from which it will be seen that the available sodium oxide in combination with the alumina is but a small proportion of the composition of the reagent, there being three inert molecules of sodium sulphate to one of sodium oxide beside the alumina. I have no doubt this exerted some influence on the sample of water to which the reagent was added in causing a more complete precipitate of lime and magnesia in some cases.

It would be better to prepare this reagent from pure alumina and sodium hydroxide. As it is, the results are comparable with those reported by Prof. Mabery.

If this reagent could be made as effective in simple practice as the authors claim, leaving practically no alumina in the filtered water, its discovery would prove to be of immense value at once.

In conclusion I would say that there is little doubt but that satisfactory reagents and means will soon be discovered whereby all objectionable waters may be successfully treated at comparatively small expense.

Later I may have something further to contribute to this end.

REVIEW.

THE RETORT COKE OVEN AND THE CHEMISTRY OF ITS BY-PRODUCTS.

There is no innovation into the realm of metallurgical science, these last days of the nineteenth century, which will affect more widely and will, one might say, so revolutionize the whole system of iron- and steel-making in this country as will the introduction of the retort oven for the production of coke, with the simultaneous recovery of the by-products, tar, ammonia, benzene, cyanides and illuminating and fuel gas.

Think of the devastation in the beehive coke oven districts for the year 1897. One has only to take the government statistics of the coke manufactured in this country for 1897 and put opposite it the coke to be made from the same coal in retort ovens of the Semet-Solvay type together with the long list of valuable by-products obtainable, to see the vast amount of valuable material destroyed annually by the present system of coking coal in beehive ovens, and to realize the extent to which humanity has been deprived of what rightly belongs to it. The figures below will illustrate what was actually obtained from the beehive coke ovens in the United States from 22,140,000 tons of

coal in the year 1897, and what would have been obtained if the same coal had been coked in retort ovens :

	Beehive ovens.	By-product ovens.
Tons coal coked...............................	22,140,000	22,140,000
Tons coke produced	13,288,984	15,940,000
Value of coke at $2 per ton	$26,577,968	$31,880,000
Value of tar..................................	......	4,428,000
Value of ammonia	......	8,856,000
Value of cyanides	......	8,020,000
Value of benzene.............................	......	4,428,000
Value of gas (surplus), 22,140,000 × 4000 = 88,560,000,000 cubic feet at 10 cts	......	8,856,000
Total	$26,577,968	$66,468,000

Difference in favor of by-product ovens $39,890,032.

It will be seen by these figures that the saving in coke alone is over 2,600,000 tons, having a value of over $5,000,000.

These comparisons are made to enable one to comprehend more clearly the immense waste coexistent with the production of coke by the beehive process. The fact is duly appreciated that should all, or a considerable portion, of the coke now made in bee-hive ovens become the product of retort ovens, the price of the by-products would be greatly diminished.

It will not be long ere the most important blast-furnaces and steel plants throughout the country will be supplied with their own by-product coke ovens, the coke going directly from the quench-ing car to the blast-furnace without handling, and the surplus gas being used for heating the various furnaces in the steel plant.

Natural gas is giving out. The people, having become accus-tomed to its conveniences will never go back to the use of coal. They must have a gaseous fuel as a substitute for natural gas.

Boards of health and sanitary organizations are crying out continually against the filthy and unhealthy condition of our cit-ies, arising from the consumption of so much soft coal. There is no longer any comfort in a home in or near a manufacturing city. Travel on steam trains is almost unbearable in certain seasons because of smoke and soot from the engine. What is the remedy? It is the retort coke oven. Retort ovens in the future will also be built in the vicinity of large cities for the pro-duction of domestic coke and illuminating gas. Not only will fuel gas be furnished at very low figures, but illuminating gas will be sold at twenty cents per thousand. No smoke will be seen issuing from chimneys and polluting the city and country for miles about, but coke will be the fuel unless gas is used. Stationary steam engines will be a thing of the past, and gas engines up to 1000 H.P. will be substituted, with less cost for power, on account of the low price of fuel gas. Traveling will

be a pleasure for coke will be used in the locomotive, in the place of bituminous coal. But what is to be done with the huge amount of tar recovered? As the production of tar increases, the price must necessarily fall and the lower price will extend the field of consumption. It is only a question of further experimentation and research to successfully incorporate pitch into pavements ; lowering the price of " dead oil" will increase the amount of creosoting of timber; there is always the value of tar as a fuel. Millions of tons of the anthracite culm of Pennsylvania and the slack of Ohio, which are now of no value, will, before long, be made into briquettes, thereby consuming thousands of tons of pitch.

But what will we do with so much ammonia? This will be a God-send to the farmer, whose fields are now crying for more nitrogen. His barnyards do not furnish enough of it, and fertilizers are now too expensive. His crops are continually drawing on the nitrogen of the soil, and it must be replaced. In England alone, 120,000 tons of nitrogen annually are abstracted from the soil by vegetable growth, wheat absorbing 37,000, barley 27,000, and oats 57,000 tons. This nitrogen, at present, is principally furnished by the niter beds of Chili. This source in time must fail—England's recourse will be to the nitrogen of her coals which will be coked about her large cities, to be no longer shrouded in black clouds of smoke which obscure the noon-day sun and pollute the atmosphere to that extent that many a man is brought to death's door before his time, and others eke out a half-dead and half-alive existence.

The ammonia formed will be converted into ammonium sulphate, which will largely replace sodium nitrate for fertilizer purposes, and in this country the price will be so reduced as to enable the farmer to use large quantities of it.

Cheap domestic coke or fuel gas from coke ovens will be the only salvation for England's large cities.

Liebig certainly was right when he said, first, "In order to preserve the fertility of the soil, there must be kept in that soil the elements necessary for plant life; second, every crop takes out a portion of these elements. Part of that taken out is added again from the atmosphere, but a part never is restored unless it is put there by human means; and third, the fertility of a soil remains unchanged if all the elements of fertility are restored to it; and fourth, the manurial product of a farm never can restore all the elements of fertility to the soil."

Once a plentiful supply of benzene, toluene, etc., is assured in this country, the aniline color manufacturer will succeed.

A cheap and plentiful supply of cyanides will enable mining engineers to work gold fields which now cannot be successfully worked.

HISTORICAL.

It is about fifteen years since the retort coke oven became a factor in the production of metallurgical coke. The now nearly perfect oven is the result of gradual development from very crude and imperfect ones. There are two types of retort ovens, one in which the horizontal flue is the characterizing feature, and of which class the Semet-Solvay oven is the chief exponent; the other type, in which the heating flues are vertical, is represented by the Otto-Hoffman oven. The first Semet-Solvay ovens, six in number, were experimental and built in 1882, near Mons, Belgium. After a trial of two years the practicability of the system was satisfactorily established and more ovens were built annually, and from 1892 the number of Semet-Solvay ovens has greatly increased, so that at the end of 1897, ovens of this system numbered over 1300. The first in this country were built at Syracuse, in 1892, twelve at first, to which thirteen more were added later. These have been running constantly ever since, with slight repairs.

There are at present in operation on this continent of the Semet-Solvay type, 25 ovens at Syracuse, N. Y.; 50 ovens at Dunbar, Penna.; 25 ovens at Sharon, Penna.; 120 ovens at Ensley, Ala.; 60 ovens at Wheeling, W. Va.; 10 ovens at Halifax; 7 ovens at Boston, Mass. The others are distributed throughout Germany, France, England and Belgium, principally in Belgium where they are very successful in coking low volatile coals, which, in the beehive oven, will not make coke.

DESCRIPTION AND OPERATION OF A RETORT COKE OVEN.

A description of a single isolated Semet-Solvay oven would be as follows: A space five feet, six inches high, sixteen to twenty inches wide, and thirty feet long, is enclosed on both sides by hollow fire-brick tile in three tiers superimposed, placed horizontally. These tiles are about three feet long and when placed end to end form a flue through which the gas, after being treated for removal of the by-products, travels and meets the air for combustion.

The gas is admitted at the ends of the top and the second flues, with a suitable amount of air which has been previously heated by the waste gases going to the chimney flue. At one end of each flue is an opening in the bottom through which the gas passes to the next flue below, the gas and flame passing through the entire length of the flues and finally to the chimney flue.

Longitudinal Section through Flues

Ground level for Pusher
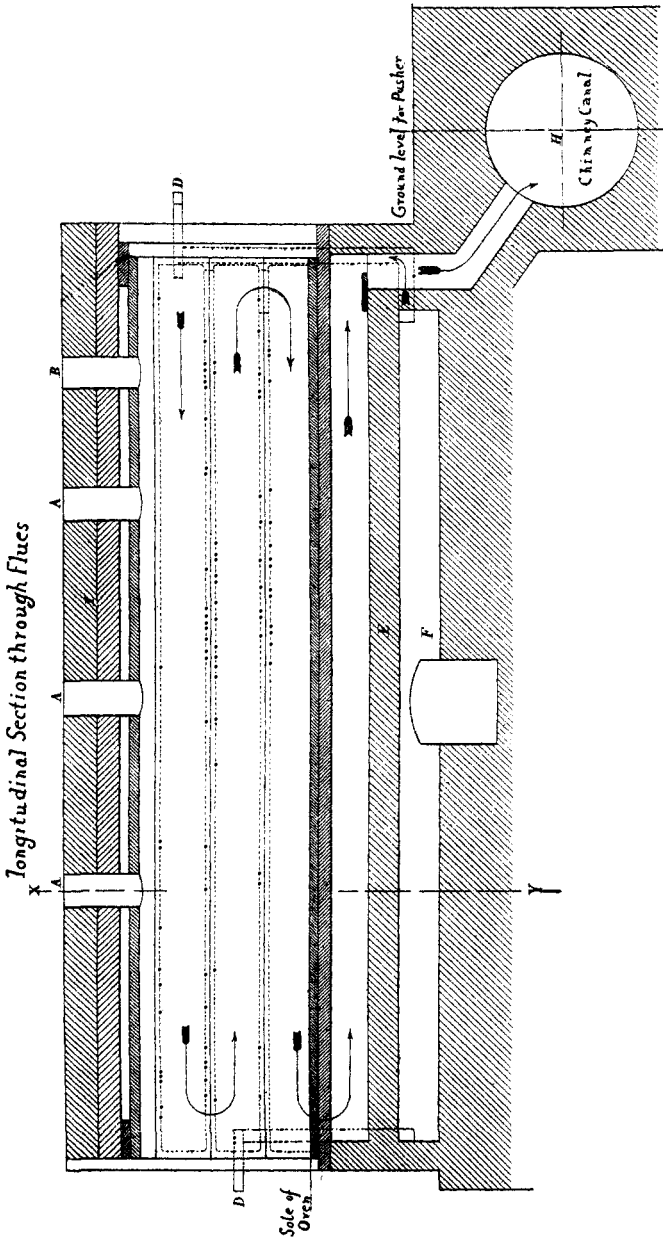
Chimney Canal

Sole of Oven

Fig. 1.
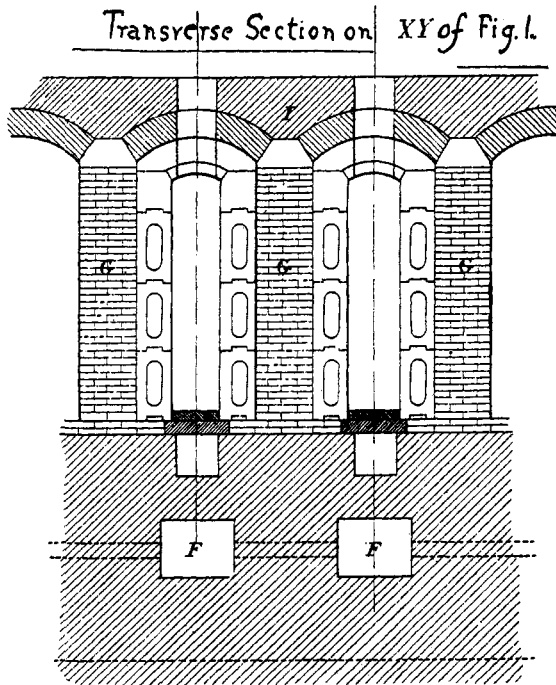
Fig. 2.

The air for combustion is drawn by the chimney draft through a flue, where it is heated by the gases of combustion passing in a flue below the oven, to a temperature of 200°–300° C. The air is admitted and regulated by means of dampers so nicely, and the gas is under such perfect control, that combustion takes place with the minimum amount of air, and the temperature of flues may be maintained as one wishes from 900°–1400° C.

The waste gases, still of about 700°–800° C. temperature, pass under boilers in the by-product plant, which make all the steam necessary to operate all the machinery about the plant, and furnish steam for distillation of the ammonia recovered. From the boilers the waste gases go to the chimney at about 250° C.

The coal, after disintegration, is elevated into bins above the ovens from which, by withdrawal of a slide, coal-cars or "larries" are filled and are then run out on tracks on the top of the ovens and the coal is charged through three holes. One "larry", holding 3,200 lbs. of coal, is charged to each hole. The total charge therefore is 9,600 lbs. of coal to an oven. The time re-

quired for discharging and again filling and closing up is about fifteen minutes.

The coal after being charged in the oven is then leveled off by means of long hoes put through a hole in the top of the doors at each end of the oven. The doors at both ends when closed and plastered up with fire-clay are practically air-tight.

The time required for coking depends upon the quality of the coal, and the width of the oven. Pocahontas coal for instance, containing nineteen per cent. volatile matter, may be coked in twenty hours in a Semet-Solvay oven, sixteen inches wide, whereas, Connellsville coal, containing thirty-two per cent. volatile matter, in the same oven would require twenty-four hours to properly coke it. If the oven is twenty inches wide, six hours more, or thirty hours, are necessary to completely expel the gas from Connellsville coal. It is a fact also that two coals containing the same percentage of volatile matter may require different lengths of time for the expulsion of the gas. Though the percentage of volatile matter is the same in the two coals, this volatile matter is made up of different percentages of oxygen, hydrogen, and carbon, and because of this difference the gas is expelled with greater or less difficulty.

An important feature in the construction of the Semet-Solvay oven is that the hollow tiles forming the walls of the oven are entirely independent of the side walls, made of fire-brick, which carry the huge mass of brickwork, coal-cars, etc., above the oven proper, and thus relieve the tile from all strains and thrusts, which would have a tendency to displace them, causing leaks, which would deleteriously affect the gas and other products. Because of the freedom from burden, the oven sides of the tile may be made much thinner than they otherwise could, resulting advantageously in conducting the heat from the flue where the combustion of the gas takes place to the mass of coal in the oven. The thick side walls and mass of brickwork above serve to hold the heat, giving it up to the oven during the time of discharging and charging, thus preventing any chilling of the oven. An expansion chamber above the oven permits the tile to expand without affecting the main body of brickwork.

The gas leaves the oven under neutral or a very slight back pressure and is drawn by an exhauster through a hydraulic main, similar to that used in gas-works, where it is washed free from dust and is partially cooled.

From the hydraulic main the gas goes to large condensers where the gas is cooled by water to 30°C. From the condensers the blower forces the gas through the washer, or scrubber, where the last traces of ammonia and tar are removed. The gas is now divided, such portion as is necessary going back to the
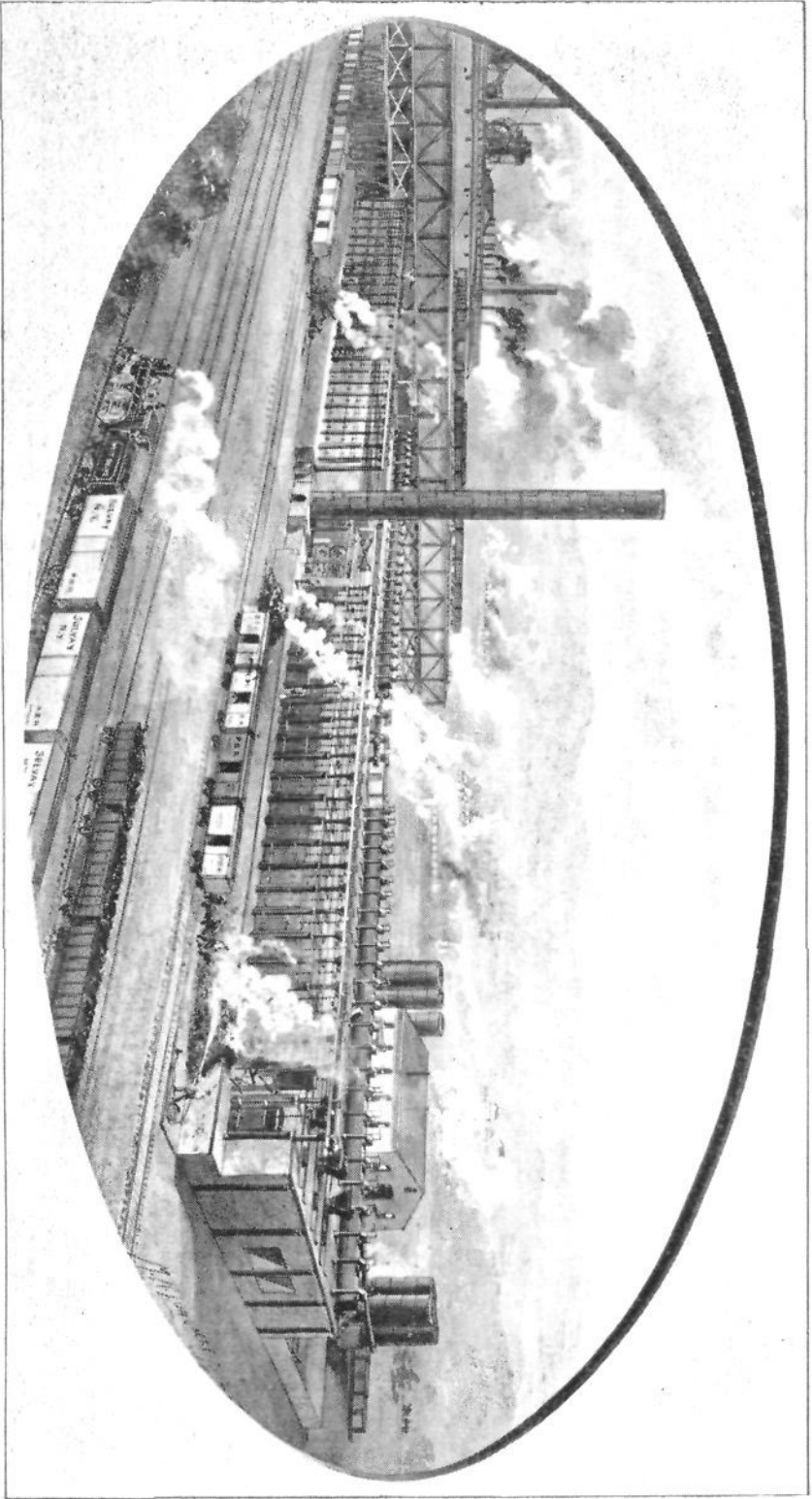
Fig. 3.—Fifty ovens at Dunbar, Pa.

oven flues to keep up the heats, the balance being used wherever fuel may be required.

When the coal is coked, a valve on the uptake pipe shuts off all connection to the hydraulic main ; the doors are swung open, or raised, the mechanical ram is put in operation and slowly forces the coke out of the oven, the coke dropping in a thin layer into an inclined car made of iron bars, and a stream of water quenches the coke. The coke holding one and one-half to two and one-half per cent. of water is then elevated for use in lime-kilns or furnaces, or loaded into cars for shipment. .

CONTROLLING THE TEMPERATURE OF THE FLUES.

By means of valves on the pipes bringing the gas to the flues for combustion, and by dampers in the air inlets, and by regulation of the chimney draft, any temperature may be obtained, from 900° to 1400° C. The temperatures of the flues are determined by means of the Le Chatelier electrical pyrometer, manufactured by Messrs. Kiser & Schmidt of Berlin, which is a platinum rhodium couple in a porcelain tube which produces a current on exposure to a high temperature and this current is measured by a galvanometer. Another pyrometer which has given good satisfaction is the Callender and Griffiths electrical pyrometer, which depends on the resistance offered by high temperatures to a current from a small battery. Fine platinum wires, through which the current passes, are heated inside a porcelain tube and are in connection with a galvanometer which indicates the temperature. The instrument is favorably spoken of by Lord Kelvin and was used by Messrs. Heycock and Neville in determining the melting-points of gold, silver, and copper.[1]

While these instruments have been found very useful to determine accurately the temperature of the flues, they are too delicate to be left in other hands than the expert. As a substitute the Seger cones enable the foreman or workman to judge very closely of the temperature. A round steel rod, six feet long, with three grooves at the end, each large enough to hold a cone, is thrust through a peep-hole in the end of the flue. After fifteen minutes exposure to the heat the cones are removed and their condition noted.

Another instrument made use of by the foreman in charge of the ovens is the telescopic pyrometer of Messrs. Mesuré & Nouell, which seems especially well adapted for coke oven work. The telescope is directed through the peep-hole against the oven side of the tile, and by the degree of incandescence the temperature is determined. Within the tube of the telescope is a polar-

[1] *Chem. Soc. Trans.*, February, 1895. See also for description : *Phil. Mag.*, July, 1891. and January, 1892. *Journal Iron and Steel Institute*, No. 1, 1892. Also a paper by Profs, Dewar and Flemming : *Phil. Mag.*, 1893.

izer, a piece of quartz, and a decomposer. By rotation of the decomposer when viewing the incandescent object, the color changes from green to red, and between these two a gray-lemon tint is seen. This is the sensible shade and the one to observe. A graduated scale on the disk shows the degrees of rotation ; a scale of temperatures corresponding to these degrees is given with the instrument.

By means of this telescopic pyrometer the foreman determines the temperature of the flues, and by proper adjustment of gas, air and draught without difficulty maintains the desired temperatures, which are:

Top flue	800°- 900° C.
Middle flue	1150°-1250° C.
Bottom flue	1050°-1150° C.

COMPARISON OF RETORT COKE AND BEEHIVE COKE.

Because of the widely different conditions under which coke in a by-product oven, and a beehive oven is made, one would naturally expect a difference in the appearance and physical characteristics of the two cokes. The heat stored up in the walls of the retort oven is immediately given up to the coal as it is charged and distillation begins, and proceeds horizontally to the center of the oven, the coal in the center of the oven not reaching a high temperature until the latter part of the time of coking. As a result of this heating from the sides, and a slight swelling or expansion, the coke in a soft state is compressed by the walls slightly, and makes that portion of the coke next the oven wall for about one inch quite dense and of little porosity, while the coke in the center presents a highly cellular appearance, and is more or less spongy : the portion between is hard, dense, and of the customary cellular structure of beehive coke. The coke shrinks away from the oven, thus making it possible for the ram to discharge it; it also separates longitudinally in the center. The thickness of the coke on either side of the center is six and one-half to seven and one-half inches, of which about one and one-half inches is extra dense, and from nothing to one inch in the center is spongy.

The total cellular space of retort coke is practically the same as that of beehive coke, and it is able, because of its strong cellular walls, to bear fully as great a burden in the blast-furnace.

The following table shows determinations of cellular space, specific gravity, etc., of coke made from Connellsville coal in Semet-Solvay ovens, and for comparison are given similar tests of beehive coke for the same coal. It will be seen that cubes taken from that part of the coke near the oven wall contain less percentage of cells and have greater weight per cubic foot than any other part of the coke. The average determinations of the cubes

taken from the center portion of the piece of coke do not vary greatly from the standard Connellsville coke.

The following is a table of physical tests arranged according to Mr. Fulton's plan:

	Grams in one cubic inch.		Pounds in one cubic foot.		Percentage by Volume.		True Sp. Gr.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.	
Standard Connellsville Beehive.							
	12.51	21.62	47.69	82.20	43.93	56.07	17.4
Connellsville Semet-Solvay Ovens.							
Outside piece··	14.39	23.27	52.47	88.64	52.47	47.53	1.87
"	18.57	25.32	70.71	96.31	59.85	40.15	1.84
Average,	16.48	24.29	61.59	92.47	56.16	43.84	1.85
Center piece ···	12.55	20.81	46.17	79.24	45.88	54.12	1.79
"	15.02	23.09	57.19	87.90	50.47	49.57	1.83
"	15.95	25.27	60.85	97.01	47.09	52.91	1.88
"	15.18	24.87	57.81	94.66	45.31	54.69	1.89
"	14.97	23.32	57.00	88.78	49.30	50.70	1.84
Average,	14.92	23.47	55.8	89.51	47.61	52.39	1.84
Connellsville Beehive.							
No. 1···········	11.93	21.18	45.41	80.61	42.57	57.49	1.74
No. 2···········	14.00	24.16	53.30	91.98	43.39	56.61	1.80
No. 3···········	15.07	24.61	57.37	93.70	45.82	54.18	1.80
Average,	13.66	23.31	52.02	88.72	43.92	56.09	1.78

While distillation in the retort oven proceeds horizontally from the outside to the center, in the beehive oven distillation begins at the top and proceeds vertically, and the coke resulting is taken out in long, slender pieces, whereas the product from retort ovens is in large square chunks.

SIR LOWTHIAN BELL'S EXPERIMENTS.

Many years ago, when the first retort coke was put on the market in England, Sir Lowthian Bell made some experiments by which he proved that retort coke would not answer for blast-furnaces; because of the soft nature of the coke the ascending carbon dioxide in the furnace would be converted to carbon monoxide by the carbon, thus diminishing the quantity of carbon which would reach the lower point in the furnace where it was to do its work. It is true that his experiments did show a considerable conversion of carbon dioxide to carbon monoxide when hot carbon dioxide was passed over retort coke in a glass tube. The coke he used, made in a Simon Carvé oven, was certainly in no respect similar to that now made in the Semet-Solvay ovens, for we have many times repeated Sir Lowthian Bell's experiments, using retort coke from Connellsville coal, and for comparison with it have experimented with the standard Connells-

ville coke, and have obtained practically the same results with both cokes. The following are some of these results :

Ten grains of the coke, size of mustard seed, was placed in a combustion tube and then in a furnace and heated at a red heat for one hour. During this time five liters of dry carbon dioxide was passed over the incandescent coke. At the end of the experiment the coke was again carefully weighed and the loss in weight determined with the following results :

SOLVAY COKE.

	Loss of carbon. Per cent.
Experiment No. 1	0.55
" " 2	0.35
Average	0.45

BEEHIVE COKE.

Experiment No. 3	0.46
" " 4	0.49
Average	0.47

It will thus be seen that the two cokes, as far as the action of the hot carbon dioxide is concerned, are practically the same.

Tests were also made of retort coke and beehive coke from Buffalo, Rochester and Pittsburg coal. Average samples were used in both cases.

By these tests it will be seen that there was less conversion of carbon dioxide to carbon monoxide with the retort coke than with the beehive coke.

CARBON DIOXIDE COKE TEST.

Kind of coke.	Weight used. Grams.	Temperature °C.	Time. Hours.	Volume CO_2. cc.	CO obtained. cc.	CO per 1000 gms. coke. cc.
Beehive, B. R. & P.	13	900° C.	4	3400	15.66	1205
Retort, B. R. & P..	13	900° C.	4	3400	14.78	1137
Beehive, B. R. & P.	25	900° C.	4	3500	29.0	1160
Retort, B. R. & P..	25	900° C.	4	3500	24.0	960

A trial of 1000 tons of retort coke, made from Connellsville coal, coked in the Semet-Solvay ovens at Syracuse, was made at the Buffalo blast-furnace in the summer of 1895, and was reported upon by John Fulton, M. E. This test showed that as good results could be obtained with this coke as with the best standard Connelsville coke.

The blast-furnace at Dunbar, Penna., has used 160 tons of retort or by-product coke per day for the past three years; the furnace at Sharon, Penna., 80 tons; and for the past year the Ensley furnaces have been consuming 360 tons, and an oven plant at Wheeling has been furnishing 180 tons to furnaces in

that locality. It will thus be seen that the successful substitution of retort coke for beehive coke in the blast-furnace is no longer an experiment.

As a foundry coke, that made at Syracuse in the Semet-Solvay ovens is much sought after by the foundrymen, who are willing to pay twenty-five cents more per ton for the retort coke than for the beehive coke.

Foundry coke made in by-product ovens in England sells for two to three shillings more per ton than coke made from the same coal in beehive ovens by the same firm.

A test in a Pittsburg foundry of by-product coke, made from Pittsburg coal, showed that it did over twenty-five per cent. more work than the best beehive Connellsville coke.

RETORT OVENS LESSEN THE IMPURITIES IN COKE.

The theoretical yield, when applied to coke, signifies the coke obtained from 100 of coal by expelling the volatile matter and not permitting the combustion of any of the fixed carbon.

In beehive ovens, the yield of coke is from five to twenty per cent. less than the theoretical yield; in the Semet-Solvay retort ovens, we find in the large number of trials we have made on different coals, that the yield is greater than the theoretical by five to ten per cent., according to the coal under consideration. This is due to the fact that by the beehive method, much of the fixed carbon is burned, whereas, by the retort method, no fixed carbon is consumed because there is no admittance of air, and through the breaking-down of the gases much carbon is precipitated in and upon the coke.

The following figures illustrate by actual results obtained, the difference between coking in beehive and retort ovens. The importance of this increase of yield from a commercial as well as from a chemical standpoint is perfectly evident.

	Syracuse.	Dunbar.	Sharon.	Ensley.	Wheeling.	Total.
Kind of coal	Buffalo, Rochester and Pittsburg.	Connellsville.	Washington.	Alabama.	Connellsville.	
Weight of coal coked per day (tons)	112	224	112	540	270	1258
Per cent. yield of coke per day	72	73	72	73	73	
Weight of coke per day (tons)	80.6	163.5	80.6	394.2	197.2	916
Per cent. yield of coke in beehive oven from same coal	65	66	65	60	66	
Weight of coke from beehive oven	72.8	147.8	72.8	324	178.2	795.6
Per cent. increase in the yield of retort oven over beehive oven	10.7	10.6	10.7	21.6	10.6	

Further trials on well-known coals give the following results :

	Beehive. Per cent.	Retort oven. Per cent.	Gain. Per cent.
Pocahontas ...·..........	62	83	33
Morris Run············	60	80	33

It will thus be seen that the retort ovens actually lessen the percentage of sulphur, phosphorus, and ash impurities of the coke, by increasing the fixed carbon.

The sulphur in coal is present in three forms, as pyrites (FeS_2), or it is combined with carbon as a hydrocarbon, or it is present as calcium sulphate.

In the retort coke oven the organic sulphide is expelled and one-half of the sulphur of the pyrites, while the calcium sulphate remains unchanged. The sulphur remaining in the coke is almost invariably lower in percentage than in the coal.

The following are tests of sulphur in various coals coked in the ovens at Syracuse, and the sulphur in the coke made from these coals, also the volatile matter in the coals.

PER CENT.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Sulphur in coal....	1.95	0.73	1.62	0.67	1.25	0.99	2.8	3.8	1.7
Sulphur in coke....	1.75	0.68	1.44	0.66	0.94	0.90	2.7	2.7	1.5
Vol. matter in coal·	38.2	23.7	27.3	25.4	31.8	37.8	40.1	40.4	29.6
Sulphur in coke supposing none evolved in coking	3.155	0.956	2.228	0.898	1.832	1.594	4.675	6.377	2.414
Per cent. sulphur removed ·········	44.32	28.95	35.36	26.53	48.67	43.54	42.25	57.66	37.85

VOLATILE MATTER IN RETORT COKE.

The volatile matter in retort coke is quite as low and sometimes lower than in beehive coke. In passing it may be stated that the customary method of determining the volatile matter in coke, as described by Blair, gives results which are slightly too high, due to combustion of some of the fixed carbon. To completely prevent oxidation of the carbon on heating over a blast-lamp for three and one-half minutes, a stream of hydrogen or nitrogen is gently passed over the coke in the crucible, thus keeping the coke in an atmosphere of an inert gas during the heating; by this method a coke will show a volatile of 1.25 per cent., whereas, by the customary method, 2.25 per cent. volatile would have been shown.

Fig. 4 is a sketch of the apparatus used for determining the volatile matter in coke. It consists of a small platinum crucible with a cover tightly fitting the top of the crucible on the inside ; through the cover is an inlet tube passing well down into the crucible, and an outlet tube on the cover. About ten grams of

fine coke are placed in the crucible, the cover put on, and a gentle stream of hydrogen or nitrogen, about two bubbles a second,
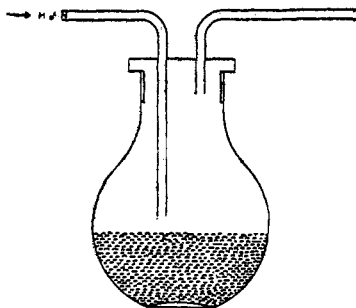
Fig. 4.

as indicated by a small bottle of water through which the gas passes, replaces the air and fills the crucible with the inert gas. The blast-lamp is then placed under the crucible and the coke heated for three and one-half minutes.

BY-PRODUCTS.

The by-products obtained from the distillation of coal in retort coke ovens are tar, ammonia, and gas, and from the gas may be recovered benzene and cyanides; all the by-products vary in quality and quantity with the composition of the coal, and are also affected more or less by the temperature to which the oven is heated. Generally speaking the quantity of tar and ammonia obtained is in direct proportion to the percentage of volatile matter in the coal. One containing seventeen per cent. volatile matter will yield $13\frac{1}{2}$ lbs. of ammonia, figured as sulphate, and 30 lbs. of tar, whereas one containing thirty-seven per cent. volatile matter will yield 27 lbs. of ammonium sulphate, and 110 lbs. of tar. We are not referring now to the western coals, known as dry coals, which are devoid of bitumen and coke with great difficulty and yield a small amount of by-products, but to the coals found in the bituminous, or semibituminous fields of Pennsylvania, Virginia, West Virginia, Tennessee, Alabama, or Nova Scotia.

From the large number of ultimate analyses which we have made of coals experimented upon in ovens, we find that coals having the highest percentage of hydrogen over and above that necessary to combine with the oxygen in the coal, are the ones which make the best coke, and produce the greatest quantity of by-products; in other words, a coal containing a high percentage of oxygen will not produce good coke, nor will it produce much tar and ammonia. If the analysis shows water of consti-

tution five to ten per cent. indicating the character of a lignite, the yield of by-products will be small and the coke of poor quality ; or having at hand the proximate analysis of a coal found in any of the above-mentioned localities, one may judge very closely the yield of by-products per 2000 lbs. of coal by referring to the following chart. A line is also given showing the yield of coke to

PER CENT. VOLATILE MATTER IN COLORS.
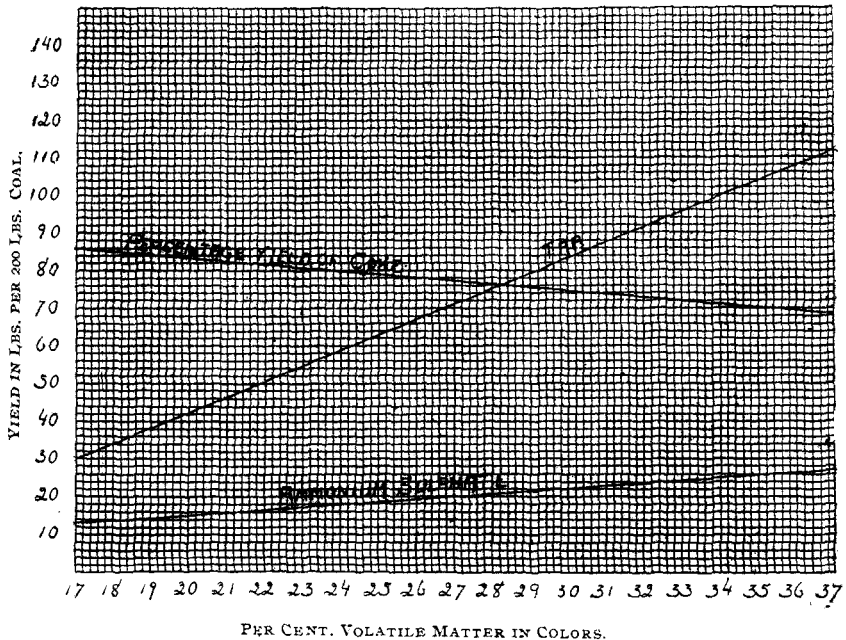
Fig. 5.—Chart showing lbs. of tar, ammonium sulphate per 2000 lbs. coal and percent-age yield of coke for coals varying from seventeen per cent. to thirty-seven per cent. volatile matter.

be obtained. The higher the volatile matter the greater will be the increase in yield of coke over and above the theoretical. On this chart the increase in yield over the theoretical for a coal containing seventeen per cent. volatile is four per cent. ; for one containing thirty-seven per cent. it is eight per cent.

AMMONIA.

Weak liquor is converted to crude gas liquor, aqua ammonia, and sulphate.

While ammonia is formed from the organic nitrogen of the coal and while it is true that those coals highest in nitrogen also produce the most ammonia, still the amount of hydrogen present

in the coal over and above that necessary to combine with the oxygen of the coal, has an important influence in the yield of ammonia.

Coking coals do not vary greatly in nitrogen, from 1.30 to 1.60 per cent., whereas the yield of ammonia from coals containing these two percentages of nitrogen is $13\frac{1}{2}$ and 27 lbs. ammonium sulphate respectively. It will thus be seen that the yield of ammonia is not exactly in proportion to the content of nitrogen in the coal. It will also be noted that this yield is a comparatively small percentage of the theoretical yield of ammonia from the nitrogen contained.

A coal of 1.30 per cent. nitrogen has a theoretical yield of 122.5 lbs. ammonium sulphate.

A coal of 1.60 per cent. nitrogen has a theoretical yield of 150.8 lbs. ammonium sulphate.

Thus in the first case eleven per cent. of the nitrogen is recovered as ammonia, and in the second case eighteen per cent. is obtained as ammonia.

William Foster[1] accounts for the nitrogen in coal when distilled in a gas retort as follows :

	Per cent.
Nitrogen of coal evolved as ammonia (NH_3)	14.50
" " " " cyanogen	1.56
" present in gas as elementary nitrogen	35.26
" remaining in the coke	48.68

The addition of two per cent. of lime will increase the yield of ammonia ten per cent. This, however, could be done only with coals very low in ash.

The amount of nitrogen left in the coke varies greatly for the different coals. Many coals having very low nitrogen show the highest percentages of nitrogen in the coke. The following figures for nitrogen in coals and coke from them illustrates this point :

	I. Per cent.	II. Per cent.	IV. Per cent.	V. Per cent.
Nitrogen in coal	1.52	1.60	1.39	1.30
Nitrogen in coke	0.553	0.354	0.749	0.53
Volatile matter in coal	36.46	31.88	23.72	21.99
Nitrogen in coke if none evolved in coking	2.392	2.349	1.822	1.663
Nitrogen evolved as NH_3, CN and elementary nitrogen	76.88	84.51	58.88	68.13
Nitrogen of the coal recovered as NH_3	19.26	13.88	15.02	11.43
Evolved nitrogen, recovered as NH_3	25.02	16.39	25.51	16.78
Ammonia, figured as sulphate, recovered per 2000 lbs. coal (pounds)	25.36	20.93	19.67	14.00

[1] *J. Chem. Soc.*, 43, 105-110.

To determine at what stage of the coking process the ammonia is expelled from an oven, a measured volume of gas was drawn through acid at different intervals and it was found that ammonia was evolved at the following rate. Eight samples of gas were tested during the twenty-four hours of coking.

RATE OF EVOLUTION OF AMMONIA PER 2000 LBS. COAL.

		Lbs.
At the end of 1 hour	....	16.2
4 hours	....	21.1
7 "	....	19.8
10 "	....	22.5
13 "	....	17.5
16 "	....	13.9
19 "	....	8.5
22 "	....	1.7

The ammonia is collected partly in the hydraulic main, partly in the condenser, and the last traces are removed from the gas in the scrubber. The liquor collected from these places is of course very weak and must be concentrated by distillation with lime to free the fixed ammonia. The weak liquors contain ammonia in the fixed and free state and include the carbonate, sulphate, sulphide, and chloride of ammonium. The weak liquors are of the following composition :

	Grams per liter.	
	Free ammonia.	Fixed ammonia.
Hydraulic main	1.18	7.14
Condenser	8.2	2.1
Scrubber	10.5	0.9

By distillation and condensation a crude ammonia liquor of seventeen per cent. to twenty per cent. ammonia is obtained. The sulphur and carbon dioxide combined with the ammonia in the weak liquor, reappear in the strong liquor. The composition of this liquor is :

Ammonia ....17 to 20 per cent.
Carbon dioxide................ ....75 to 80 grams per liter.
Hydrogen sulphide................30 to 35 " "

The quantity of ammonium sulphide, of course, depends upon the amount of the sulphur in the coal. There is always carbon dioxide in the gas from the oven in excess of the ammonia, hence a large amount of ammonium carbonate is necessarily formed. The principal other impurity in the crude concentrated liquor is ammonium cyanide, often present in such quantities as to make it profitable to recover it as potassium ferrocyanide ; the greater part of the cyanogen, however, passes away in the gas, and after passing the scrubber may be treated for its removal.

Instead of making the crude yellow gas liquor of commerce, as above described, the process of distillation may be so carried on as to remove the carbon dioxide and hydrogen sulphide, and a product formed which is perfectly colorless, containing twenty-nine per cent. ammonia, and known in the trade as aqua ammonia. The following table shows the relation of °Bé to per cent. ammonia in aqua ammonia :

AQUA AMMONIA.

Table adopted by National Ammonia Co.		Table by G. Gerhardt.	
Specific Gravity, 60° Fah.	Degrees Baumé (Gerhardt).	Per cent. ammonia.	Factor.
1.0000	10	0.0	0.0000
0.9930	11	1.6	0.055168
0.9864	12	3.3	0.1138
0.9793	13	5.05	0.1741
0.9726	14	6.80	0.23445
0.9660	15	8.33	0.2872
0.9594	16	10.17	0.35066
0.9530	17	11.88	0.4096
0.9467	18	13.88	0.47858
0.9400	19	15.63	0.5389
0.9342	20	16.42	0.6006
0.9281	21	19.25	0.6637
0.9221	22	21.12	0.7282
0.9191	22.5	22.07	0.76097
0.9161	23	23.03	0.7941
0.9132	23.5	24.00	0.8175
0.9102	24	25.00	0.8620
0.9073	24.5	25.98	0.8958
0.9045	25	26.98	0.9303
0.9016	25.5	27.60	0.9516
0.8986	26	29.00	1.0000
0.8959	26.5	29.69	1.0237

To meet the demands of manufacturers of fertilizers, the gases from the distiller may be absorbed in 60° sulphuric acid contained in a lead-lined tank called a saturator, and crystals of ammonium sulphate obtained. The color of the crude commercial ammonium sulphate is usually gray, but is sometimes blue. Blue sulphate brings a much lower price than the gray. The blue color is due to the presence of Prussian blue formed from the ammonium cyanide in the weak liquor. By special treatment of this liquor before distillation a gray sulphate may invariably be obtained.

TAR.

As previously stated the amount of tar recovered varies from 30 to 110 lbs. per 2,000 lbs. coal, according to the composition of coal. The tar, like the ammonia, is separated from the gas in the hydraulic main, condenser, and scrubber.

The quality of tar from retort coke ovens varies greatly ; the

quantity as before stated depends upon the composition of the coal, the temperature of the ovens, and the pressure of the gas between the oven and the hydraulic main ; the same may be said to be true of the quality of the tar.   It is also true that coals, identical as far as the proximate analysis is concerned, sometimes produce tars which are widely different in composition.   It is difficult to say why this should be so; it is probably due to slightly different conditions of operation, and partly due to a difference in the coal which is not shown in the proximate analysis.   The relation of the carbon to the hydrogen in the volatile matter is different.   A coal in which the hydrogen is a large percentage of the carbon in the volatile matter, produces a tar containing much naphthalene ; and we find on the other hand that the amount of naphthalene in a tar from a coal very low in hydrogen is very small.   To illustrate : In one of our plants the tar obtained is so highly charged with naphthalene that on distillation the very first distillate up to 100° C. solidifies, whereas, in another plant, the tar obtained shows only traces of naphthalene, though the coals used are almost identical, judging from the proximate analysis.   Analyses of these two coals and the tar obtained are :

ANALYSES OF COALS.

	A. Per cent.	B. Per cent.
Volatile matter	34.20	32.68
Fixed carbon	57.15	59.40
Ash	8.65	7.92
Sulphur	0.93	1.19

ANALYSES OF TAR.

	A.	B.	I.	II.
Specific gravity	1.163	1.203	1.205	1.231
	Per cent.	Per cent.	Per cent.	Per cent.
Water	2.40	2.70	1.40	1.10
Light oil	4.60	2.03	3.12	1.63
Creosoting oil	1.26	0.50	0.29	0.34
Dead oil	22.81	16.40	25.09	19.23
Naphthalene	6.0	trace	0.20	1.72
Anthracene	0.6	``	0.19	0.24
Soft pitch	68.80	70.50	67.40	74.14

Tars A and B show what differences may exist in tars made from coals very similar in proximate analysis.   I and II represent two tars from gas houses, which also vary greatly, but as a usual thing are found to be of a much higher specific gravity and to contain less light oils, making them inferior for the manufacture of benzene, and the dipping of paper for tarred paper.

The analyses of tar given above were made by a method which gives results that enable a tar distiller to judge of what the com-

mercial value of the tar is. A tar distiller wants to know how much light oil, naphthalene, dead oil, and soft pitch a tar will give. There is as yet no market for anthracene in this country. Most analyses given in books show too low a percentage of pitch. There is practically no market for hard pitch. To produce a salable pitch distillation must be stopped at 355° to 360° C. The method of analysis used for the determination of the commercial value of tar is as follows :

In the first place no test should be made on a quantity less than a gallon.

Method.—Weigh out ten lbs. tar in a measured cylinder, and in this way determine the specific gravity of the tar.

The thermometer in the distillation of tar should be placed one-half inch above the surface of the liquid.

Keep the tar at a temperature of 50° C. for twelve hours. Water comes to the surface, which is to be removed and measured, and is to be reckoned in the analysis of the tar.

Put the balance of the tar into a copper still, of two gallons capacity, and begin the distillation very slowly at first, the distillate coming one drop per second. Have a beaker of water, into which place a drop of the distillate when the light oil is coming over, to indicate the point when the light oil changes into heavy oil and sinks in water. The distillate is then turned into another receiver, and the light oil and water in the first receiver carefully measured. The distillation is then continued up to about 360° C., or to such a point as produces a roofing pitch in the still, which may be determined by taking a sample from the still, putting in water, and testing the cooled sample.

If it has cohesive properties, that is, if it makes a gum, it is of good quality. If it is brittle, the distillation has been carried too far, and the residue in the still will be hard pitch, which is unsalable.

The temperature of the condenser should be kept at 75° C. during this distillation. The distillate should stand for some twelve hours at a temperature of about 60° F. The roofing pitch in the still, after cooling, should be removed by unsealing the top, which is bolted, and turning the still upside down ; upon gently heating the bottom of the still the pitch will drop out in one large cake. This is then weighed and constitutes the percentage of roofing pitch in the tar.

The distillate contains the creosote oil, dead oil, naphthalene, and a portion of the anthracene, it being necessary to have held in the pitch some of the anthracene to produce a pitch of the right quality for roofing purposes. The distillate with its crystallized naphthalene and anthracene is transferred to a Canton flannel cloth and compressed to remove the liquor as much as

possible by hand ; then it is placed between one-quarter inch
iron plates and put into a vise and pressed for about one-half
day, every little while tightening the vise; this pressed cake
represents the crude naphthalene and crude anthracene over and
above the amount remaining dissolved in the dead oil.   The
liquor resulting upon compressing and removing the naphthalene
and anthracene contains the creosoting and dead oil.   This oil
is placed in a small copper still of about one liter capacity.
The distillate resulting up to 200° C. is the creosoting oil; the
balance in the still is dead oil.

To separate the anthracene from the naphthalene melt up the
material from which the oil has been pressed, put in a still and
distil up to 280° C.   (This distillate is crude naphthalene.)
Now save the fraction distilling from 280° C. to dryness (this is
anthracene mixed with a little anthracene oil.)   Press this as
with the larger amount before, and the solid matter remain-
ing in the cloth is the crude anthracene.   This subtracted from
the total will give the crude naphthalene also.

PRACTICAL TEST FOR ROOFING PITCH.

The practical test for roofing pitch is to take a sample, place
it in the mouth and chew it, and if there is a sufficient amount
of cohesion to produce a gum, the roofing pitch is of good qual-
ity.   This is a very crude test, but is the one used in the tar dis-
tillation works.

GAS.

A portion for heating ovens ; the surplus for illumination,
fuel purposes, or for power in gas engines.

The total volume of gas evolved from a coal is of course di-
rectly proportionate to its percentage of volatile matter and the
heat to which it is exposed.   This holds true of the gas from a
retort coke oven, provided leaky flues do not admit air to burn
the gas in the oven, or under conditions of excessive pressure
gas is not driven into the flues and there burned.   But in well-
constructed and well-regulated ovens this need never occur.

The total volume of gas from a coal containing thirty-three to
thirty-four per cent. volatile matter is about 10,400 cubic feet
per long ton, or 9,280 cubic feet per 2000 lbs.; from a coal of
twenty per cent. volatile matter, about 7000 cubic feet per long
ton, or 6250 cubic feet per 2000 pounds.

The quantity of gas necessary to be returned to the oven for
heating is from fifty to fifty-five per cent. if the coal is thirty-two
to thirty-four per cent. volatile.   Less gas is required to coke
coals of low volatile composition.   Thus Pocahontas coal con-
taining nineteen per cent. volatile matter requires only two-
thirds as much gas for coking as Connellsville coal, which con-
tains thirty-two per cent. volatile.

I give below the results obtained from the coking of a coal in an isolated oven ; analyses of this gas taken after passing the purifying box were made hourly during the period of coking, which was twenty-four hours.

Photometric readings were made every five minutes, the tests averaged and recorded for every hour calculated for a consumption of five feet per hour at 60° F. and thirty inches mercury, each candle-power being equal to 120 grams spermaceti per hour. The photometer used was a sixty-inch bar photometer.

The analysis of the coal used in this test was as follows :

	Per cent.
Volatile	35.71
Fixed carbon	59.36
Ash	4.93
Sulphur	2.4
Nitrogen	1.52

	Cubic feet.
Total volume of gas from 9,400 lbs. coal	43,747
" " " " " 2,000 " "	9,280
" " " " " 2,240 " "	10,400

Using this same coal in the entire twenty-five ovens for forty-eight hours and turning the excess or surplus gas into holders, we found that this excess gas amounted to 44.5 per cent. of the total gas ; in other words :

Total gas	9,280 cubic feet per 2000 lbs. coal.
Percentage gas for coking	55.5 per cent.
Volume gas for coking	5,150 cu. ft.
Percentage of surplus gas	45.5 per cent.
Volume of surplus gas	4,130 cu. ft.

These figures represent accurately the distribution of the gas when making blast-furnace coke. If only domestic coke is to be the product, fifteen to twenty per cent. less gas will be required for the coking process.

The following are the records of gas analyses made hourly, and from a perusal of them we see that the methane at the beginning is very high, forty-six per cent., and that it soon falls to forty per cent. and remains at this figure for about twelve hours, and then begins to fall off until, at the discharge, the gas contains only 10.2 per cent. The hydrogen on the other hand starts in at 28.9 and is ever increasing, until at the end it has reached 77.0 per cent. The illuminants (olefines) are highest, 6.8 per cent., in the beginning and gradually diminish, until after sixteen hours they are practically nil. The carbon monoxide, nine per cent. in the first test, gradually decreases until in the last test four per cent. is found.

The high nitrogen in the early tests is due to an excessive suction on the oven :

Fig. 6.—Hourly record of analyses, candle power and B. T. U. per cu. ft. of gas from one coke oven.

Time.	Carbon dioxide.	Ethyl- ene.	Oxygen.	Carbon monoxide.	Methane.	Hydrogen.	Nitrogen.
10.40 A.M.	0.0	6.8	1.0	9.0	46.0	28.9	8.3
11.50	1.2	6.8	1.0	6.4	40.5	34.3	9.8
12.40 P.M.	1.6	6.7	0.7	6.7	40.8	36.7	6.8
1.40	2.0	6.0	0.6	6.9	39.5	40.2	4.8
2.40	2.0	5.6	0.4	6.8	40.3	42.1	2.8
3.40	2.0	5.5	0.3	6.8	39.6	44.0	1.8
4.40	2.0	4.8	0.4	7.0	41.5	43.3	1.0
5.40	2.5	4.7	0.5	7.0	39.2	44.7	1.4
6.40	2.5	4.8	0.8	7.2	38.8	43.9	2.0
7.40	2.3	4.2	0.5	6.9	36.4	47.2	2.5
8.40	2.3	3.6	0.4	6.8	38.9	45.2	2.8
9.40	2.1	3.7	0.3	6.6	39.7	46.0	1.6
10.40	2.1	2.7	0.3	7.0	39.3	47.5	1.1
11.40	1.5	2.2	0.4	6.6	39.2	48.9	1.2
12.40 A.M.	1.4	1.7	0.8	6.5	38.8	48.5	2.3
1.40	0.7	1.4	0.4	5.9	33.1	52.9	5.6
2.40	0.8	1.0	0.3	5.4	28.9	59.2	4.4
3.40	0.5	0.8	0.2	5.0	26.9	60.2	6.4
4.40	0.0	0.0	0.3	4.9	22.3	68.9	3.4
5.40	0.2	0.0	0.3	5.5	18.3	70.8	4.9
6.40	0.0	0.0	0.4	5.3	16.4	72.1	5.8
7.40	0.2	0.0	0.2	4.3	12.9	73.5	8.9
8.40	0.0	0.0	0.4	4.0	10.8	75.0	9.8
9.40	0.0	0.0	0.2	4.0	10.2	77.0	8.8

The following table shows the calorific value of the gas from hour to hour and also the candle-power :

Time.	Average candle-power for each hour.	Calories per cubic meter.	Calories per cubic foot.	B. T. U. per cubic foot.
10–11 A.M.	15.1	6539	185	734
11–12	16.7	6104	173	686
12–1 P.M.	17.2	6201	175	694
1–2	16.5	6088	172	682
2–3	15.8	6158	174	690
3–4	16.0	6135	174	690
4–5	13.9	6195	175	694
5–6	13.3	6004	170	674
6–7	13.9	5963	169	670
7–8	13.4	5739	162	642
8–9	11.3	5821	164	650
9–10	11.9	5931	168	666
10–11	12.9	5802	164	650
11–12	13.5	5748	162	642
12–1 A.M.	12.2	5621	159	631
1–2	11.4	5151	145	575
2–3	9.3	4871	138	547
3–4	6.8	4669	132	523
4–5	4.2	4377	124	492
5–6	2.6	4074	115	456
6–7	1.6	3927	111	440
7–8	0.0	3607	102	404
8–9	0.0	3439	97	384
9–10	0.0	3235	91	361

From a study of these figures it will be seen that as an illuminating gas it is not of much value after ten hours. In calorific value, however, it has diminished only slightly.

From the following table it will be seen that the volume of gas expelled per hour remains pretty nearly constant for seventeen hours and then falls off rapidly :

1. Time.
2. Cubic feet of gas expelled from the oven per hour.
3. Average of the several readings of the candle-power during each hour.
4. Total cubic feet of gas expelled from hour to hour.
5. The percentage of total cubic feet of gas expelled at the end of each hour.
6. Average candle-power of the total gas.

1.	2.	3.	4.	5.	6.
10–11	2032	15.1	....	..	...
11–12	2272	16.7	4304	9.8	15.9
12–1	2075	17.2	6379	14.5	16.3
1–2	1934	16.5	8313	19.0	16.4
2–3	1974	15.8	10287	23.5	16.2
3–4	2068	16.0	12355	28.2	16.2
4–5	1880	13.9	14235	32.5	15.9
5–6	1880	13.3	16115	36.8	15.6
6–7	1880	13.9	17995	41.1	15.4

1.	2.	3.	4.	5.	6
7–8	1974	13.4	19969	45.6	15.2
8–9	2068	11.3	22037	50.3	14.8
9–10	2162	11.9	14199	55.3	14.6
10–11	2256	12.9	26455	69.47	14.4
11–12	2162	13.5	28617	65.41	14.4
12–1	2068	12.2	30685	70.14	14.2
1–2	2350	11.4	33035	75.51	14.0
2–3	2162	9.3	35197	80.45	13.8
3–4	2350	6.8	37547	85.82	13.4
4–5	1598	4.2	39145	89.48	12.9
5–6	1410	2.6	40555	92.70	12.4
6–7	1034	1.6	41589	95.06	11.9
7–8	940	0.0	42529	97.21	11.3
8–9	889	0.0	43418	99.24	10.8
9–10	329	0.0	43747	100.00	10.4

In the above tables we have the means of determining the most advantageous disposition to make of the gas from a plant of retort coke ovens.

First, the first forty-five per cent. of the gas expelled may be received in a holder and used without enrichment, as is done with the gas from the ten Semet-Solvay ovens at Halifax. These ovens were erected to take the place of others of a different type which were a failure. Or, second, the entire gas from the ovens may be enriched and brought from 10.4 to 16 or 17 candle-power and used for illuminating purposes; or third, the entire gas may be pumped to street mains for domestic fuel supply, without enrichment.

In either of the two last cases producer gas would be substituted for the coke oven gas for heating the ovens. This is perfectly practical, and profitable, if there is a demand for all the coke oven gas.

The following table shows the composition of the surplus gas, and of the balance of the gas which would ordinarily be used for heating the ovens; Fig. 5 also represents graphically the analyses of gas, etc.

ANALYSES.

	Carbon dioxide.	Illuminants.	Oxygen.	Carbon monoxide.	Hydrogen.	Methane.	Nitrogen.
Surplus gas	1.8	5.5	0.6	6.4	40.5	40.2	4.9
Heating gas	0.8	1.2	0.3	5.6	60.4	26.8	4.9
Average	1.3	3.4	0.45	6.0	50.45	33.5	4.9

HEAT UNITS.

	Volume in per cent.	Volume per 2000 lbs. Cu. ft.	Volume per long ton. Cu. ft.	Calorific power.		Candle-power.
				B. T. U.	Calories per cubic-meter.	
Surplus gas	45.5	4130	4732	685	6112	15.2
Heating gas	55.5	5150	5668	532	4734	8.3
Average and total	100.0	9280	10400	608.5	5423	11.7

To compare with retort coke oven gas in composition and fuel value are taken figures of retort gas, given by C. D. Jenkins, State gas inspector of Massachusetts. in his report of 1896. For analyses of natural gas, average of figures given by Prof. F. C. Phillips, *Am. Phil. Soc.*, 17, have been adopted.

	Natural gas. Per cent.	Illuminating gas. Per cent.	Coke Oven gas. Per cent.	Water gas. Per cent.	Producer gas. Per cent.
Carbon dioxide..........	0.48	1.75	1.3	0.14	4.5
Illuminants	0.0	4.88	3.4	...	0.0
Oxygen.................	0.0	...	0.45	0.13	0.6
Carbon monoxide	0.0	6.82	6.0	37.97	25.5
Methane	92.47	33.90	33.5	7.65	1.0
Hydrogen...............	0.0	46.15	50.45	49.32	12.0
Nitrogen...............	7.05	6.50	4.9	4.79	56.4
B. T. U. per cu. ft.......	984	623	608.5	381	138

From the above figures it will be seen that coke oven gas is greatly superior for heating purposes to producer and water gas, and only slightly inferior to illuminating gas. Of course, natural gas, composed so largely of methane, yields a much greater number of calories.

BENZENE OBTAINED FROM THE TAR AND FROM THE GAS.

Benzene and the other products of this series are evolved during the early stages of the coking process. They are condensed and appear in the lighter portions of the tar, or become fixed in the gas, and may be removed only by pressure and low temperature, or by dissolving in oils. By far the greater proportion of the benzene from a ton of coal is recovered from the gas, only about ten per cent. from tar. As the illuminating quality of a coke oven gas is largely due to the benzene (C_6H_6) contained, it is evident that the removal may greatly deteriorate its value for lighting purposes, while the heating value of the gas is only slightly affected. The first product obtained after treating the absorbent containing the benzene is known in the trade as "light oil." The light oil obtained from the gas is six and six-tenths lbs. to eight and five-tenths lbs. per long ton of coal, and varies with the percentage of volatile matter in the coal.

The light oil contains from fifty-eight to sixty-three per cent. of benzene, divided thus :

	Per cent.
Ninety per cent. benzene....................	57
Fifty per cent. benzene......................	2
Solvent naphtha	4

Distillation of this light oil gives a product distilling as follows :

Density at 15° C...................... 0.92
First drop........................... 81.5° C
At 100° C................... .... 50.0 per cent. distilled
At 125° C..................... ...... 66.0 "   "   "
At 150° C .... 71.0 "   "   "
At 170° C ....·......... 74.0 "   "   "

From the distillation of this product the ninety per cent. and
fifty per cent. benzene and solvent naphtha of commerce are ob-
tained.   The analyses of these products are as follows:

NINETY PER CENT. BENZENE.

Density 0.89
First drop at .... 81.5° C.

Per cent.

At   85° C............................... 40
At   90° C............................... 77
At   95° C............................... 86
At 100° C............................... 91-92

FIFTY PER CENT. BENZENE.

Density 0.884
First drop at .... 87° C.

Per cent.

At   90° C............................... 7.5
At 100° C............................... 52
At 120° C............................... 90-91.5

SOLVENT NAPHTHA.

Density 0.88
First drop at ....116° C.

Per cent.

At 120° C............................... 6
At 160° C............................... 99-91.5

CYANIDES.

As in the case with ammonia, cyanogen is evolved in greatest
quantity about the eighth to the tenth hour of coking.

The formation of cyanogen in illuminating gas has been
accounted for by Kuhlman through the action of ammonia on
carbon, carbon monoxide, and carbon disulphide in the follow-
ing reactions:

$$C + NH_3 \quad = CNH + H_2, \text{ or}$$
$$C + 2NH_3 \quad = CN, NH_4 + H_2;$$
$$CO + NH_3 \quad = HCN + H_2O, \text{ or}$$
$$CO + 2NH_3 = CN, NH_4 + H_2O;$$
$$CS_2 + 2NH_3 = CNS, NH_4 + H_2S.$$
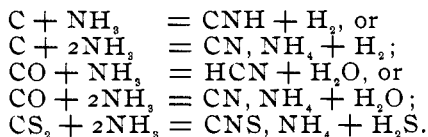
In the retort coke ovens we have similar conditions to the gas
retort.   It is, however, different in that the charge of coal is
much greater, and the temperature is not so high; the quantity

of cyanogen obtained therefore is not so great from the retort coke oven, for high temperature is conducive to high yield. We find on testing the gas from the oven before entering the hydraulic main, that both thiocyanate and cyanides of ammonia are present; but that on testing the liquor from the hydraulic main, we do not find any ammonium cyanide or ammonium ferrocyanide. Even though the temperature of this liquor in the main is low, and one would expect the ammonium cyanide to remain in solution, we find that in the struggle for ascendency, carbonic acid and other acids expel the cyanogen, and it passes on with the gas.

In the examination of the ammonia liquor from the condenser, we find only a small amount of thiocyanate present, but a comparatively large amount of ammonium ferrocyanide. The only explanation to offer for this is that ferrous sulphide is formed by contact of the hydrogen sulphide with the very large expanse of metal in the condensers. This ferrous sulphide in an atmosphere of ammonia as an alkali forms with hydrocyanic acid, ammonium ferrocyanide. In the scrubber we find thiocyanate, but no ammonium cyanide or ferrocyanide.

Thiocyanate found in the different liquors is:

    In hydraulic main···· 1.501 grams per liter ammonium thiocyanate.
        Condenser········· 0.0912
        Washer ·········· 0.0058

The gas leaving the scrubber contains the cyanogen in the form of hydrocyanic acid, and when hydrocyanic acid is recovered by the usual method, $i. e.$, passing the gas through an alkaline ferrous carbonate or sulphide absorbing solution, by which potassium ferrocyanide is formed, we find a considerable amount of sodium thiocyanate in the solution. In fact, our tests show that in this absorbing solution the cyanogen is divided as follows:

                                                        Per cent.
    Cyanogen as $K_4Fe(CN)_6.3H_2O$ ······················· 92.61
         "   KCNS ······························· 7.39

The cyanogen recoverable from coke oven gas, figured as potassium ferrocyanide $(K_4Fe(CN)_6.3H_2O)$ amounts from 1.25 to 1.50 lbs. per 2000 lbs. of coal.

The amount of cyanogen recovered in weak ammonia liquors, as ammonium thiocyanate and ferrocyanide, if added to the above yield, would increase the yield of potassium ferrocyanide one-tenth lb. per 2000 lbs. of coal.

                                        J. D. PENNOCK.