DEVELOPMENT AND CONDITION OF THE COKE
INDUSTRY BY THE UTILIZATION OF
BY-PRODUCTS.

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[*Address at the fifth meeting of the German Mining Engineers, held at
Breslau, September 5, 1892.*]

Industrial innovations, promising considerable profits, as a rule are introduced eagerly and soon become common property. This cannot be claimed of a branch industry, the distillation of coal with saving of by-products, of which I will treat especially to-day.

The distillation of coal consists in the carbonization of coal in closed chambers, *i. e.*, the expulsion of volatile matter by heat externally applied. The remaining solid residue, carbon, is termed coke.

The object of the dry distillation of coal is twofold, according as the volatile matter or the solid constituents are considered as principal products. The yield of volatile matter as principal product is the object of the manufacture of illuminating gas, and the remaining solid constituents are by-products. The gain of the solid constituents by the distillation of coal is the object of the manufacture of coke and the products of volatile matter are saved as by-products.

I will treat the saving of these by-products of the coke industry and its development, illustrating the subject by means of drawings furnished by Dr. C. Otto & Co., of Dahlhausen, Germany.

With the introduction of the manufacture of illuminating gas about 1820, was connected also from the beginning the gain of tar and ammonia, but the rational saving of these by-products of the coke industry is of a later date, for no material results had been attained ten years ago. Per

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haps, the reason has been that, on account of moderate competition, the value of coal and coke was greater and there was little inducement to seek for higher profits, to be realized by costly experiments, and this indifference was strengthened by the erroneous opinion that obtained, that the quality of coke was impaired in the process of saving by-products.

'The oldest reports of saving tar from coke ovens date from 1768, and according to those reports so called muffle ovens and also coke ovens were in operation, by which tar was saved, at Sulzbach near Saarbruecken. But it seems that those first trials were not successful.

Archibald Cochrane, Earl of Dundonald, obtained a patent in 1781 to gain tar, volatile oils, alkali, acids, pitch and coke from coal by the combustion of the coal itself, without external heating. This first trial in England also was without success.

Knab in Commentry, Department Allier, France, erected a group of coke ovens with saving of by-products in 1856 and adopted for them the apparatus similar to that used in the manufacture of illuminating gas. The ovens were 2 metres wide, 1 metre high, 7 metres long, and with bottom heating. The gases, deprived of tar and ammonia were conducted back to the ovens, still in use to-day, and burned under the bottoms of the ovens. A comparison of the results obtained by Knab with those obtained to-day shows that the former were insufficient, principally on account of the considerable width of the ovens, and partly due to the quality of the coal. Such ovens, it is said, are still in operation at Flénn near Mons. The priority of Knab is contested, for it is reported that fifty ovens of the Powels-Dubochet system were in operation near Saarbruecken in 1854; the by-products were not saved, for the products of distillation were burned under the ovens. The ovens were only designed to gain a higher percentage of coke, for the carbonization took place in air-tight closed chambers. Such ovens were also in operation at La Villette, Department Seine, in 1860, producing an excellent furnace coke, besides a poor gas, which was mixed with rich gas from the usual gas retorts. As the gas was used for illumination it

is obvious that tar and ammonia must have been condensed.

Patents were obtained by Jones and Blackwell in 1861 to save tar and ammonia water by coking coal in piles, but without success. The Knab ovens were improved substantially by Carves in 1862, by heating besides the bottoms, also the side walls by flues. The gases from the air-tight closed ovens were exhausted, and cooled, and conducted to coke scrubbers to be deprived of tar and ammonia, and then to be used for heating the ovens.

Fifty-three Knab-Carves ovens were erected at Bes-sège, Department Gard in 1873, and 100 ovens at Terrenoire near St. Etienne, Department Loire, in 1879. After many experiments the ovens were given a width of only 0.6 metre, in order to cause a better penetration of the heat. The gases from the coking process, deprived of tar and ammonia, were conducted to a small grate by a tube and here consumed. The combustion products pass under the bottoms of the coke ovens, ascend to the upper of the three side flues, and finally descend through the side flues into the main canal and to the chimney.

The construction of the Knab-Carves ovens was adopted by Albert Huessener for the construction of a coal distillation plant at Bulmke, near Gelsenkirchen, and to this gentleman is due the credit of being the pioneer for saving by-products of the coke industry in Germany. Huessener first erected 100 ovens with coal distillation in Germany in 1881, and demonstrated that this industry could be made successful.

Numerous new constructions succeeded each other, but not all of them were well received, especially because the prejudice, already mentioned, that the quality of coke was impaired by the exhaustion of gas, was hard to overcome. There was also a general apprehension that German coal in comparatively cold running ovens would furnish a bad coke.

The credit of overcoming these prejudices and of constructing and introducing an oven which meets the highest requirements, is due to Dr. C. Otto & Co., of Dahlhausen on

the Ruhr, and especially to Dr. Otto of the firm, who fortunately is enabled to speak here instead of myself, as the foremost representative of this industry; and who, by the erection of ten trial ovens at Holland Mine, November, 1881, laid the foundation of a common system very widely introduced to-day. The oven was perfected by the combination of Siemens regenerators, patented by Gustav Hoffmann, Superintendent of the Silesian Coal and Coke Works, at Gottesberg, with the Dr. Otto system, and the first ten trial ovens were put in operation at the Carl-Georg-Victor Mine

FIG. 1.

near Gottesberg, in 1883, by Director Berndt, who has been prominent in the introduction of coal distillation.

This combination, which I will term Otto-Hoffmann oven hereafter, embraces small chambers of 0·4 to 0·6 metre wide, about 10 metres long and 1·6 to 1·7 metres high to the counter-pillar, closed air-tight by doors on both ends. The construction of these ovens is based on the combination of Siemens regenerators by Hoffmann with the common Otto oven, perfected by numerous improvements from time to time. In May, 1886, there were in operation 500 such ovens, of which 330 were in Westphalia, 110 in Silesia, and 60 in Austria, each oven coking about 1,000 tons of coal per annum, yielding, without regard of the varying yield of

some brands of coal, 750 tons of coke, thirty tons of tar and ten tons of ammonia.

Fig. 1 shows a longitudinal section of a Otto-Hoffmann coke oven, the pusher being located at the end *a*, while the coke is delivered at the end *b*, where it is quenched. Instead of the openings of the common Coppée oven, by which the gases of the coking chamber first enter the vertical flues of the side walls and then pass into the bottom canals to be consumed, there is no direct connection between the coking chamber and the interior of the side walls. In the arch of the oven are three openings *c*, to charge

FIG. 2.—Section of oven.

the oven, and two openings *d* by which the gases of the coking process escape. In the side walls below the counter-pillar is located a horizontal flue *c*, *Fig. 2*, by which all vertical flues are connected. The length of the bottom canal *f* is partitioned by a wall into two equal parts *h* and *i*. Each of these halves is in connection with a regenerator *R* or *R'*, respectively, in which the air necessary for the combustion of gas is heated. Further, the pipes *p* and *p'*, fed by gas-distributing pipes *q* and *q'*, enter one-half of the bottom canal, respectively.

The regenerators are long canals, latticed by bricks, running transversely beneath all chambers. At one end they

FIG. 3.—Plan of condensation plant.

are in connection by an adjusting trap either with the air-distributing pipe *k*, *Fig. 3*, or backwards with the chimney. As soon as the oven is heated and the coking process is in progress, the gases of the coal escape by the openings *d* into the stand-pipes, similar to those attached to the retorts of gas works, and from there by an open valve into the gas receiver, whence they are conducted by conducting pipe *v*, *Fig. 3*, to the condensation. Here the gas is deprived of the by-products, tar, ammonia and benzole, and then conducted back to the ovens.

Before we describe the condensation we will explain the operation of the ovens by *Figs. 1* and *2*. Assuming that the ovens are in operation, then the gases are conducted to the condensation, as already described, and back to the ovens by pipe line, *Fig. 3*. There is an adjusting trap in the return pipe line by which, according to the position of the trap, the gas enters into gas-distributing pipes *q* or *q'*. If the gas enters into pipe *q* and from here through cock *r* of pipe *p* into the bottom canal *h*, then the trap of the air-distributing pipe is so adjusted that the air enters into the air-distributing canals *s*, *Fig. 1*; thence by small openings *t* in the arch into regenerator *R*, where it is heated and then by slits *u* also enters into bottom canal *h*. In this bottom flue the combustion takes place. The hot products of combustion ascend by the vertical flues of the side walls into horizontal flue *e*, and descending pass through the vertical flues of the other half into bottom section *i*, and from there by slits *a* into regenerator *R'*, heat the canal, pass by the small openings *t'* into canals *s'*, and from here by the adjusting trap into the chimney. After a certain time the adjusting traps are reversed and the gas take a reversed course. Originally it was intended (and also executed by the first plants) to heat the air and also the gas by a second regenerator, located at each end of the ovens. This second regenerator has been abandoned, for it was considered more important to heat the ten times greater quantity of air to a high temperature than to heat also a comparatively small quantity of gas and besides to risk dangerous explosions.

In all later plants there is only one regenerator on each side of the ovens, shown by the accompanying drawings, and the Otto-Hoffmann oven has been simplified considerably by this device and without impairing its efficiency.

The air is heated in the regenerator to about $1,000^{\circ}\text{C}$. and it is due to this heating that only a part of the gas is required to heat the ovens, and a considerable quantity is at disposal for other purposes.

I will now try to give a general survey of the arrangements of the condensation plant, shown by *Figs. 3, 4 and 5*.

When the gas generated in the ovens has entered the receiver by the valves it is drawn through the apparatus by exhauster *A*. In this course are inserted several arrange-

FIG. 4.—Side elevation of condensation plant.

ments, for instance, two coal-dust separators *B* cooled by air, in which the greater part of the tar contained in the gas, and also the coal-dust forced along, precipitate, thus reducing clogging of the apparatus by the latter.

The gas then enters into condensers *C*; square, vertical and riveted boxes in which are fastened a number of wrought-iron pipes through which runs the cool water. The gases ascend around the pipes, while the products of condensation, tar and ammonia water, run off continually at the bottom.

After the gas has passed the coolers it enters into the first scrubbers *D*; these are square and the gas is distributed over a number of pipes which are dipped into water. The gas is first washed in this apparatus by weak ammonia

water in order to enrich the latter, by which also tar precipitates. The apparatus is so constructed that the water continuously enters at the top and runs off at the bottom.

This water and also the products of condensation of the air and water coolers run into a large cistern, in which tar and ammonia water precipitate.

The exhausters *A* have been aspirating till now and from here the gas is forced by them.

The temperature of the gas increases a few degrees by the rapid compression in the exhausters and, therefore, it is conducted through coolers *E* to lower the temperature

FIG. 6.—Plan.

possibly to $13-18^{\circ}$ C., according to the temperature of the cooling water. After the gas has passed the coolers *E* it enters into the bell-washers *F*. The gas enters at the foot of the apparatus and is distributed to a number of bells, the lower rim of which is toothed and immersed in water, and is forced through the teeth, thus coming into intimate contact with the water. The washers contain four to six stories if necessary, and the water flows from above downwards. The gas flows in the contrary direction and is always

forced against the fresh water, by which all the ammonia and the rest of the tar are precipitated completely.

The gas, deprived of tar and ammonia, can now be conducted to the ovens to be consumed, if it should not be preferred to remove other products of the gas, as benzole, which is done by special methods. Quite a number of such plants are in operation, but the operators treat the manufacture of benzole as a secret.

Before the gases from the condensation enter into the distributing pipes g and g' by the adjusting traps, it has to pass a small gas tank, acting as a stand-pipe, to regulate the pressure of the gas, and its principal object is always to show conspicuously to the supervising officer the pressure

FIG. 7.—Section 5-6 of plan.

of the gas exactly, for the temperature of the ovens can be kept uniform only by maintaining a constant pressure. Temperature measurements by the pyrometer of Steinle & Hartung, controlled by metal compositions, indicated in :

The bottom canal,	1,200° to 1,400° C.
Side walls,	1,100° to 1,200° C.
Regenerators at the beginning of air inlet,	1,000° C.
Regenerators at their ends,	720° C.
Chimney,	420° C.

The tar from the distillation, separated by specific gravity in cisterns is pumped into tank H , *Fig. 4*, by a pump located on the wall, driven by shaft G , and then it is tapped into tank cars to be shipped to the tar distillation works.

The ammonia water of the cistern is similarly pumped into tank *J*, and from here it is conducted to the apparatus of the ammonia factory.

The ammonia factory has two column apparatus *O*, system Gruenberg-Blum (other factories use the apparatus of Dr. Feldmann with equally good results) each of a capacity of 30,000 litres equal to thirty tons of ammonia water. The water enters at the top of the column, running from column to column downwards. Contrary to the course of the water flows dry steam, by which the ammonia is absorbed and forced along. The ammonia combined with water is dissolved by lime water. The lime water is pumped from lime box *Q* into the apparatus located above the stair column.

FIG. 8.—Section 3-4 of plan.

The steam saturated with ammonia is conducted either to the boxes *P*, lined with lead into sulphuric acid, and the ammonia and sulphuric acid combine to form sulphate of ammonia, or into coolers *K* to be condensed to concentrated ammonia water.

In order to obtain salt the ammonia fume is conducted to sulphuric acid and when the acid is saturated the salt is brought on the dripping platform *T*.

In order to obtain concentrated ammonia water, the product of condensation of coolers *K* is run into storage *U* of a capacity of about ten tons and thence by air pumps into railroad car tanks.

The sulphuric acid necessary for the manufacture of the salt is furnished by railroad car tanks and stored in tanks *V*,

by means of air pumps and after its settlement it is conducted alternately from *V* and *V'* to tanks *P* by siphons and lead pipes.

The waters from apparatus *O* are conducted to a purifier, where the lime settles and the water runs off pure.

The Otto-Hoffmann ovens with coal distillation are most numerous introduced to-day, and there were in operation in Germany alone:

	<i>Ovens in Operation</i>	<i>Under Construction.</i>
1884,	40	120
1885,	120	140
1889,	605	
1891,	1,205	

The Otto-Hoffmann ovens are distributed as follows:

Coal District Westphalia,	470
Silesia,	705
Saar,	30
	<hr/>
	1,205

The cost of such ovens is about 5,000 mks. per oven, and 7,000 mks. per oven for rest of the plant, or together 12,000 mks.; or a plant of sixty ovens would require an investment of about 720,000 mks. This cost seems exceedingly high, but the profits are so considerable that it may be ignored. Further, it must be regarded that all the important machinery, exhausters, ventilators, pumps are arranged in duplicate, by which the cost is increased considerably, and also that interruptions of operations are excluded, if a portion of the apparatus should become defective.

The quality of coke from the Otto-Hoffmann oven is a very good one and the gain is higher than from the same coal in common ovens. Formerly the gain from dry coal was about sixty-seven per cent. It is about seventy-five per cent. now, which is accounted for by the fact that the ovens with coal distillation always are closed air-tight, and therefore the combustion of the coal in the ovens cannot take place.

It can be assumed that one Otto-Hoffman oven produces 1,000 cubic metres of gas per day and consumes of these 600 cubic metres, leaving 400 cubic metres for other purposes.

A plant of sixty ovens in Westphalia furnishes a gas surplus of 24,000 cubic metres per day, by which boilers of 375 square metres heating surface can be heated. The condensation would require 140 to 150 square metres, leaving at disposal for other purposes about 230 square metres.

The following figures are from Upper Silesia : production per day 1,150 cubic metres ; consumption per oven, 650 cubic metres ; gas surplus per 60 ovens per day, 30,000 cubic metres.

Saar District and Westphalia : production per day, 1,000 cubic metres ; consumption per oven, 600 cubic metres ; gas surplus per 60 ovens per day, 24,000 cubic metres. One hundred cubic metres of gas are equal to 87·5 kilo-

FIG. 9.—Section 1-2 of plan.

grams of coal, or 24,000 and 30,000 cubic metres of gas, respectively, equal to 21,000 and 26,250 kilograms of coal, respectively.

Instead of utilizing the surplus gas for heating boilers it might be used for illumination also, as is done at the Friedenshoffnung and Carl-George-Victor Mines at Gottesberg. A brief calculation of the results of a plant of sixty ovens in Westphalia is given in the following figures : 60 ovens with a distillation process of 48 hours = 30 ovens per day ; per month 30 working days = 900 ovens per month. Each oven is charged with 7,100 kilograms of wet coal, containing about 12 per cent. of water, equal to 6,250 kilograms of dry coal.

Per month $900 \times 6,250 = 5,625,000$ kilograms of dry coal. According to experience, 100 kilograms of dry coal furnish on an average 1.15 kilograms of sulphate of ammonia = 64,687 kilograms per month and 2.75 kilograms tar = 154,687 kilograms per month.

100 kilograms of sulphate of ammonia are worth to-day	<i>Mks.</i>
21.00 mks. = $64,687 \times 21$	= 13,584
100 kilograms are worth 3.50 mks. = $154,687 \times 0.035$ =	<u>5,424</u>
Receipts per month,	19,008

Total expenses :

Wages and other operating expenses,	<u>5,700</u>
Gross profits per month,	13,308
per annum	159,696

or 2,661 mks. per oven from the by-products only, against an investment of 12,000 mks. per oven or 7,000 mks. for the coal distillation; to which must be added the profits from the manufacture of coke. Interest and redemption are excluded in the calculation.

The results of the plants are more favorable in Upper Silesia, where the gain of sulphate of ammonia is as high as 1.25 per cent. and 4.5 per cent. of tar.

The results of the Saar District are not so favorable, especially in regard to ammonia.

I have mentioned already that the manufacture of benzole is still held as a secret, and I will remark only that the gain of benzole varies between 0.3 and 0.7 per cent. of the dry coal. On account of the fluctuating value of benzole I will give no estimate, as this might not be correct to-morrow.

However, the course of the manufacture of benzole indicates that by and by also other products contained in the gas may be saved, and further developments of this industry are probable.

I must mention that besides the construction described a number of other systems are in operation with satisfactory results; for instance, the considerable plant of Appolf ovens at Florentine Mine, near Lagiewnik, which obtain remarkable results.

Machine Inspector Donders made the first experiments in 1883-84 to save the by-products without heating the air and without deterioration of the quality of coke, and his success led to the erection of the extensive plant referred to.

There were in operation 15,700 coke ovens in Germany in 1891, producing 7,700,000 tons of coke, of which about seventy per cent. was produced in the Ruhr District (Rhineland and Westphalia). The total number of these ovens could produce 110,000 tons of sulphate of ammonia and 275,000 tons of tar of a value of 32,000,000 mks. but only 18,000 tons of sulphate of ammonia and 45,000 tons of tar with a value of $5\frac{1}{2}$ million mks. are produced by the manufacture of coke with coal distillation.

The figures of imports and exports of sulphate of ammonia (Chili nitrates and guano) from 1885 to May last show that the import of sulphate of ammonia since 1885 has not increased, but has decreased slightly, while the export is unimportant. But the import of Chili nitrates has increased enormously from 157,000 tons in 1885 to 396,000 tons in 1891, and to 235,000 tons within the first five months of this year.

The value of imported sulphate of ammonia in	Mks.	Mks.
1891 is estimated per 100 kilograms,	24'00 =	7,466,000
Chili nitrates, per 100 kilograms,	17'50 =	69,239,000
Guano, per 100 kilograms,	15 80 =	7,865,000

against an export for the same period of:

	Mks.	Mks.
Sulphate of ammonia, per 100 kilograms,	24'00 =	230,000
Chili nitrates, per 100 kilograms,	18'50 =	1,831,000
Guano, per 100 kilograms,	16'00 =	444,000

Therefore, 84,065,000 mks. have been sent abroad for nitrates. Furthermore, these figures also show that by the reconstruction of all existing coke ovens of Germany to coal distillations, an overproduction would be excluded, for they could supply only twenty-five per cent. of the demand for nitrates, but 19,000,000 mks. would be saved to the country, and also an additional 8,000,000 mks. for tar.

Although we cannot expect that the total imports of nitrates can be supplied by sulphate of ammonia, the

latest experiments of Professor Wagner at Darmstadt have demonstrated more favorable results, and he was enabled to declare before the last annual meeting of the gas and water experts that, while formerly he did not recommend the universal application of sulphate of ammonia for agricultural purposes, because manuring with Chili nitrates warranted results with more safety, he was now prepared to advise the farmers to its universal application, for he could state the conditions by which favorable results of different soils and plants could be obtained with safety.

It is not to be apprehended that with the application of sulphate of ammonia the increased production would be accompanied by reduced prices, for the value of nitrates is regulated by the world's markets.

The development of the tar industry is a continuous one and its rapid extension is of much importance for coal mines, for it will supply them with pitch for the manufacture of briquettes from coal otherwise hardly marketable. According to *Gluck Auf* and the *Mine and Factory Gazette*, the consumption of pitch for the manufacture of briquettes is 150 tons per day, which would require 300 tons of tar, while the coke ovens in operation furnish about one-half of this, and the manufacture of briquettes certainly will be increased.

You will conclude from my address that the saving of by-products simultaneously with the manufacture of coke is of importance, not only for the coal and iron industry, but also of the highest importance from a politico-economic standpoint, and therefore its further development should be encouraged to the utmost.