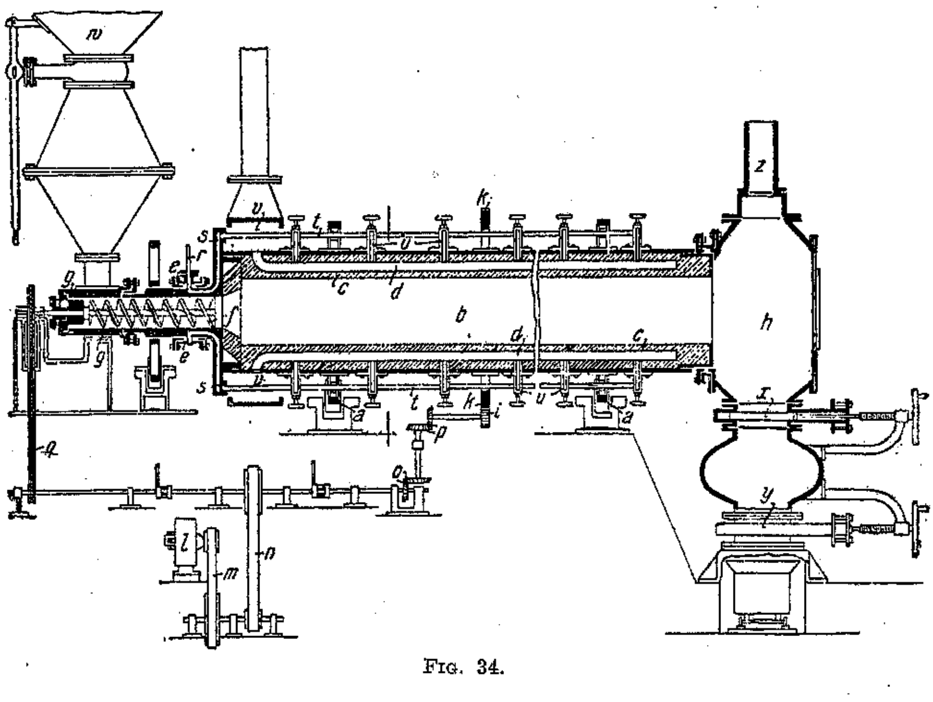


FIG. 34.

This involves further steam raising, a combination which even with good heat exchange means a large expenditure of fuel and of cooling water.

Hot Producer Gas as Heating Medium.—Maclaurin [77] effects carbonisation by means of hot generator gas instead of superheated steam. A small gas generator (Fig. 37) is directly joined to a shaft furnace, so that the gas passes through a conduit from the upper zone of the generator under the grate of the shaft furnace. The hot gas, made from a low-grade fuel in the generator, carbonises the coal charge in the shaft furnace. The carbonisation products of the coal mix with the generator gas, and their liquid constituents are separated by condensation. The semi-coke is drawn off at the bottom of the shaft furnace. This method of carbonisation, by means of unburned generator gas, comes close to the conditions prevailing in the carbonising generators to be discussed below. The whole difference in principle lies in that a fuel of lower grade is gasified in the place of the semi-coke in the shaft furnace. As in the carbonising generators, there is a necessity of finding an application for the generator gas which is produced in large quantities, and the recovery of the low-boiling constituents from the large volume of generator gas would probably be a matter of difficulty.

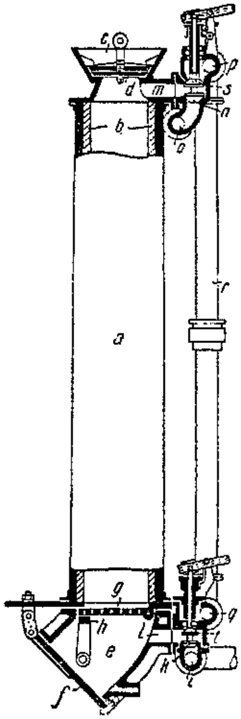


FIG. 36.

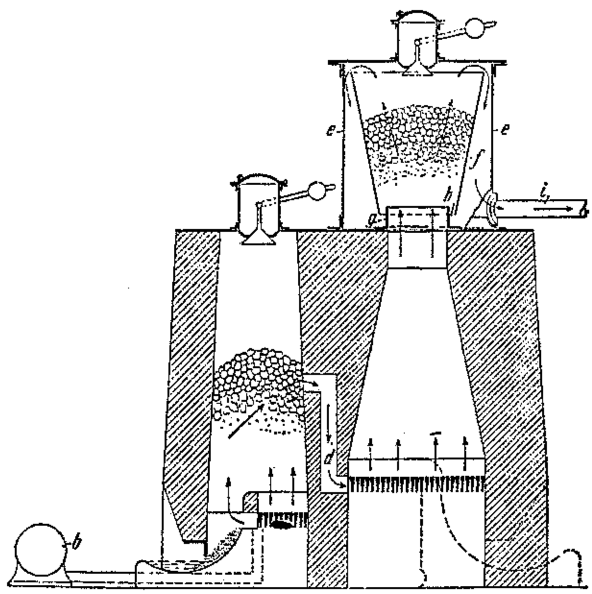


FIG. 37.

Nielsen [78] also makes use of the sensible heat of producer gas for the carbonisation of coal. His process differs from Maclaurin's in the fact that he employs a rotary inclined retort (Figs. 38 and 39).

The hot gas from a producer is passed by a short connection into the discharge end of a rotary retort, 27·5 metres long, consisting of two lengths of tube built up of boiler plate. The retort is designed for a throughput of 100 tons of coal per day. The inside of the retort is lined with firebrick to reduce the loss of heat by radiation. The producer gas traverses the rotary

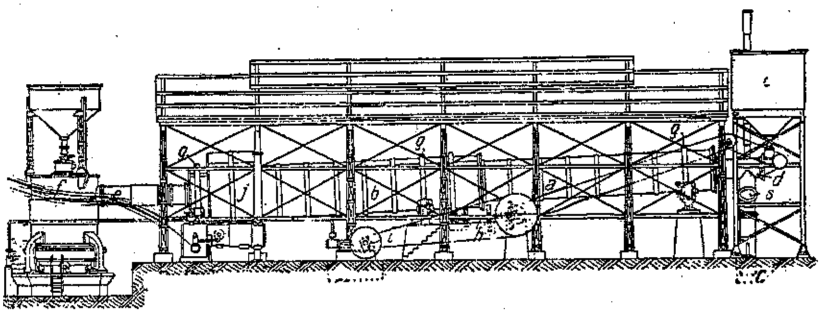


FIG. 38.

retort in counter-flow to the coal, which travels from the upper to the lower end. In order to keep the gas as free of dust as possible, the coal is charged into a trough which projects 3 metres into the retort. As the producer gas mixes with the products of carbonisation, gas is discharged at the upper end of the retort. The products always pass from the high-temperature zones,

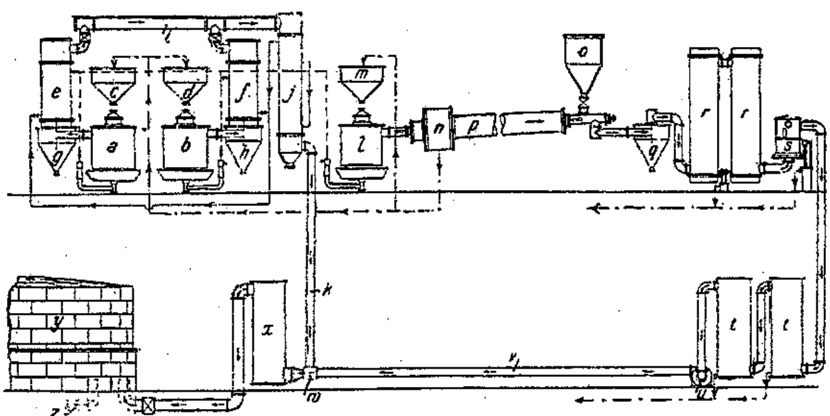


FIG. 39.

at which they are formed, to zones of lower temperature, a provision by which secondary superheating is avoided. The mixture of the two gases is taken from the outlets to the condensers and tar separators for the recovery of primary tar, benzine and ammonia, in the usual way.

Hot Coke-oven Gas as Heating Medium.—Sutcliffe and Evans [79] have conducted researches into the problem of low-temperature carbonisation, with the object of obtaining a smokeless fuel. By mixing coal rich in gas with lean or oxidised coal they propose to improve the physical structure of coke, the various coals being ground and briquetted at high pressure without the addition of a binder. Their briquettes are described as being sufficiently hard and strong for carbonisation in high vertical retorts. Provided that a high enough compressive strength of the briquettes can be obtained, these inventors consider retorts with a daily throughput of 1000 tons possible. They propose to effect the low-temperature carbonisation of their compressed fuel by forcing hot coal gas through a perforated cylinder, axially mounted in the vertical retort so that it takes up the products of carbonisation. The gas is continually reheated in two regenerators, one of which is giving up its heat to the return gas, while the other is brought up to temperature again by the combustion of the surplus carbonisation gas, with the usual arrangement for changing over. The authors give no particulars of the recovery of oil. The proposals by Evans and Sutcliffe are mentioned, because they consider the problem of coke formation from a particular and interesting point of view.

Carbonisation by Means of Flue Gases.—A process which Seidenschnur [80] investigated and worked out jointly with the Allgemeine Vergasungsgesellschaft may become of importance for the production of tar from brown coal. Seidenschnur established, in the first instance, that cautious carbonisation of bituminous brown coal in a current of superheated steam will give a higher tar yield than that obtainable in the laboratory without the application of steam. This tar is particularly rich in oils of high viscosity, and contains, in addition, considerable proportions of undecomposed bitumen. The essential feature of this distillation is, however, that very little combustible gas is produced. He obtained 60 to 70 litres of gas per kg. of coal (briquettes), but 70 per cent. of this gas consisted of carbon dioxide with a little hydrogen sulphide. Seidenschnur considers that with this mode of tar production an appreciable liberation of valuable gas could be avoided; carbonisation might be effected by means of the products of combustion of producer gas with which the distillation gases might be wasted without causing any loss. No low-boiling hydrocarbons (benzine) are contained in the tar or gas, but they could be obtained by a subsequent distillation of the tar at atmospheric, or a higher pressure. Whether such a process would be applicable to bituminous coal is questionable, as it yields, unlike brown coal, a small percentage of low-boiling hydrocarbons which must not be lost. In an experimental plant the process is worked in the following way: gas is made in a producer from Grude coke; the producer gas is then burned in a small combustion chamber with the theoretical amount of air to a mixture of carbon dioxide, steam and nitrogen, which enters hot into the lower portion of a vertical retort charged with brown coal in briquette, or lump form. The gases leave the retort at the top together with a little distillation gas, and are