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THE MODERN BY-PRODUCT COKE OVEN

A Practical Method of Conserving our Coal Supply

A PAPER

BY

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THE MODERN BY-PRODUCT COKE OVEN.

By Mr. Carl A. Meissner.

In presenting a paper before this institute on the manufacture of by-product coke for metallurgical purposes, I wish to state that this is too comprehensive a subject to cover in detail within the time available at this meeting, but I will endeavor to place before you a few outlines, which I hope will prove of some value to all the varied industrial interests represented here to-day.

It is quite appropriate that this year, being the twentieth anniversary of the installation of the first by-product coke ovens in the United States, should be one in which the different technical societies have devoted a great deal of time to the subject by the presentation of a number of very valuable and interesting papers. These papers, written by practical and technical men engaged in the construction and operation of by-product coke-oven plants, have naturally covered the ground, as far as the general matters of interest are concerned, very thoroughly, and it is difficult to place before you in the outlines of this paper much of anything that is novel or that has not already been touched upon by previous writers.

The indication of keen interest in this subject, evidenced by the publication of so many papers on it within the last six months, is undoubtedly very encouraging, as this is always an outward manifestation of a desire on the part of the industrial world to know more about that particular subject.

Statistical Data.[1]

Permit me to say a few words on coal and coke statistics.

World.—The latest figures available show that the total coal production of the world in 1910 was approximately 1,277,786,160 tons, of which about 165,345,000 tons are estimated as having been used for coking purposes.

The approximate production of coke in the world in 1910 was 110,230,000 tons. This gives some idea of the magnitude of the industry, which, of course, has increased since then. Unfortunately, I have found no reliable data to show the proportion of by-product or retort and beehive coke in these world-production figures.

Germany.—The total coal production in Germany in 1911 was 258,223,763 tons. Of this amount there were used for coking approximately 38,580,500 tons, from which were produced 28,003,911 tons of coke, all in retort ovens.

Of these retort ovens, about 80 per cent were of the by-product recovery type, while 20 per cent were of the nonrecovery type. Beehive ovens were abandoned in Germany about 20 years ago as being too wasteful and the coke made in them too expensive for their coal

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[1] All tons referred to are net tons.

conditions. The German coal cost is high due to deep shaft mining, irregular and frequent thin seams, steep dip of seams, and compulsory gob filling. These conditions compelled the German manufacturers to develop the retort oven as the most economical means of coking their coal, enabled them to increase their yield of coke from coal, made available the gas evolved in the coking process, and permitted the recovery of the valuable by-products, such as ammonia, ammonium sulphate, tar, benzol, etc.

United States.—The total bituminous coal production in the United States in 1911 was 405,757,100 tons, of which 53,278,248 tons were used for manufacturing coke. The coke production in 1911 was 35,551,489 tons, of which 27,703,644 tons were made in beehive ovens and 7,847,845 tons were made in by-product ovens; 10,446,584 tons of coal were used to produce the by-product coke and 42,831,664 tons of coal were used to produce the beehive coke. From the above it will be seen that about 22 per cent of the total coke production in this country was from retort ovens as against 100 per cent in Germany.

In this connection I should like to call your attention to the fact that Germany recovered its by-products in 1911 from 80 per cent of the coke made, while the United States recovered the by-products from only 22 per cent of their coke made. The United States is therefore far behind in the conservation of its coal and its by-products as compared with Germany.

United States Steel Corporation.—The United States Steel Corporation in 1912 used a total of 40,877,862 tons of coal. For coking purposes, the Steel Corporation used 24,401,577 tons of coal. They produced a total of 16,719,387 tons of coke, of which 5,164,547 tons were made in by-product ovens and 11,554,840 tons were made in beehive ovens; therefore, about 31 per cent of their total coke production was made in by-product ovens. It required 6,624,877 tons of coal to produce the by-product coke and 17,776,700 tons of coal to produce the beehive coke.

Sulphate of ammonia production and consumption.—The following tabulations, giving the world's sulphate of ammonia production, and also some data as to sulphate of ammonia consumption in the United States, Germany, and the United Kingdom, have been taken from a pamphlet issued by the American Coal Products Co. These tables speak for themselves.

Sulphate of ammonia consumption.—The following table gives the estimated quantity of sulphate of ammonia and its equivalent in other forms of ammonia consumed in the countries specified:

[Net tons.]

Year.	United States.	Germany.	United Kingdom
1900	36,011	140,763	72,800
1901	43,756	185,186	76,492
1902	54,270	192,902	71,400
1903	58,650	190,146	80,304
1904	71,331	220,460	76,720
1905	80,584	234,790	84,000
1906	84,182	252,977	91,840
1907	132,000	264,552	98,000
1908	121,874	286,598	100,800
1909	140,192	302,030	97,440
1910	179,178	385,805	97,440
1911	230,743	407,851	98,000
1912	232,003	468,478	100,800

World's sulphate of ammonia production.

[In tons of 2,000 pounds.]

Country.	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
England	261,818	275,630	301,534	324,263	350,972	364,255	391,037	411,808	424,032	424,473
Germany	154,322	190,697	209,437	259,040	316,360	345,020	363,759	411,157	460,761	512,569
United States	41,887	54,674	65,311	74,956	99,339	87,632	106,482	115,899	127,034	200,486
France	46,296	47,398	52,138	54,122	58,091	57,980	59,083	61,728	66,138	295,460
Belgium and Holland	38,580	42,990	26,675	33,069	60,626	38,580	44,092	47,398	47,398	
Spain	....	....	11,023	11,023	13,227	....	13,227	9,920	183,532	
Italy	49,603	52,910	4,960	5,511	12,125	88,184	13,227	13,227		
Other countries	....	....	44,643	44,092	71,649	....	80,467	87,081		
Total	592,508	664,301	715,723	806,078	982,369	981,653	1,071,377	1,158,222	1,308,898	[1] 1,432,990

[1] Approximate.

United States ammonia consumption, expressed in sulphate equivalent.[1]

[In tons of 2,000 pounds.]

	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912
Imports	8,411	14,486	18,146	16,777	16,667	15,288	9,182	32,669	34,274	40,192	63,178	103,743	67,003
Total consumption	36,011	43,765	54,270	58,650	71,331	80,584	84,182	132,000	121,874	149,192	179,178	230,743	232,003
Average price	$57.40	$55.16	$59.90	$62.10	$61.71	$62.92	$62.33	$61.93	$59.90	$56.04	$55.60	$62.21	$65,95

[1] The figures for consumption and price are for the calendar year, while those for imports are for the fiscal year ending June 30.

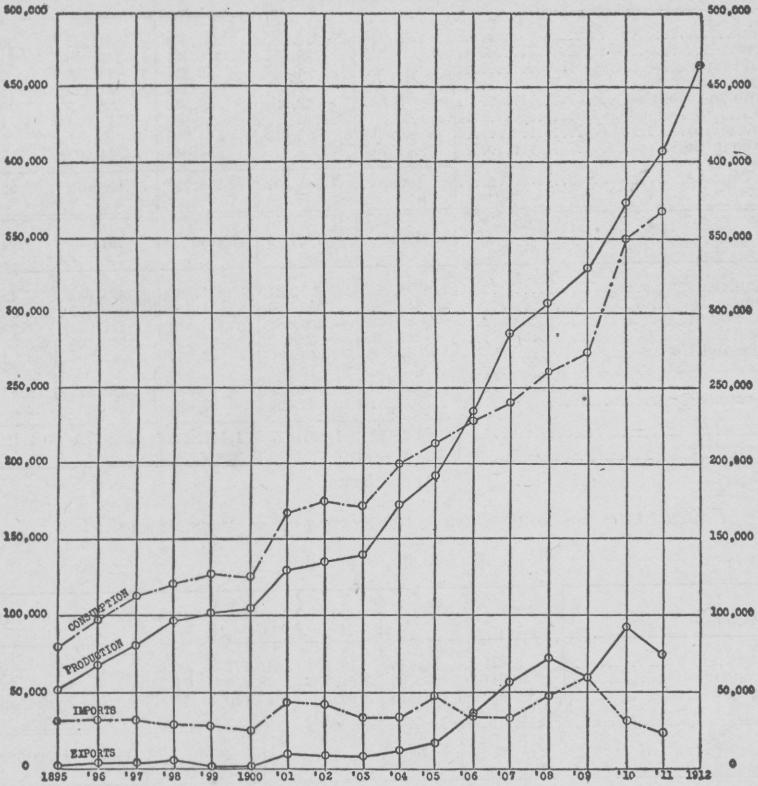
GERMANY.

PRODUCTION, CONSUMPTION, IMPORTS AND EXPORTS

OF

SULPHATE OF AMMONIA.

(IN METRIC TONS OF 2204.6 LBS.)



FERTILIZERS USED IN THE UNITED STATES IN 1910.

I wish here to insert a table, taken from the American Fertilizer Hand Book, 1912, which is of great significance as indicating what are the possibilities still ahead of us in this country in the use of fertilizers. A study of the table will show the enormous amount of fertilizer which will be required to put the consumption on a normal basis for all States.

Fertilizers used in the United States in 1910.

Name of State.	Fertilizer used.	Value of fertilizer used.	Improved farm lands.	Pounds used per acre.	Value of fertilizer per acre.
	Net tons.		*Acres.*		
Georgia	1,022,048	$16,819,000	12,264,000	167.00	[1] $1.37
South Carolina	975,039	15,130,000	6,085,000	320.00	2.49
North Carolina	630,905	12,245,000	8,800,000	143.00	1.39
Alabama	[2] 425,000	7,627,000	9,687,000	88.00	.79
New York	[2] 375,000	[1] 7,057,000	14,825,000	50.00	[1] .48
Virginia	344,951	6,925,000	9,861,000	70.00	.70
Pennsylvania	[2] 300,000	6,756,000	12,660,000	47.00	.53
Maryland	225,000	3,375,000	3,353,000	137.00	1.01
Ohio	[2] 175,000	4,163,000	19,210,000	18.00	.22
Florida	172,641	4,930,000	1,803,000	191.00	2.74
Indiana	151,856	3,695,492	16,903,000	18.00	.22
Mississippi	132,776	2,699,000	8,959,000	30.00	.30
Maine	[2] 125,000	4,063,000	2,358,000	106.00	1.72
New Jersey	125,000	4,206,000	1,800,000	139.00	2.34
Arizona	[2] 200	6,000	349,000	1.00	.01
Arkansas	[2] 25,000	596,000	8,062,000	6.00	.07
California	36,660	2,132,000	11,380,000	6.00	.19
Colorado	[2] 2,000	58,000	4,291,000	.93	.01
Connecticut	[2] 62,500	1,930,000	984,000	.12	1.96
Delaware	23,000	864,577	714,000	64.00	1.21
Idaho	[2] 700	21,000	2,773,000	.50	.008
Illinois	32,000	571,000	28,005,000	2.00	.02
Iowa	3,500	107,000	29,467,000	.24	.004
Kansas	[2] 2,400	73,000	29,858,000	.16	.002
Kentucky	58,000	1,348,000	14,334,000	8.00	.09
Louisiana	88,396	2,001,000	5,268,000	34.00	.38
Massachusetts	[2] 65,000	1,931,000	1,162,000	112.00	1.66
Michigan	40,000	936,000	12,819,000	6.00	.07
Minnesota	[2] 2,100	63,000	16,609,000	.21	.003
Missouri	31,585	662,000	24,528,000	3.00	.02
Montana	200	10,000	3,631,000	.11	.002
Nebraska	[2] 1,000	29,000	24,356,000	.08	.001
Nevada	160	8,000	745,000	.43	.01
New Hampshire	[2] 50,000	510,000	927,000	108.00	.55
New Mexico	480	24,000	1,464,000	.65	.02
North Dakota	[2] 300	9,000	20,439,000	.02	.0004
Oklahoma	8,000	26,000	17,496,000	.91	.001
Oregon	2,520	63,000	4,253,000	1.00	.02
Rhode Island	10,300	309,000	178,000	115.00	1.74
South Dakota	350	11,000	15,802,000	.04	.0006
Tennessee	58,612	1,212,000	10,875,000	11.00	.11
Texas	34,000	589,000	27,120,000	3.00	.02
Utah	[2] 380	19,000	1,357,000	.56	.01
Vermont	22,000	570,000	1,633,000	27.00	.35
West Virginia	32,500	520,000	5,482,000	12.00	.09
Washington	2,000	79,000	6,354,000	.63	.01
Wisconsin	2,500	122,000	11,882,000	.42	.01
Wyoming	[2] 100	5,000	1,256,000	.16	.004
Total	5,878,659	[1] 117,205,069	477,448,000	[3] 25.00	....

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[1] Revised.

[2] Estimated. The values and areas given are from the United States census, advance reports. The quantities of fertilizers consumed are in most cases those given by the State officials as actual figures or as estimates.

[3] Approximate.

HISTORICAL.

The earliest form of coke oven was the old mound-shaped Meiler, used primarily for charcoal, and then for coke burning.

The sides and the top of the old Meilers were made of sod, later of clay and finally developed into stone or brick side walls. Air passages were made in the early Meilers, to allow of the proper combustion of the gasses. These passages were partly vertical and partly horizontal.

As the walls became more permanent, the passages became flues, and from these were developed the two types of horizontal and vertical flue ovens, up to their present state of efficiency. The Meiler itself was developed into two distinct types of ovens—the mound or beehive and the rectangular or retort.

The following are extracts from a chronological statement made some time ago, showing the typical historical events in the development of retort coke ovens with recovery or nonrecovery of the by-products.

100 B. C.—It appears that the Chinese used coke as an article of commerce some two thousand years ago, and in the Middle Ages it was manufactured for use in the arts and for domestic purposes.

1620 A. D.—This is the earliest record that we have of coking coal in a regular oven, when a patent was granted to Sir William St. John, in England, for making coke in a beehive form of oven.

1700.—J. Becher, a German chemist, took out a patent to save tar from coking coal, and to utilize it for preserving ropes and wood.

1737.—Clayton, of England, appears to have been the first to notice that in addition to coal tar and oils, a combustible gas was formed when coking coal.

1781.—A patent was issued to the Earl of Dundonald for making coke in beehive ovens, and also for producing "tar, pitch, essential oils, volatile alkali, mineral salts, etc.," which appears to be one of the early, fairly successful attempts at saving the by-products.

1792.—William Murdoch, a Scotchman, who was a mechanical engineer, associated with James Watt in steam-engine building, is recorded as being one of the first to experiment successfully with making gas from coal, in retorts.

1812.—The streets of London were first lighted by gas, presumably an outcome of Murdoch's experiments.

1826.—We find the first definite records of beehive coke being manufactured in England on a fairly large scale for metallurgical purposes.

1830.—The first records of the rectangular, or retort, oven are found in Germany, having open walls, forming a rectangular space which contained the charge. The walls were pierced by horizontal and vertical flues.

1834.—The first gas from retorts in the United States was made, together with gas coke, and William Firmstone, in 1835, made good gray forge iron at the Mary Ann Furnace, in Huntington County, Pa., from Broad Top coal.

1841.—The first Connellsville coke ovens are said to have been erected and the coke shipped to Cincinnati, Ohio, by water.

1857.—In this year Appolt built his first ovens in the shape of vertical and later horizontal retorts. He utilized his gas only for heating his oven through horizontal flues. He represents practically the first type of closed retort coke oven, utilizing the gas for its own heating.

1861.—Coppee built the first of his Belgian type of ovens, and was the first to demand the use of crushed coal.

1893.—The first battery of Semet-Solvay ovens was built at Syracuse, N. Y.

1895.—The first battery of Otto-Hoffman ovens was built at Johnstown, Pa.

After 1895 progress in the construction of by-product coke ovens in the United States was somewhat slow. The constructive difficulties of a by-product plant were many in the earlier days, and the successful mechanical and chemical features in so complicated a system had to be worked out by careful study and experience. The subject was somewhat tempting to many engineers and inventors, and, particularly in Europe, a great variety of systems was proposed. Many were tried out and failed, so that it was naturally difficult for the American engineer to decide what system to adopt without running too great a risk in subsequent operation of the ovens.

Gradually, as the European types were developed, minor types were eliminated more or less and the Europeans settled down to practically three or four standard types, which were the Otto-Hoffman, Koppers, Collin, and Coppee. The Semet-Solvay Co. had, however, consistently been faithful to their early type of horizontal flue ovens, and by constant study and experiment finally developed their present six-flue high regenerative oven.

ADVANTAGES OF BY-PRODUCT COKE OVENS OVER BEEHIVE COKE OVENS.

The great advantage which the by-product coke oven has over the beehive oven lies in a number of factors:

1. The by-product coke plant can be constructed at or near the blast furnaces which are to consume its coke, and thus be under the same management.
2. It is practicable to ship to it coking coals from any section within a radius of a favorable freight rate.
3. Many coals not suitable for coking in beehive ovens become available for by-product ovens by mixing with other coals and are so used to make a first-class blast furnace coke.
4. Coking coals in by-product ovens permit of the full recovery and use of the very valuable by-products and the gas.
5. The cost of making by-product coke at the iron and steel works is considerably less than the cost of making beehive coke at the coal mines and transporting the coke to blast furnaces, especially when located some distance away from the beehive districts.
6. The profits thus obtained give a substantial return on the investment in by-product coke plants, large though such investment may at first appear.

In fact, the by-product coke oven is changing the economic geography of the available coal fields for coking purposes in the United States.

This is not the case with the beehive ovens, which in most cases are placed near the coal mine that supplies their coal, and when the mine is exhausted the beehive plant has to be abandoned. Many coals from large fields will not coke at all or only partially in beehive ovens, and the recovery of by-products from beehive ovens, while frequently attempted, has almost invariably proved to be an economic failure.

It is true that in Germany a number of by-product coke oven plants are built at the collieries and ship the coke to blast furnace plants, but conditions are somewhat different over there, and many of the large steel works are located at or near the collieries and thus are able to utilize more directly the surplus gas produced in the by-product oven.

COSTS, BEEHIVE VERSUS BY-PRODUCT COKE OVENS.

A great deal has been said about the comparative cost of by-product coke ovens versus beehive coke ovens. We have studied this very carefully and find that this is dependent entirely on the location of the beehive-oven plant and the attendant conditions of such a location. Comparing, for instance, a by-product plant at Gary, Ind., with a beehive plant in the Pocahontas (W. Va.) region, both on a large scale, and taking into consideration the mine investment, houses required for workmen, and everything connected with the construction ready for operation of either type, we find that the beehive oven installation complete costs more than the by-product oven installation complete for the same number of tons coke produced per year. Comparing the above by-product plant with a similar beehive oven installation in the Connellsville regions, where all conditions are more favorable and where the difference in the yield of coke from coal coked in the beehive oven and in the by-product oven is very materially less than it is in the Pocahontas region, we find that the cost of a beehive oven installation complete is considerably less than the cost of a by-product coke oven installation complete per ton coke produced per year.

A feature of supreme importance in the use of the by-product oven is the greater coke yield obtained in this type than in the beehive oven from the same coals. This amounts to about 23 per cent to 25 per cent in the low volatile coals, such as Pocahontas, and from 5 per cent to 12 per cent in the high volatile coals, dependent on their original content of volatile matter. This subject is not fully understood and generally appreciated and yet is of vast importance in the conservation of our coal fields. A concrete example will be of interest:

	Pocahontas coal coked in—	
	Beehive coke oven plant.	By-product coke oven plant.
Number of ovens	6,154	560
Coking time ....hours	72	17½
Yield of coal to coke ....per cent	60	82
Net tons of coal required to produce 2,880,000 tons coke per year	4,800,000	3,512,000
Net tons of coal saved per year by use of by-product coke ovens for above coke production	....	1,288,000

This amount of coal saved, if it were coked in by-product ovens, would produce about 1,000,000 tons of coke per year. What this means in coal conservation is so plain that no further comment is necessary.

COAL DATA.

Mixture of high and low volatile coals.—As to the use of high or low volatile coals, alone or in mixture, for the purpose of making a good blast-furnace coke, our experience has been varied. We started at Joliet making coke out of 60 per cent high volatile and 40 per cent low volatile coals, finally settling on 20 per cent high volatile and 80 per cent low volatile coals. Neither mixture gave us any trouble in the coke ovens, but the 80 per cent low volatile mixture gave us a better furnace coke. Later, however, when we understood the operation of the ovens more thoroughly and our oven organization had been taught to do better teamwork, we found that we could make a first-class furnace coke out of 40 per cent high volatile and 60 per cent low volatile coals.

At the Farrell, Pa , by-product plant we are using successfully 60 per cent of high volatile and 40 per cent of low volatile coals. At our Birmingham, Ala , by-product plant we are using a mixture of medium coals, averaging about 29 per cent in volatile matter.

At Wheeling, W. Va., the Semet-Solvay ovens are making coke for the Riverside furnaces of the National Tube Co. out of 80 per cent high volatile Connellsville coal and 20 per cent low volatile coal, averaging 32 per cent in volatile matter.

At the Zenith furnace, at Duluth, I have seen some very fair looking coke made out of 100 per cent Pittsburgh seam screened coal, averaging 36 per cent in volatile matter. This was used in a small furnace and it might be a question as to how such coke would work in a large furnace.

You can, therefore, see that it is not safe to lay down any hard and fast rule as to whether the by-product coke oven demands high or low volatile coal, nor are there any definite proportions that determine the value of the quality of the coke. It is a question of cutting and trying and above all of having uniform and good coke oven operations and adapting the furnace practice to these conditions. Eternal vigilance and the least possible variation in the operations is the sine qua non of successful by-product coke oven operation.

Weathering of coal.—There is another factor which though not yet fully understood, affects the quality of the coke quite materially, and that is the deterioration in the coking quality of the coal from weathering. We have found that some of our coals, especially the low volatile ones, when exposed to the weather in large stock piles for a certain period of time will heat and the resultant coke will be rough and almost furry in appearance and seriously affect the furnace practice. This appears to be the case to a much less degree in some high volatile coals. In fact, I have been told at Duluth that the Pittsburgh seam slack, when not crushed too fine, will show but very slight effects of weathering after having lain all winter in the stock pile.

Coal crushing.—The process of preparing the coal for coking, so as to get the best quality of coke, involves, in the first place, proper crushing, and, if several varieties are used, proper mixing. As a rule we find that fine crushing, say to 85 per cent of the coal to go through a ⅛-inch screen, is advisable. The crushing has the effect of breaking up the particles of slate so that they will be intimately mixed with the coal and therefore distribute themselves evenly through the cellular structure of the coke, while any larger pieces of slate in the coke always break the bond of the cellular structure and give more chance for the undue breakage of the coke into small pieces. Besides, I think there is a tendency toward a slight fusion effect of the finer crushed ash material in the cellular structure, which may have a tendency to strengthen it somewhat.

Coal washing.—The washing of coal for the manufacture of by-product coke is frequently a necessity with some of our American coals. In Germany washing of coal for coking purposes is almost universal, if not entirely so. At most of the plants in that country the run-of-mine coal is classified, and the screenings are washed for coke-oven purposes. They, however, as a rule do not have much sulphur to contend with in their coals, which is a very different proposition from some of our American coals.

At Johnstown, Pa., almost from the beginning of operations the coal has been washed to reduce the ash and also sulphur, which latter, however, is not so excessive. The Tennessee Coal, Iron & Railroad Co. also wash practically all their coals for coking purposes, ash reduction being the prime factor there. The Illinois coals also require washing, and, in fact, much of the Illinois coals for steam and general purposes are rough washed, the coal being crushed to about 1 inch in size for washing.

The washing at Johnstown is done in bumping table washers, while in Alabama and for the Illinois coals the jig washers will find more favor. We will probably use a coarse and fine jig and have been experimenting with a wet classifier for the very fine coal, or "fines," as it is called. At the same time experiments are being made with dry cleaning of coal, but the results on this are still somewhat variable, though I strongly approve of studying out the possibilities of dry cleaning by means of air pressure or exhaust, as this presents many advantages over the wet washing, if the former can be made a practical and economical success.

That many of the coals will be greatly improved by washing or dry cleaning is unquestionable. Even a comparatively low-ash coal will, through carelessness in mining or irregularity of coal seam, occasionally run high in ash and possibly sulphur, and washing or dry cleaning will remove such irregularities, giving a more uniform quality of coke and a better furnace practice.

To show that the washing of coal is not a new or unknown feature in the United States, it may be of interest to state that 21 per cent of all the coal used for coking in the United States is washed. In Alabama the greater part of coal for coking purposes is washed.

Coal drying.—One of the great objections to washing coal at the mines lies in the fact that the present methods of drying the coal demand very large and expensive storage bins, and even then are not very satisfactory, as the coal will still contain a fairly large percentage of moisture. This increases the freight haulage cost from the mine to the coke ovens and in winter can become very objectionable through freezing of the coal, requiring expensive and costly thawing-out installations. Even where the washing is done at the plant the amount of water still contained in the coal after coming from the drying bins makes the crushing and mixing more difficult, and the charging of very wet coal is detrimental to the oven walls, in all probability also increasing the coking time.

Numerous experiments have been made to dry the coal mechanically and continuously, especially by centrifugal methods, and we believe that we have been able to work out a method at the Joliet plant, which promises success, by continuously drying the washed coal down to 5 to 6 per cent moisture. This is a matter of interest to all coal washeries and further experimentation on this subject will be carried on, as it might be a determining factor in arriving at a decision whether to wash the coal at the mines or at the coke plant.

Quality of By-Product Coke for Blast-Furnace Use and Effect of Operation on Quality

We have found in our practical experience that when made right, from many suitable coal mixtures, widely varying in volatile contents, by-product coke will give results in the blast furnace equal in every respect to the best of beehive coke. This, in my opinion, is unqualifiedly correct. It is further true that such by-product coke is preferable to beehive coke when the latter has been shipped from different coking operations and thus made from different coals, because the by-product coke when made from the same coal mixture is more uniform chemically and physically. I could point to some very unsatisfactory experiences where 15 or more different kinds of coal were shipped to the by-product coke ovens, the resultant coke being very irregular both in analysis and physical quality. I emphasize "when made right" in referring to the quality of the by-product coke, for upon this depends its value.

The type of oven is not of such prime importance in this respect as the proper operation of the oven and the uniformity of its coal mixture. There are now five or six types of by-product ovens in operation, all of which are good. Some are more simple in construction and operation than others, but all are capable of making a good coke from similar coals if properly operated. That is the crux, and I want to call your particular attention to this.

The by-product oven being a more delicate and complicated apparatus than the beehive oven naturally requires more care and attention. The coking time must be brought to the lowest practical point. This must be determined by experience. It must then be held there as closely as possible. The pushing must be regular; the temperatures of flues—and hence of ovens—must be held to conform to the coking time and be kept uniform. Overcoking is fatal to good coke, tending to make a friable and small coke. Further, the pressure exerted in pushing over-coked coke always tends to produce a larger percentage of small coke than when pushing a normally coked oven. Under-coking is bad, though, in my opinion, perhaps slightly less so than over-coking, tending to the production of lumpy coke, black soft ends, and a softer cellular structure throughout. Increasing the coking time beyond what it should be has always given us bad results when tried.

Our experience so far indicates that when it becomes necessary to curtail the production of coke it is distinctly more profitable to suspend operations on one battery of a plant, keeping it heated with gas, and that the only time we are justified in prolonging the coking time is because of a temporary coal shortage likely to last but a short time. The experience at the Joliet ovens, where we have suspended operations on one battery a number of times, fully justifies the statement that it is preferable to do this than to prolong the coking time, which will then deteriorate all of the coke produced.

The uniformity of the coal mixture has a very important bearing on the quality of the coke. Each coal has its own individual characteristics in affecting the quality of the coke. In the case of some coals this difference is slight and negligible; in the case of most coals, it is marked and distinctive and has probably not been as fully understood or realized as it should be and will be in the future.

A tabulation showing what we consider good physical tests for a standard quality of blast furnace coke may here be of interest:

Mixture.	Shatter test.		Specific gravity.		Porosity or percentage of cell space.
	Through 2-inch screen.	On 2-inch screen.	Apparent.	True.	
80 per cent Pocahontas 20 per cent Ronco	15.16	84.84	0.976	1.841	47.03
80 per cent Pocahontas 20 per cent Rend, 1 Ills	16.11	83.89	.950	1.824	47.92
60 per cent Pocahontas 40 per cent Ronco	14.06	85.94	.992	1.834	46.31

Constructive Features of By-Product Coke Ovens.

Brick. As to the constructive features of a by-product coke oven, there is not time to go into this in great detail, so I will confine myself to some general facts. When the coke committee was discussing the construction of the Joliet ovens, they realized the importance of a shorter coking time than that of the German ovens, which then had a coking time of about 28 to 34 hours, and this brought up the question of the brick to be used. We required a strong brick that would stand the abrasion, the high temperature and permit of a rapid transmission of heat into the coal body from the flues through the oven walls.

The brick very largely used in Germany was a quartzite. Experiments with silica brick had meanwhile been made by the Semet-Solvay Co. and also by the Cambria Iron Co. After quite an exhaustive study of this subject, the coke committee recommended at Joliet, Ill., constructing No. 1 battery of silica brick, the raw material for same being obtained from the Baraboo district of Wisconsin; No. 2 battery of a St. Louis quartzite brick, the raw material being composed of Missouri clays, and Nos. 3 and 4 batteries of German quartzite brick obtained from Arloff, Germany.

Following are the average analyses of these different kinds of brick:

Sample.	Date.	Loss on ignition.	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O
Silica	Apr. 4, 1908	0.02	94.06	0.87	2.23	2.52	0.15	0.15
St. Louis quartzite	Apr. 5, 1908	.12	79.29	2.26	16.66	.49	.36	.82
German quartzite	Mar. 3, 1908	.11	83.15	1.57	13.19	.37	.34	1.17

No. 1 battery, the oven walls and flues of which consist of silica brick, has always been the best battery in the matter of heat regulation and operation, owing to the ability of the silica brick to transmit the heat better than the quartzite brick. We believe the battery whose oven walls are constructed of silica brick will outlast the batteries whose oven walls are constructed of quartzite brick, both American and German. We have not yet had to reline any of the ovens constructed of silica brick, while we have spent a certain amount of money repairing the ovens constructed of the German and American quartzite brick. The indications also are that we use considerable less gas to get the same coking time with the silica brick than we do with the quartzite brick.

We do not find much difference in the operation of the ovens constructed of American and German quartzite brick.

After the construction of the Joliet plant, the consensus of opinion of the coke committee was that all future plants should be built with silica brick, that is, the oven and flue walls, due care being taken to arrange for the necessary expansion.

Regenerators.—Regenerative ovens are more advantageous for installation at steel works, as a larger supply of surplus gas is available through regeneration than through recuperation, and this surplus gas is a very valuable asset to the steel plant. Later on I will give some further data as to the use and value of this surplus gas.

Whether to place the regenerators under each oven or longitudinally along the whole battery has been a subject of considerable discussion. I have seen many ovens of the latter type which have given uniform combustion temperatures; but, on the whole, I prefer the type having the regenerators under each oven, as I think it is easier to control the temperatures in such regenerators. Also, in a battery of ovens of this type, operations are not liable to be influenced by the action of any oven either not operating properly or shut down for repairs or other reasons.

Flues.—As to vertical or horizontal flue systems, both are in operation in this country. The horizontal flue system ovens are doing very good work and have, in my opinion, a merit of simplicity, and as far as I have been able to observe, the combustion of gas and air in them has been controlled just as completely as in the vertical flue ovens, so that just as uniform temperatures can be attained in either system.

The combustion in, as well as the accessibility to, the vertical flue ovens seems to me to be more easily and better controlled in those types whose flues open to the top of the oven than in those whose flues are only accessible from below or entirely closed in, and the great objection to many of these latter types is that if anything goes wrong at any time with any flue, it is almost impossible to remedy this without stopping the oven and tearing out some of the brickwork, while this is not necessary in types that open to the top of the oven, or in the horizontal type. It is just in this respect that many of the newer and some of the older types of ovens fail to appeal to me, because their system of combustion and carrying off of waste gases is too complicated and too inaccessible.

It is sometimes claimed for these types that they will give a more perfect combustion by this method; in fact, the laudable effort on the part of the engineers studying this problem is toward perfection of combustion. On the other hand, from a practical viewpoint, I fail to see why there should not be obtainable in the standard vertical flue types or in the horizontal type of oven a very perfect combustion and temperature regulation of flues and oven walls. I do not see the necessity for extreme refinement and complication when the simpler form can, to my mind, be made to accomplish what is required.

A feature to be studied and watched very carefully is the construction of the flue walls in such a manner that leakage or short circuiting of air and products of combustion from one flue to the other can not take place. This is usually caused at the very beginning when the oven is heated up and expands, and any flue system that is complicated and has more than the absolutely necessary passages upward or alongside the oven walls subjects itself to danger from this source. It is for this reason that it is always a dangerous experiment to construct any large number of ovens without having first experimented in a practical way with a certain type on a fairly large scale, or to construct an oven from paper; that is, from drawings without previous practical experimentation and covering a sufficient period of time.

Air ports and draft.—A very important matter to be kept in mind is the area of the air ports and flues in which the combustion takes place, as upon it will largely depend the coking time. For a short coking time plenty of area is required to enable the operator to burn sufficient gas to give him the temperatures he desires. The earlier construction rather erred in this, with the result that frequently there is not quite sufficient draft to give the necessary rapid combustion for high heat. While this can be corrected through increased stack draft or induced draft, yet for new construction it is a problem worthy of very careful study. In my opinion there should be one draft stack to every battery of coke ovens with sufficiently large flue area to take care of atmospheric or other fluctuations.

Taper of coke ovens.—It has been found that a taper of about 4 inches in the width of the oven from the pushing end to the discharging end is of great importance, especially where swelling coals are used, but even where this is not the case a taper is always of advantage, as thereby less resistance is offered by the walls of the oven to the movement of the coke. After the first effort of putting the coke mass into motion the pushing is made easier, less small coke is produced, and the walls of the oven are conserved. Practically all the different coke-oven systems now have arranged their heating flues in such a manner that the necessary amount of heat penetrates into the coal mass at the wide end of the oven in the same time as it does in the narrow end.

Width of oven and coking time.—The question of the width of oven is a very important one, and to my mind it has by no means been determined that the width of oven now generally adopted—namely, an average of about 19 inches—is the limit to which we can go and produce satisfactory coke within a reasonable coking time. In modern systems, the heating arrangement is so flexible that with a wider oven sufficient increased heating can be applied to attain a similar coking time to that in the narrower oven. As a matter of fact, we built our early ovens for a 24-hour coking time after considerable discussion on this very subject of width of oven in connection with coking time. On the same width of oven we reduced this coking time down to 16.5 or 17 hours. At the Birmingham, Ala., ovens the taper was decreased, causing an average increase in width of three-fourths of an inch more than in the Gary, Ind., ovens. This was for a high volatile coal mixture compared to the Gary, Ind., mixture, and yet the coking time at Birmingham is down to 17.2 hours and will undoubtedly be still further reduced. The coke ovens at Farrell, Pa., with a width of 17 inches and no taper, have a coking time of 20 hours. The Riverside coke ovens, with a 17-inch width, are running on a 20-hour coking time.

The same applies to the use of high volatile coal. It has been claimed that with high volatile coal the coking time would be materially increased; in fact, that the coking time increased in proportion to the width of oven and the higher volatile matter contained in the coal mixture.

I think we are demonstrating to-day that with mixtures of 20 per cent, 40 per cent, 60 per cent, 80 per cent, and 100 per cent of more or less high volatile coals we are having practically the same coking time, providing the conditions of heating the oven are sufficiently taken care of to accomplish this.

We have changed our coal mixture at the Joliet and Gary, Ind., plants from 20 per cent to 40 per cent high volatile coal without any practical change in the coking time. There is no question that we will reach a limit when, with the best of heating arrangements and burning of ample gas, we will arrive at a point where the coking time will become directly proportionate to the width of the ovens. The same may become true of the larger admixture of high volatile coals.

This whole subject of increased width, height, and length is of great importance in determining the ultimate capacity of by-product coke ovens, so far as the daily output of a given plant is concerned, as the greater this output is the more economical the operation would become, though great care has to be exercised not to exceed whatever may be the ultimate limits of size. At present we do not know what these are. I do not think, though, that we should stand still in our efforts to determine same.

Coke-oven doors.—Another problem that we have all been working on for some time is coke-oven doors. The by-product oven ought to have a self-sealing door. The present system of clay-luting the doors is expensive as far as labor and material is concerned; it takes considerable time, and if not done properly causes leakages through variations in pressure which burn up part of the coke and deteriorate the by-product and the gas.

A self-sealing door that is simple, strong, easily adjusted and taken care of and not subject to warping, is a prime necessity. Quite a few attempts have been made in this direction—some of them fairly successful—but we do not consider that any of them are quite satisfactory as yet.

General.—There are many other practical matters that I could discuss which are of interest, such as position of foul gas main, charging of coal, etc., all of which require careful consideration and are liable to affect the quality of the coke, but time is lacking for these to-day, so I merely call attention to them.

Coke-oven batteries.—The extent of the expansion of a whole battery of ovens and its various directions are now pretty well understood, and practically all the different systems successfully use every proper precaution for taking care of same. In the earlier days this question of expansion frequently caused trouble. As to the number of ovens that can be included in a battery, this is practically a matter of choice and local conditions. We have in most of our plants 70 ovens to a battery, but are building one battery of 92 ovens, and in Germany there is one battery of 120 ovens. As long as expansion has been properly taken care of between individual ovens no danger should result to a whole battery, regardless of the number of ovens in it. I would, however, hardly think it suitable for our operating conditions to have more than 100 ovens in a battery.

Coke Quenching and Screening.

One of the serious problems that confronts by-product coke-oven operators is the proper method of quenching and screening the coke, especially on a large scale, when but six minutes are allowed between the time of pushing one oven and the next oven to be served by the same screening station, as in a large plant like Gary, Ind.

At Joliet we have the quenching bench directly in front of the oven. A certain amount of water is sprayed over the coke as it is being pushed out of the oven and the mass of coke then, after steaming, is watched to note any appearance of red-hot coke, which can be quickly quenched by hand with a small hose. This method of quenching permits of three or four charges lying in front of the battery, gives time enough to quench without soaking the coke, and insures a very reasonable and low uniformity in moisture. An objection to this system is the heavy mass of steam formed directly in front of the oven while the coke is being quenched and is steaming off.

At most of the other plants in the country various types of quenching cars are used, into which the coke is pushed and then conveyed by motor or locomotive to a quenching station, where water is sprayed over it. After that, different plants handle this coke in different ways. At some plants the quenching is still done in front of the oven in the car. This is very objectionable. Most plants have a separate quenching station away from the ovens. In some the coke is held on these quenching cars long enough to steam off and any small pieces of red-hot coke are quenched by hand with a small hose.

At other plants the coke is partially quenched in the car and run on to inclined platforms or pockets where it is again hand quenched before sliding it into elevators or belts, which convey it to the screening station.

To hold coke on quenching cars is expensive, as it means an extra supply of these rather costly cars, and is hardly practicable for a large plant. The system installed at Joliet, on the whole, has worked out very well; but the system adopted at Farrell, of pockets with inclined sides from which the coke is dropped on a belt, seems to me to be very efficient and very simple. As these pockets can be made long enough and their inclined sides wide enough to hold a number of charges of coke, it gives the coke sufficient time to be properly quenched and steamed off.

At Duluth a different system will be tried out—having the quenching platform away from the end of the ovens, so that the coke can be quenched preliminarily in the car, then dropped on this platform away from the ovens and the quenching process finished there.

At one plant the coke is partially quenched on the car, then raised to a wide inclined screen, upon which it rests sufficiently long to steam off and be hand quenched with a small hose before it is dropped over the screen into the railroad car. This is as yet experimental, but looks very promising.

Where the coke has to be completely quenched directly on the car and the car supply is inadequate, the coke has to be practically drowned or saturated with moisture. This not only fills the pores of the coke, but, in my opinion, also tends to crack it into small pieces and is very detrimental. The resultant coke will always be very high in moisture.

Methods in operation in Europe of quenching the coke in ladles or pans by practically steaming it, while undoubtedly capable of producing good results are, in my opinion, hardly applicable to operating conditions in this country, unless materially modified to meet the same.

The coke after being quenched is then raised to the screens, either by means of large hoists or belt conveyors. We have had some very good results by using a belt conveyor. If proper precautions are taken in the quenching of the coke, a belt will last a long time. The belt method of elevation permits of a more even distribution of the coke onto the screen than when the whole mass is precipitated out of the large bucket. Of course, a plant has to be laid out for this purpose.

The proper screening of the coke I consider an absolute necessity, whether this be done on an inclined plate screen or in a rotary screen, and good screening can only be accomplished by the coke being fed gradually onto the inclined screen, or if a rotary screen is used, having same long enough to distribute the mass of coke as it falls into it. Too long a rotary screen is apt to grind the coke at its lower end more than is perhaps necessary, while too short a rotary screen will not permit of the mass of coke, even when coming from a belt, to separate properly, unless the belt feed is made slow enough to prevent any large accumulation of coke on the screen.

At some plants the coke is not screened at all at the coke plant, but is carried direct to the blast-furnace coke bins and screened as it drops out of the bins. As a rule this has not been satisfactory, because the mass of coke in the bins is too large and the passage over the screens too swift to permit the fine particles to drop through the screens. It may be that sufficient screening can be arranged in this way, but that is to my mind subject to demonstration. A good deal of the success in screening also depends on the dryness of the coke, as the fine particles of dust will cling to a wet coke very persistently and can not be shaken off.

There is still some difference of opinion among blast-furnace men as to the detrimental effect of coke breeze. To my mind there is no question but that the more free from breeze the coke goes into the blast furnace, especially under our present furnace-operating conditions with high percentages of Mesabi ores, the better the results obtained will be. At one plant an experiment was made using unscreened coke in the blast furnaces, which resulted in a material increase of the blast pressure, the furnaces refused to drive, and the coke consumption was increased. Of course, in considering the thoroughness of screening it is necessary to also consider what can be done with the coke breeze and coke dust, where it can be utilized, and what its market value will be. At most of our plants the coke dust is used in making bottoms in soaking pits and other similar places, and in some districts the coke breeze commands a fair market as domestic coke. The experience that we have had with a special grate system has been very satisfactory for the burning of coke dust up to one-fourth inch in size.

The screened coke, varying with the handling it receives, is apt to be somewhat irregular in size and experiments are now being made to determine whether it would be advisable to crush the oversize coke, say over 4 inches, to practically 4-inch coke and less, and thus obtain better results in the blast furnace. There is a large variance of opinion on this subject. Many of the furnacemen, accustomed to the use of beehive coke in rather large pieces, find it hard to accommodate themselves to the idea that furnace coke should be small, but the physical structure of beehive coke and by-product coke is so different that the experience of those who have so far studied this matter closely inclines one very strongly to the advisability of a uniform, fairly small coke with our present furnace-burden mixture. By-product coke is denser in cellular structure than the average beehive coke, and, burning more slowly, the exposure of a large number of surfaces accelerates combustion in the hearth. Besides, it seems that with the large amount of fine ore now used a more even distribution of the fuel in the burden as it descends in the blast furnace must be of advantage. If it is finally determined that a smaller and more uniform size of coke is advisable, it is not a difficult matter to arrange for the oversize coke to be screened out in the first screening, crushed, and rescreened before delivery to the blast-furnace bins.

Blast-furnace coke bins.—I wish to add a word as to the coke bins at the blast furnaces. The ideal blast-furnace coke bin is one which has no angles flatter than the angle of natural repose of coke and coke dust, and which therefore allows no dead material to accumulate and lie inert on the bottom and in corners of pockets. In other words, the bin should be so constructed that all of the coke moves downward toward the chutes every time the coke is drawn, so that if any coke dust is present a regular proportion of it will be contained in every skip of coke drawn. A coke chute located directly over the skip is, of course, preferable to a row of pockets in that it saves the labor of hauling coke in the larry cars from the bins to the skip.

VARIOUS TYPES OF BY-PRODUCT COKE OVENS.

Referring to the many types of retort coke ovens that are in the market, it will probably be of interest if I add some illustrations of these coke-oven systems that are of particular interest at this time, together with a short description of each system.

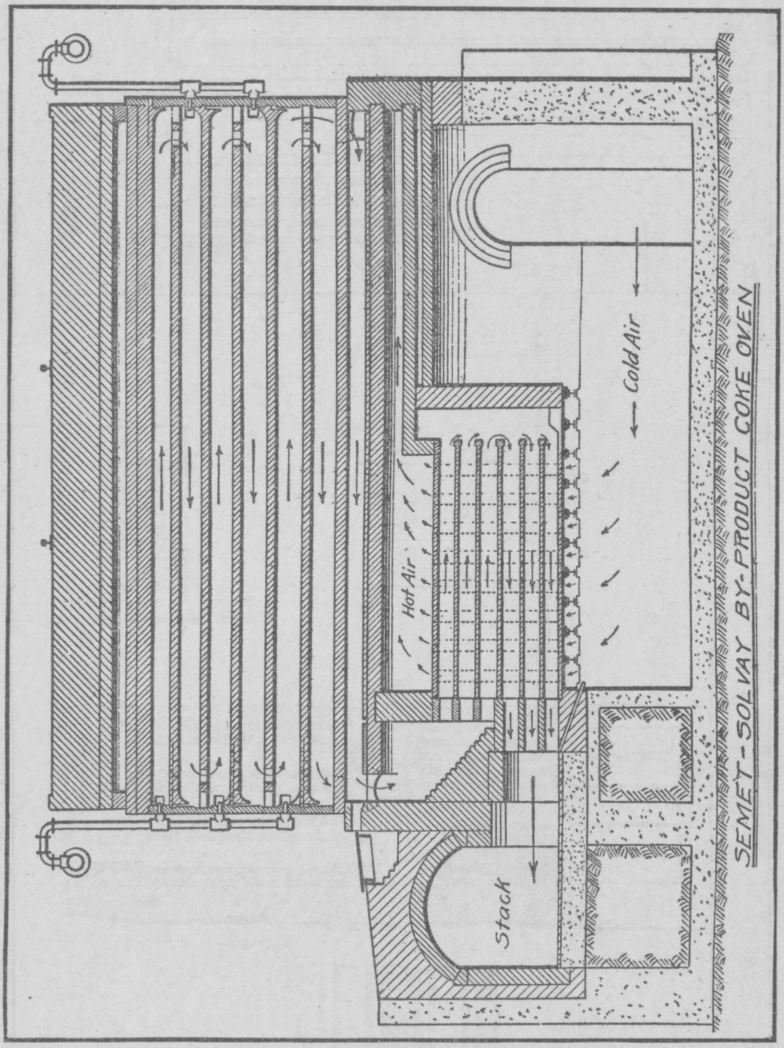
SEMET-SOLVAY RECUPERATIVE RETORT COKE OVEN.

This oven, until very recently, has been entirely nonregenerative, but recuperative, and heating is performed in horizontal flues instead of in vertical flues. The most modern plant in this country is of the 6-flue type, which is the result of gradual evolution from the original 3-flue oven.

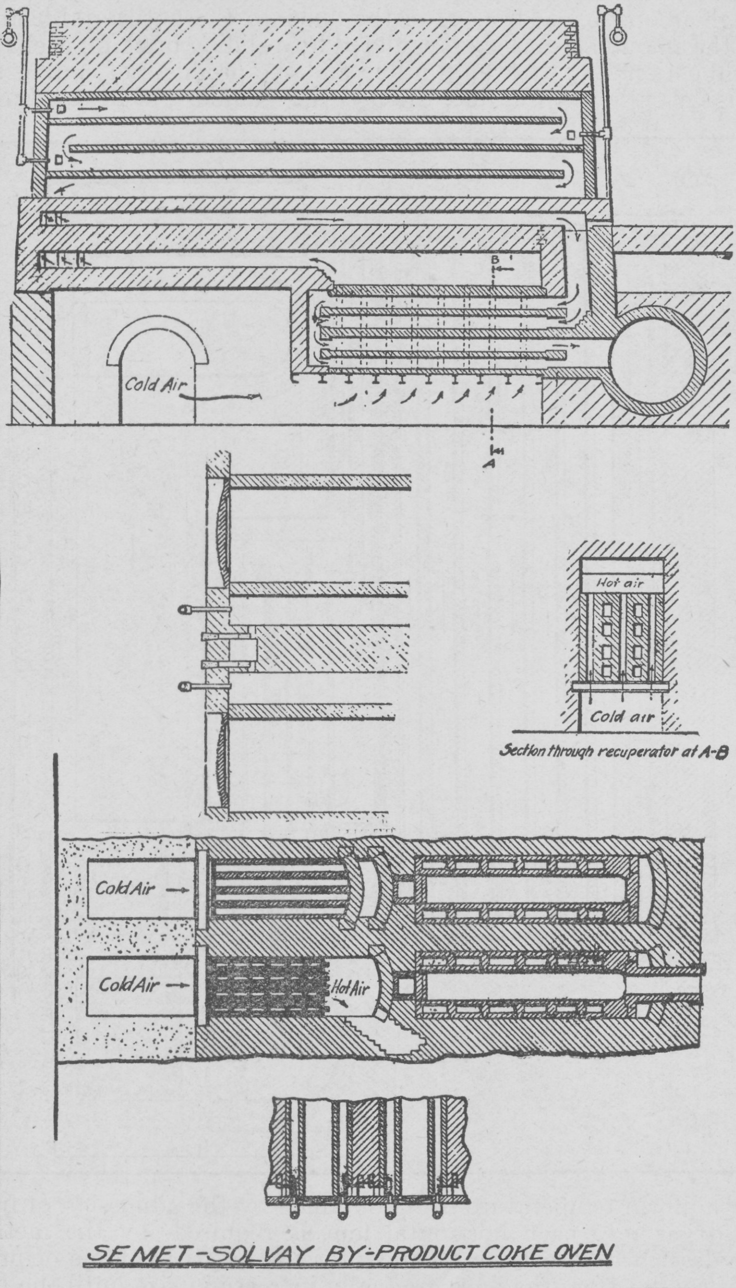
Gas for combustion is supplied to each horizontal flue from a burner pipe entering at the end of the flue.

The air for combustion of the gas is drawn by stack draft through the recuperators into risers at the ends of the oven, whence it passes through an opening at the end of the flue into the horizontal heating flues, the amount of air being regulated by a sliding brick for each flue.

Combustion starts in the top flue and the products of combustion traverse each horizontal flue, the necessary amount of heat to maintain a uniform temperature being obtained by the admission of fresh air and gas into each horizontal flue as required, by the method above described. In order to allow for the greater volume of products of combustion, the flues gradually increase in size until the bottom flue is reached; this is reduced in size, as only a portion of the products of combustion pass through the bottom flue.



SEMET-SOLVAY BY-PRODUCT COKE OVEN



Section through recuperator at A-B

SEMET-SOLVAY BY-PRODUCT COKE OVEN

The products of combustion pass out into the recuperators, partly from the bottom flue and partly from a sole flue located beneath the oven, the amount to pass through each of these being regulated by a sliding brick.

A feature which adds to the strength of the Semet-Solvay oven is an 18-inch division wall between the ovens. This allows the operation of an adjoining oven while an oven is being repaired.

The earlier type of Semet-Solvay ovens had no taper, while in the later types sufficient taper to meet the requirements of the coal used is employed. This taper is accomplished by tapering the central division wall.

SEMET-SOLVAY REGENERATIVE RETORT COKE OVEN.

One of the more recent developments of the Semet-Solvay type is the regenerative ovens. The design has been worked out so that the construction is very simple. A pair of regenerators are located beneath each oven, with the chimney flues between them. The reversal of the gases takes place throughout the entire system of regenerators and horizontal flues, so that during one period of reversal the gases flow upward through the flues and during the other period downward. The gas is supplied continuously and is reversed automatically by the gas currents without any attention by the operator.

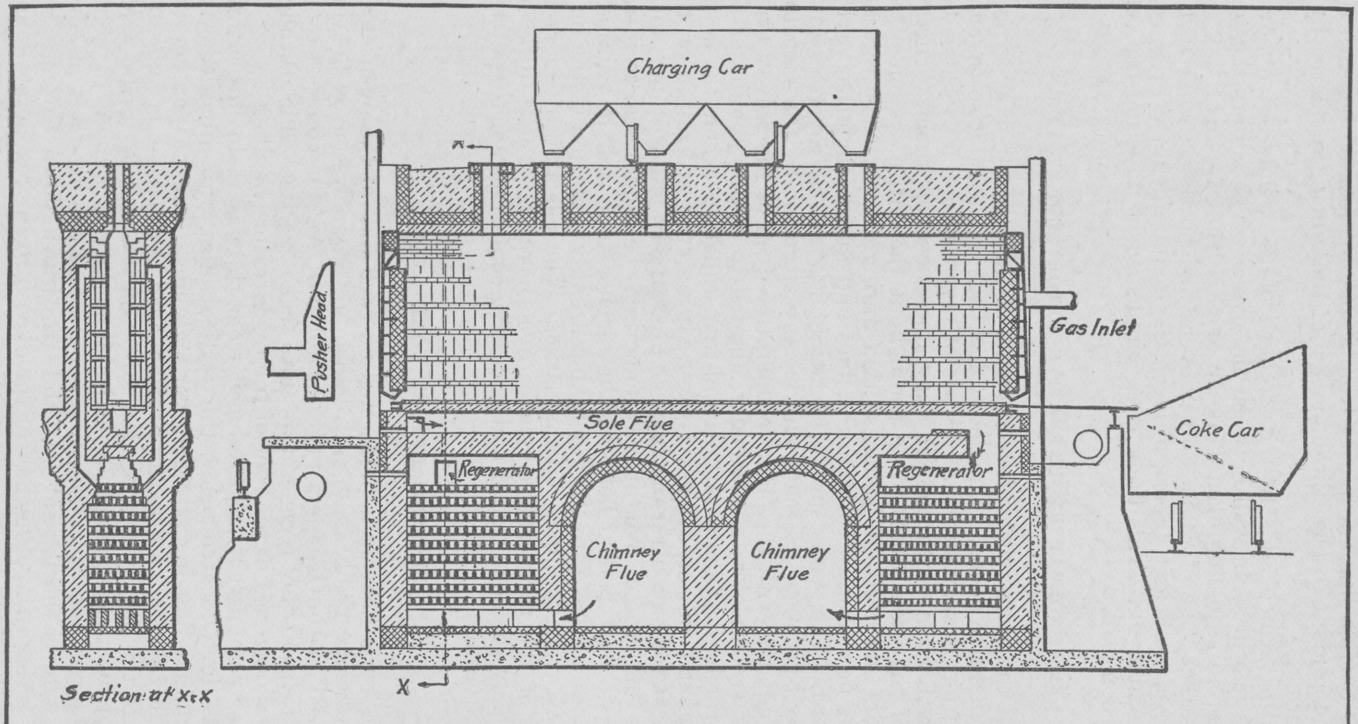
As compared with the older recuperative oven of the Solvay type, the regenerative oven is especially adapted to coking conditions requiring the highest temperatures and to installations where the maximum amount of surplus gas is desired, and the utilization of the waste heat for steam raising is of comparatively minor importance. Even in this type of oven it may sometimes be economical to introduce waste heat boilers between the regenerators and the chimney, because the air has capacity for taking up only a portion of the heat delivered by the products of combustion. The selection of the recuperative or the regenerative type of oven has in each case to be determined by the commercial and operative conditions existing at the plant in question.

KOPPERS RETORT COKE OVEN.

In this type heating is performed on each half of the oven alternately, reversal being made each half hour. One system of heating is followed in the Koppers type, as follows: Air for combustion is delivered from the regenerators into each vertical flue through individual openings in the roof of the regenerator chamber.

Gas for combustion is introduced from the gas main into a firebrick gas duct, located below the vertical flues, and provided with an individual opening to each vertical flue. The gas enters the vertical flue through a fire-clay nozzle placed in the gas-duct opening, the size of the nozzle opening depending on its location in the oven.

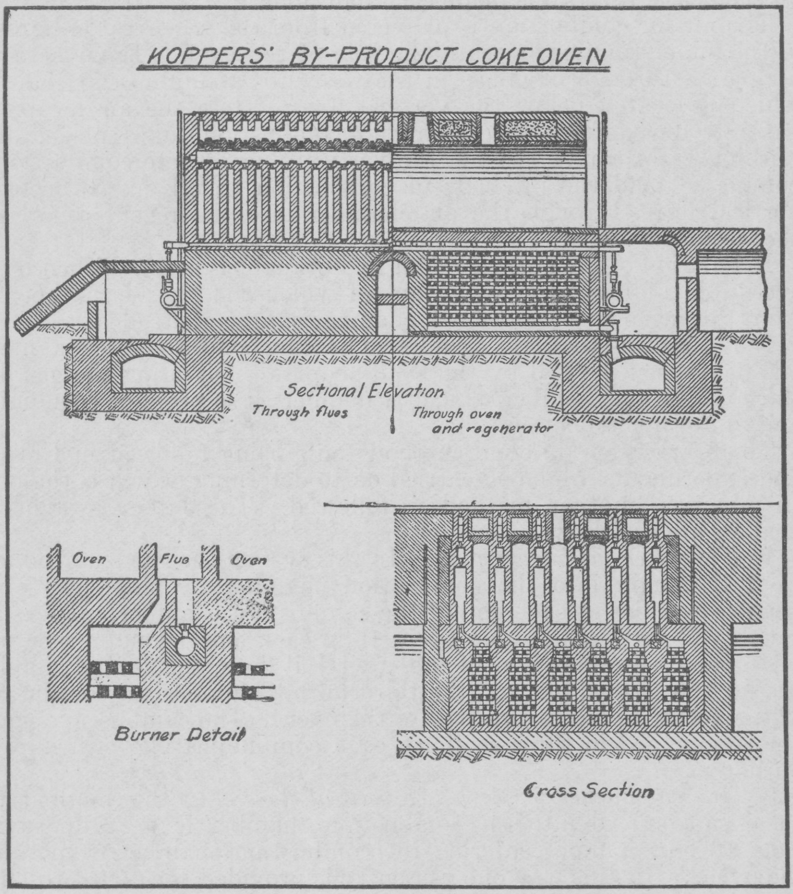
The air meets the gas in the vertical flue at a point about 10 inches above the gas nozzle, combustion occurs, and the products of combustion enter a horizontal flue and are drawn down through the vertical flues on the other half of the oven into the regenerators and thence to the stack.



SEMET SOLVAY REGENERATIVE RETORT COKE OVEN

Individual regulation of the draft is accomplished by means of a sliding brick in each vertical flue, which controls the size of the opening into the horizontal flue. This is to overcome the tendency of the gases to take the shortest route to the chimney, which would result in the center flues taking away the bulk of the hot gases and, therefore, causing unequal heat.

Access to this sliding brick is afforded by an opening to each vertical flue from the top of the oven, this opening normally being closed by a plug. This inspection hole also allows access to the nozzle in case it is desired to change same.



Regulation by means of a sliding valve is provided for the air supply for each individual oven, and the sliding brick before referred to provides individual regulation of the air supply to each vertical flue during the period of combustion.

Regenerators in the later Koppers installations are individual for each oven.

RETORT COKE OVENS OF THE OTTO SYSTEM.

In two of the four types of Otto ovens described below, heating is performed on each half of the oven alternately; the products of combustion pass down the vertical flues of the other half of the oven. In the other two types of Otto ovens the oven is divided into four sections. The products of combustion formed in simultaneously heating, for instance, the first and third sections pass down the vertical flues of the second and fourth section respectively. In each case, reversal is made each half hour.

The air for combustion is delivered from the regenerators into an air chamber running beneath the sole of the oven. From here the air passes through openings in the wall into a combustion chamber which is located below the vertical flues. Here the air meets the gas introduced from the main and combustion takes place. The burning gases travel through the vertical flues, where combustion is completed, and the products of combustion travel down the other vertical flues, through the air chamber into the regenerators, and thence to the stack.

Regulation of the amount of air and draught is accomplished by an accessible sliding brick, by means of which the size of the opening from the regenerator to the air chamber can be controlled.

In attempting to arrive at uniform heating conditions several methods have been devised by the Otto people of delivering the gas into the combustion chamber in such a manner as to produce economical and uniform combustion.

There are three different methods now being followed in Europe, and experiments are being carried on to determine which is the best. In America another method is followed. These four systems of heating are as follows:

1. *Three tier gas-burner plan.*—In this system the gas is introduced from the main into the combustion chamber by three gas pipes located in a tier at each end of the combustion chamber. There are usually 32 vertical flues per oven, 16 in each half. One burner supplies gas for the first four of these vertical flues, the second supplies gas for the second six, and the third burner supplies gas for the rest of the vertical flues in this half of the oven. The combustion chamber is arranged in three sections, each communicating with its own burner.

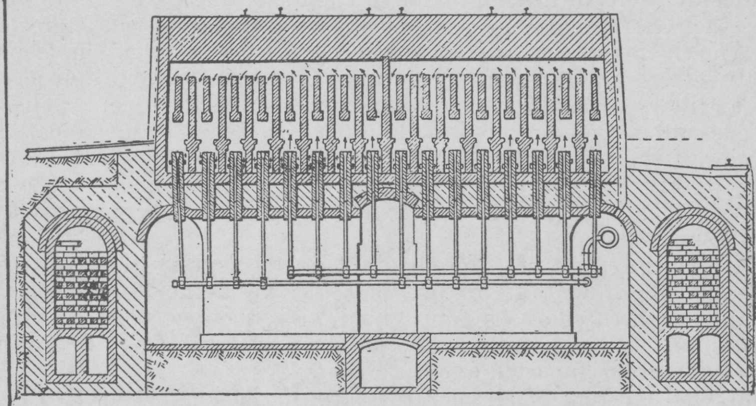
2. *One gas burner for each two vertical flues.*—In this method the gas is introduced into the combustion chamber in a 32 flue oven, from 16 burner pipes entering the combustion chamber from below the ovens. In this way one gas entry is provided for each two flues.

The heating operation is conducted as follows: Supposing the gas burners are numbered from 1 to 16. During one-half hour, gas enters the combustion chamber from burners 1 to 4 and 9 to 12, and the products of combustion travel through the vertical flues supplied from burners 5 to 8 and 13 to 16, respectively. The next half hour this process is reversed, and so on.

In this method the travel of the off-heat gases appears to be under better control than in the former method of heating, on account of not having to travel so far. In other words, the off-heat is withdrawn from each quarter of the oven instead of from each half.

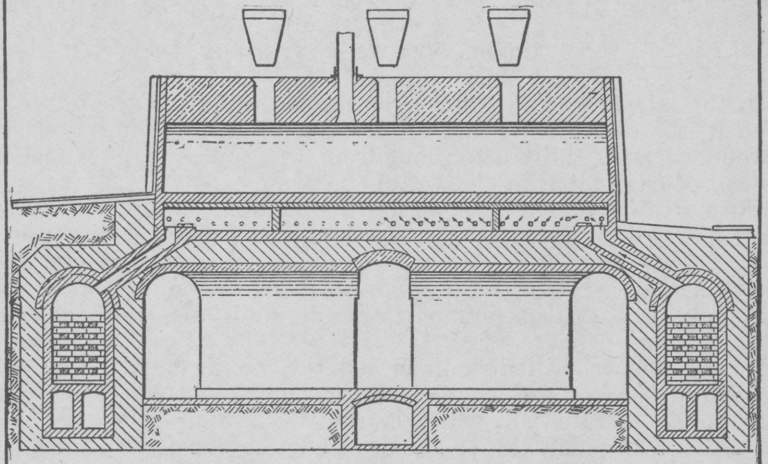
OTTO BY-PRODUCT COKE OVEN

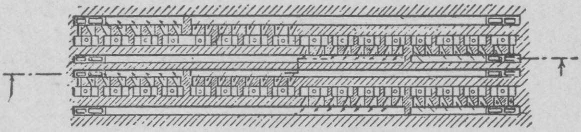
One burner for each two vertical flues



OTTO BY-PRODUCT COKE OVEN

One burner for each two vertical flues





Section through gas and air flues

3. *One gas burner for each vertical flue.*—This is the latest method and has not been exhaustively tried out as yet. Theoretically the results ought to be better than the other methods described.

The products of combustion are withdrawn similarly to the scheme described under head of "One gas burner for each two vertical flues."

4. *American system of end burner and under burners.*—After using various methods of heating, none of them, so far as known, following any exact German methods but always comprising some modification, the American representatives of the Otto type of ovens have practically settled on a system of heating, employing one end burner and two auxiliary or under burners for each half of the oven. That is, the gas enters the combustion chamber through a burner located at the end of the oven wall, and any further gas supply which may, in the judgment of the heater, be required, is furnished by the two under burners, which deliver gas into the combustion chamber from the alleyways below.

An essential point of difference in the American system is the fact that only one downtake for products of combustion to the regenerators for each three ovens is provided, and vice versa one air intake. In Germany, special stress is laid on the necessity of having an individual downtake for each oven.

The Otto system of regenerators are of the long type, two being provided, running the entire length of the battery.

The sketch on page 39 shows the heating system using one gas burner for each two vertical flues. This method probably gives the best results. Other methods can be followed from this sketch.

COLLIN RETORT COKE OVEN.

In the latest type of Collin oven no reversal from one half of the oven to the other half occurs, gas for combustion being alternately introduced from the bottom and from the top of the vertical flues instead of from alternate halves of the oven.

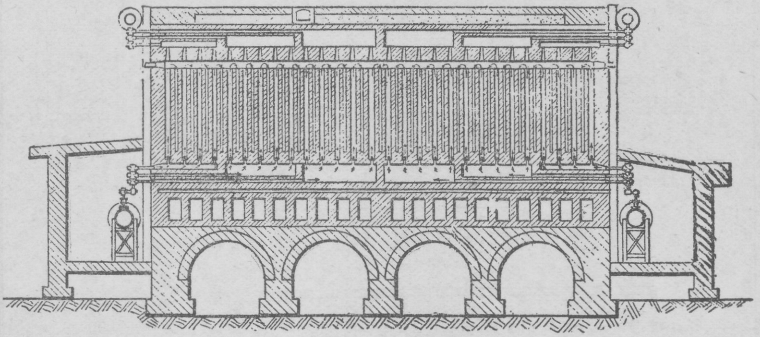
During the first half-hour period the gas for combustion comes in contact with the regenerated air for combustion on entering the bottom of each main vertical flue (of which there are 28 per oven). After burning upward, the products of combustion descend through a second set of 28 flues immediately adjoining and enter into a sole flue.

During the second half-hour period the gas for combustion enters the top of each of the 28 main vertical flues and comes in contact with the regenerated air, which issues from the top of the 28 smaller flues, through which the products of combustion flowed during the first half-hour period. Combustion occurs downward through the main vertical flues, the products passing into the sole flue.

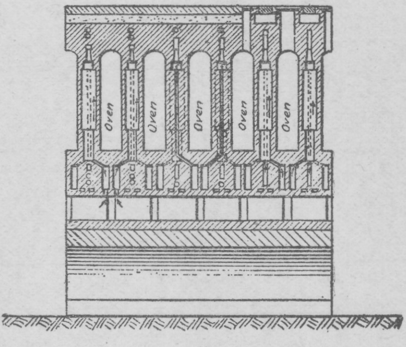
The products of combustion pass from the sole flue into a series of rectangular brick passages located beneath the entire battery of ovens and running at right angles to the oven chambers. This series is divided into two sections, one of which receives the products of combustion for each half-hour's heating. These two sets of firebrick passages lead into two regenerators located between the ovens and the draft stack.

The gas for combustion is introduced by the tier system of end burners, there being four for each end at the bottom of the oven in the latest systems and two for each end at the top of the oven.

One of the four bottom burners is reserved for the end or outside flue alone, and the others each supply the gas requirements of four to five vertical flues.



COLLIN BY-PRODUCT COKE OVEN

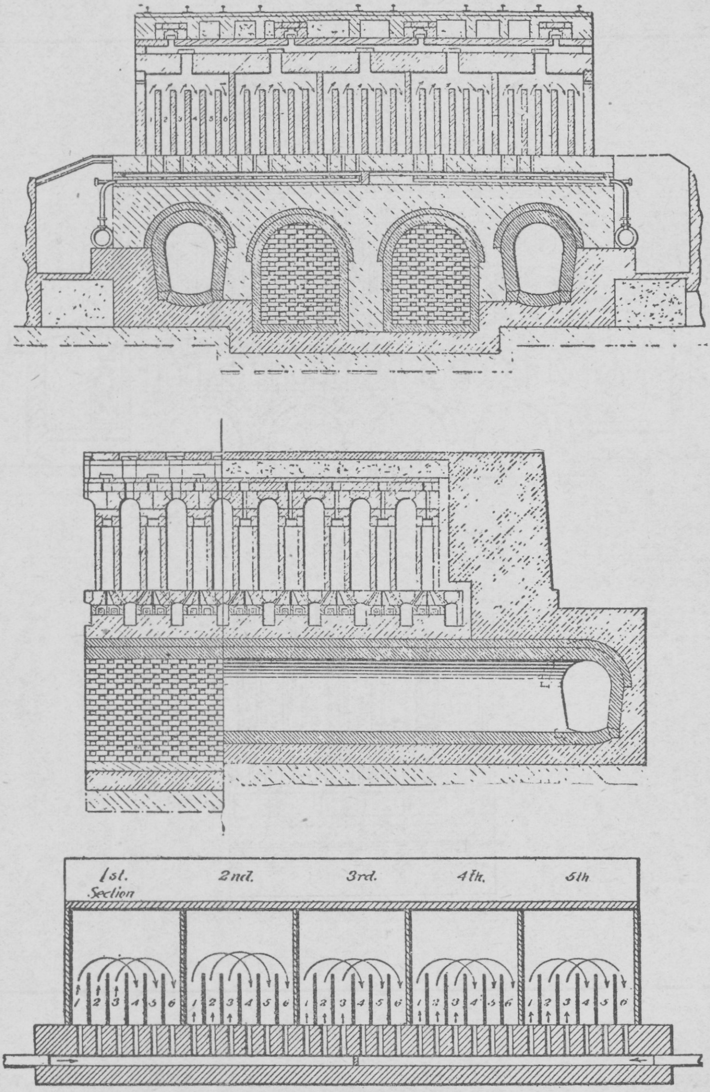


COPPEE RETORT COKE OVEN.

In the latest type of Coppee regenerative ovens the side wall is composed of 30 vertical flues, divided into 5 groups of 6 flues, each group forming 1 combustion chamber.

Under each side wall of the oven are four gas-distributing flues, two at the front end of the oven and two at the back, and gas for combustion is supplied through these alternately each half hour; that is, one at the front and one at the back are on gas one-half hour and the

COPPEE BY-PRODUCT COKE OVEN



ARRANGEMENT OF FLUES IN COPPEE COKE OVEN other one at the front and back are on gas the next half hour, and so on.

Supposing the vertical flues are numbered from 1 to 30, the first group would comprise flues 1 to 6. During one-half hour gas for combustion would be delivered from one front duct to flues 1 to 3, combustion would there occur, and the products of combustion pass through flues 4, 5, and 6. Simultaneously gas would be delivered to flues 7, 8, and 9; 13, 14, and 15; 19, 20, and 21, etc.

During the next half hour gas would be delivered from the other front duct to flues 4, 5, and 6, and the products of combustion pass through flues 1, 2, and 3. Simultaneously gas would be delivered to flues 10, 11, and 12; 16, 17, and 18, etc.

Products of combustion pass into a sole flue, thence into a collecting main running the length of the battery, and thence into the regenerators en route to the draft stack.

There are two regenerators running the entire length of battery, and while one is preheating the air for combustion in one period the other is being heated by the products of combustion.

The regenerated air for combustion traverses the system in the opposite direction to the travel of the products of combustion, finally passing from the sole flue through oblique openings into the base of the vertical flues, where it comes in contact with the gas and combustion occurs.

STILL RETORT COKE OVEN.

This is a vertical flue oven, and is built in two types, viz, off-heat type, with no by-product recovery, and regenerative type with by-product recovery.

The regenerators are common to all the ovens in a battery, and extend the length of the battery on each side. The Still Company state that separate regenerators can be used.

The vertical flues are not accessible from the top. The Still Company state that top inspection can be arranged for.

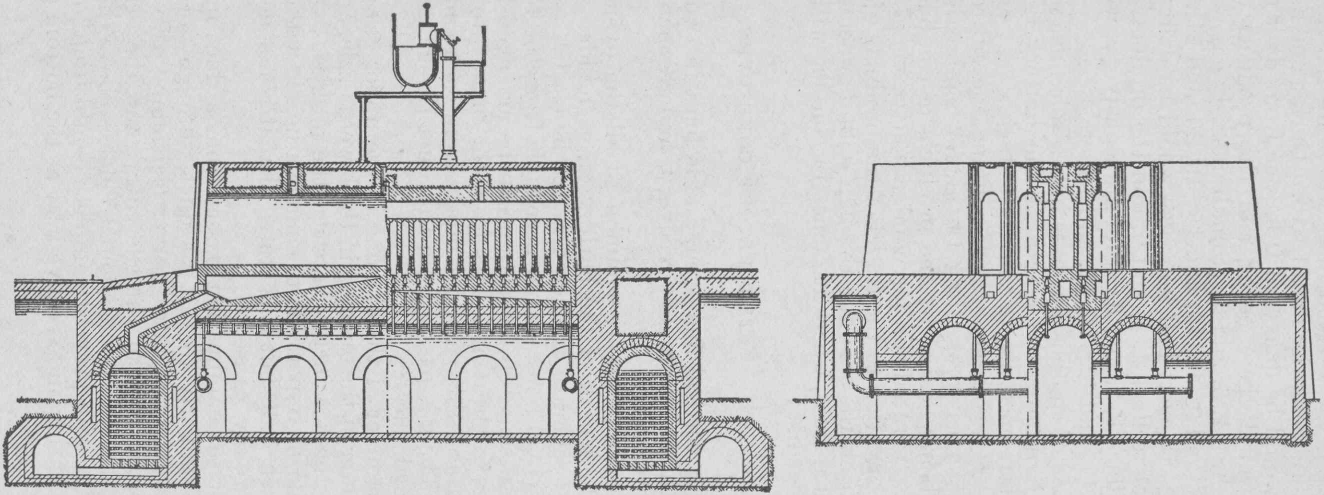
The gas for heating passes from the main into a gas duct beneath the oven, and this gas duct tapers from each end of the oven to the center. The gas passes from this duct through a double nozzle into the vertical flues.

The diameter of the opening in the upper gas nozzle is about half the diameter of the opening in the lower nozzle, and there is a vertical space of about 4 inches between the nozzles.

It would be impossible to change a nozzle without tearing out part of the oven wall, but it is stated that it is not necessary to change a nozzle for any cause.

The air for combustion passes from a duct underneath the oven tapering similarly to the gas duct, through ports into the vertical flue; it is delivered into the vertical flue at two points, one located at about the level of the gas entry, and the other, by means of a slotted brick, at a point about 15 inches above the other entry. The idea of this is to prevent complete combustion low down in the flue, thus preventing an excessive heat at the bottom of the oven.

STILL REGENERATIVE BY-PRODUCT COKE OVEN.



OTHER TYPES OF COKE OVENS.

There are other systems which we have been or are studying, most of which are not in extensive operation as yet, and I will, therefore, not take up your time to describe them in this paper.

Up to the present time, all retort coke ovens have been of the horizontal type, but the late Dr. F. Schniewind, whose loss is keenly felt by all interested in coke manufacture because of his long connection with and his intimate knowledge of all matters pertaining thereto, advised me a short time before his death that he was trying to develop a vertical coke oven, believing that it would have many advantages over the horizontal type of oven now in existence. Considerable experimenting in this direction has been done abroad.

TABULATION OF BY-PRODUCT COKE OVEN PLANTS IN THE UNITED STATES AND CANADA.

Following is a table showing the location and number of ovens installed in this country and Canada by the three principal coke-oven builders, namely, the Semet-Solvay, Koppers, and Otto-Hoffman. This list is not indicative of the capacities of the plants, some being old and the ovens of smaller capacity than the latest installations:

Semet-Solvay.		Koppers.		Otto-Hoffman.	
Location.	Number of ovens.	Location.	Number of ovens.	Location.	Number of ovens.
Syracuse, N. Y	40	Joliet, Ill	280	Johnstown, Pa	372
Dunbar, Pa	110	Gary, Ind	560	Glassport, Pa	120
Ensley, Ala	240	Corey, Ala	280	Everett, Mass	400
Benwood, W. Va	120	Woodward, Ala	60	Sydney, C. B	520
Detroit, Mich	175	Joliet, Ill	35	Hamilton, Ohio	100
Chester, Pa	40	Sault Ste. Marie, Ont	110	Lebanon, Pa	232
Tuscaloosa, Ala	60			Buffalo, N. Y	188
Milwaukee, Wis	160	Total in operation	1,325	Camden, N. J	150
Lebanon, Pa	90			Sparrows Point, Md	200
Geneva, N. Y	46	In construction:		Wyandotte, Mich	30
Cleveland, Ohio	100	Duluth, Minn	92	Farrell, Pa	212
South Chicago, Ill	280	Woodward, Ala	80	Indianapolis, Ind	100
Steelton, Pa	120	Sparrows Point, Md	6	Duluth, Minn	50
Waukegan, Ill	13	Indiana Harbor, Ind	66		
Ashland, Ky	54	Youngstown, Ohio	68		
Indianapolis, Ind	41	St. Louis, Mo	56		
		Total in construction	368		
Total	1,689	Grand total	1,693	Total	2,674

BY-PRODUCT RECOVERY OPERATION AND APPARATUS.

GENERAL.

I have so far discussed only the retort oven itself and the process of coking. I would now like to call your attention to the various methods in use for the recovery of the by-products from the gases evolved in the coking process, namely, gas, ammonia, sulphate of ammonia, and tar as well as benzol. This again is a very broad subject, and I will try to confine myself as closely as possible to the points of main interest.

Briefly, the gas as it leaves the ovens through the foul gas main, located above the ovens, is taken over to the by-product plant in large mains and ordinarily is there cooled, the tar extracted, naphthalene thrown down as far as possible, the ammonia is scrubbed out of the gas by passing it through water towers or other apparatus, weak ammonia liquor is distilled, the ammonia passed into lead-lined saturators containing sulphuric acid and sulphate of ammonia is formed, or the distilled ammonia is placed in tanks and shipped as strong ammonia liquor. This is an outline of the old indirect process.

In the direct recovery process the scrubbing of ammonia from the gases is avoided by passing the gases through the saturator after the tar separation has been accomplished. In some of the so-called direct processes the tar is separated by cooling the gases and in this case a certain proportion of the ammonia is precipitated with the tar and must be distilled. In some of the direct processes the tar is separated without precipitation of the ammonia salts. These latter processes are, therefore, more preferably called direct than the processes where some of the ammonia is precipitated, which should more properly be called semidirect.

There is also another process in which the sulphur contained in the gases is utilized, generally referred to as the "thio-sulphate process," of which I will give you later a brief but more detailed description.

We have, therefore, at present really four processes that are largely used all over the world for recovering by-products—namely, the indirect, the semidirect, the direct, and the thio-sulphate.

The effect of the coking time upon the recovery of by-products, particularly ammonia, is a subject that has not been fully worked out. Apparently the longer coking time increases the percentage of recovery of ammonia and the losses in ammonia become greater as we decrease the coking time up to a certain point. I doubt whether this point can at the present time be definitely settled upon, because there are other reasons for ammonia losses than the coking time itself. We have generally felt that with a short coking time we do not get as much of the total available ammonia as at plants having a longer coking time.

I understand that in Germany they recover up to 95 per cent of the total ammonia available in the coal, and on this subject I should be glad to hear the experience of some of our friends in the by-product business in this country and in Europe. A factor that assists the Germans is that their coal is almost invariably washed and, therefore, contains a certain amount of moisture, which is effective in obtaining a larger percentage of the available ammonia.

So far as our experience has gone, we seem to have no material difference in our recovery percentage when running between 16½ and 20 hour coking time. We have practically no experience over any period of time on 24-hour coking time, excepting at Farrell, but there the conditions are to my mind not of such a nature as to be quite comparable to our conditions at the other plants. This subject is undergoing careful study at all our plants.

The same applies more or less to the question of whether a hot top of the oven is more likely to increase the loss of recoverable ammonia than a cooler top. The general impression so far has been that the cooler top is the better in this respect. Points like these have to be carefully balanced, because from them arises the question of what is more economical to produce, a good blast furnace coke or a larger by-product recovery. The object of the Steel Corporation has always been, and I think rightly so, to make a good furnace coke and then to recover as much of the by-products as is consistent with this. The money loss through inferior coke and its detrimental effect on blast-furnace practice soon offsets any slight gain through increased ammonia yield at the coke oven.

I believe you will be interested at this time in a few illustrations and a short description of the different by-product apparatus for extracting the tar, ammonia, and benzol from the gas, which latter is then returned to the ovens for heating or carried off as surplus gas to the steel plant or other places where it is to be used.

THE INDIRECT PROCESS FOR RECOVERY OF AMMONIA.

In the indirect process the gas coming from the ovens is air and water cooled to allow the deposition of tar and combined ammonia liquor, and is then passed through scrubbers where the free ammonia contained in the gas is washed out by means of water. This weak ammonia water, together with the ammonia liquor separated from the tar, is then treated with steam and milk of lime in a still, and the ammonia vapors either passed into an acid saturator or else condensed into a strong ammonia liquor, depending on whether it is desired to produce sulphate or liquor.

KOPPERS SEMIDIRECT SULPHATE PROCESS.

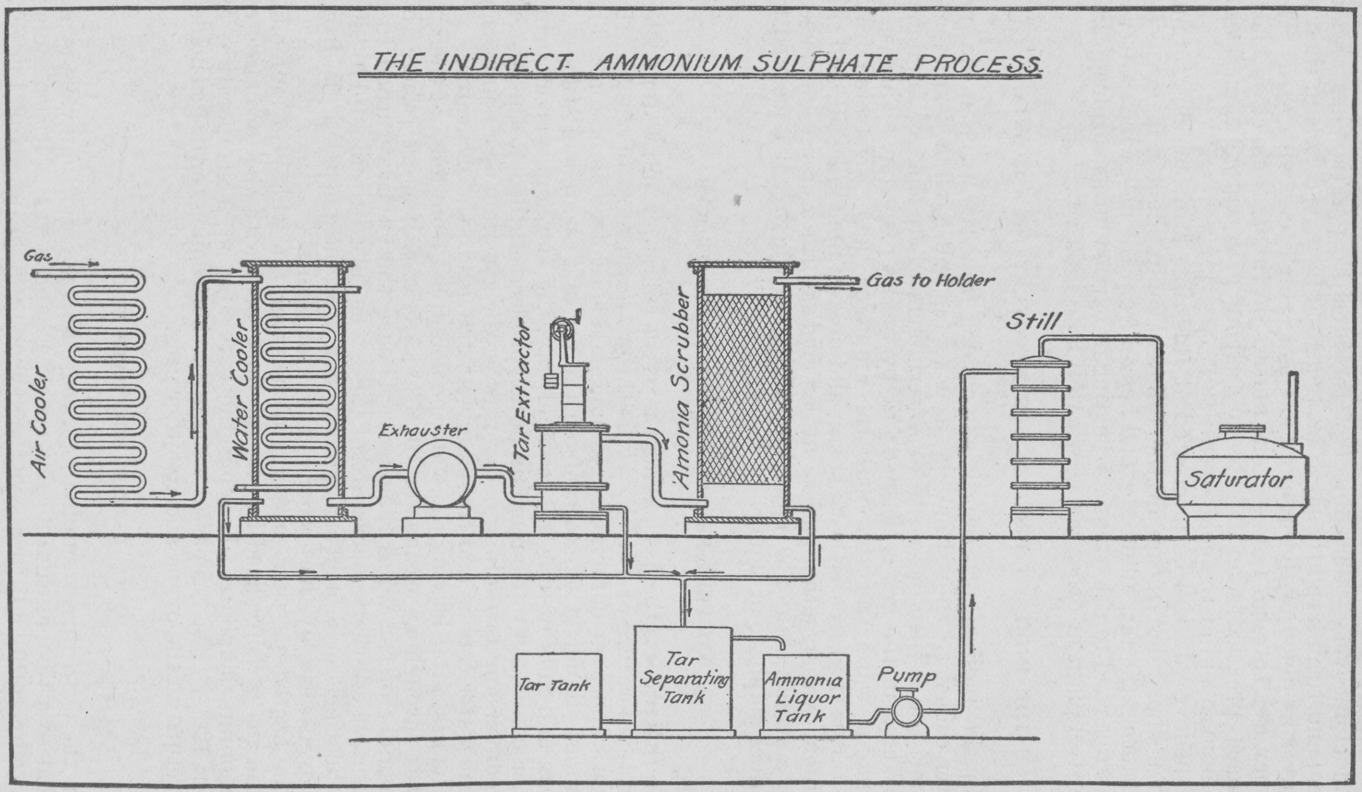
In this process the gas leaving the ovens is first air and water cooled to a temperature of 104° F. This throws down most of the tar, the water vapor, the combined ammonia, and some free ammonia. The ammonia liquor is separated from the tar and treated in stills with steam and milk of lime in the usual way, the ammonia vapors being either converted into ammonia liquor or else returned to the system for conversion into sulphate by entering the gas main at a point prior to the water coolers and traveling with the gas to the saturator.

The gas, after leaving the water coolers freed from most of the tar, passes through an exhauster to P. & A. tar extractors, where the remainder of the tar is removed. Thence the gas is returned to a heater, where the temperature of the gas is raised to about 176° F., the heating medium being exhaust steam or the uncooled gas from the ovens, usually the former in the later plants.

The heated gas then passes into the saturator, where the ammonia in the gas is neutralized by the sulphuric acid with the formation of ammonium sulphate. Leaving the saturator at a temperature of about 120° F., the gas passes without further cooling to the gas holder for return to the ovens and its other uses.

OTTO DIRECT SULPHATE PROCESS.

In the Otto direct sulphate process the gas from the ovens is air cooled to a temperature of about 200° F. and is then further cooled to a temperature a little above the dew point of steam, about 160° F., by means of a tar spray.



THE INDIRECT AMMONIUM SULPHATE PROCESS.

The object of cooling to about the dew point is in order to prevent the deposition of ammonia liquor, which would occur if cooled to a lower temperature, and thus necessitate the use of stills as in the other processes. By keeping the temperature a little above the dew point this ammonia remains as vapor in the gas. Experience has shown, however, that some ammonia is invariably thrown down with the tar.

The spraying with tar is performed by Körting injectors in a two-compartment tar tank in series, so the gas is twice sprayed. The temperature of the spraying tar is kept at the right degree by means of water-cooling pipes in the tank.

The surplus tar washed out of the gas overflows into a regular separating tank, where the ammonia liquor which has come down with the tar is removed. The amount of this liquor is small.

The tar-washed gas then passes through a stationary bell similar in function to a P. & A. tar extractor, where the last of the tar is supposed to be removed, but on account of the high temperature of the gas some tar continues to remain therein.

The gas then passes through a covered gas main to the saturators, where neutralization of the ammonia occurs with the formation of ammonium sulphate, which is ejected and dried in the usual way.

On account of the imperfect separation of the tar from the gases, some tar is always deposited in the saturators; therefore it is equipped with a lead dam and siphon to allow the top portion of the mother liquor to be withdrawn into an open-top tank in which the tar is skimmed off and the mother liquor returned to the saturator.

On account of the gas entering the saturator being fairly well saturated with water vapor, which, if deposited here would weaken the acid bath and prevent proper absorption of the ammonia, the saturators are equipped with steam coils made of lead, and the bath is kept heated by means of steam to a temperature high enough to insure the retention of the water vapor in the gas.

The ammonia liquor separated from the tar is heated by steam coils in a small tank and is then introduced direct into the saturator.

After leaving the saturators the gas enters a tank containing brick baffles to allow separation of the acid, and thence to horizontal tubular water coolers, where the gas is cooled, to separate the water and as much naphthalene as possible. At some places a further naphthalene extractor is being installed.

After leaving here, the gas is drawn through an exhauster and pumped to the gas holder, ovens, etc.

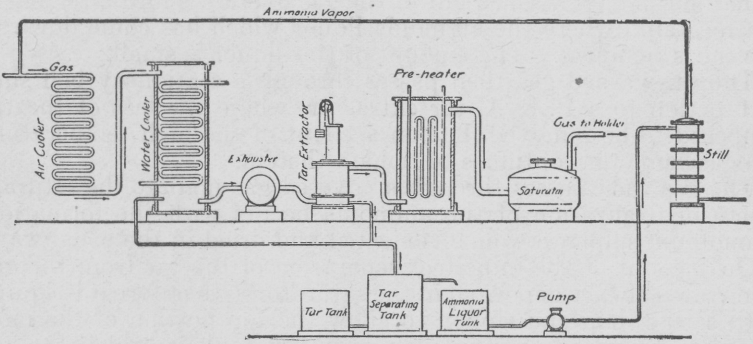
Temperatures taken at a representative plant at the various stages of the operation were as follows:

	°F.
Entering Körting injectors	200
After spraying with tar	162
Entering saturator	160
Leaving saturator	185
Entering water coolers	171
Leaving water coolers	102

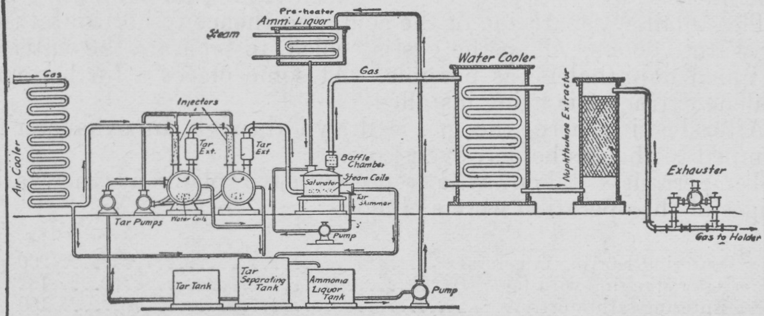
COLLIN SEMIDIRECT SULPHATE PROCESS.

In this process the gas from the ovens passes through the usual horizontal tubular water coolers, where most of the tar and combined ammonia are separated, then through a P. & A. tar extractor, where

KOPPERS' DIRECT AMMONIUM SULPHATE PROCESS.



OTTO DIRECT AMMONIUM SULPHATE PROCESS



the remainder of the tar is separated. The cleaned gas then passes through another set of water coolers exactly similar to the first set, and then through the exhausters to the saturator.

Two saturators in series are used in this process, set at different levels in the building.

The cleaned gas enters the upper saturator, the bath of which is kept at about 25 per cent free acid, and the liquor from this bath is used as the saturating medium in the second or lower saturator, into which pass the ammonia vapors from the stills, which are used in this similarly as in the Koppers process.

One advantage claimed for this system of treating the ammonia in two saturators, one for the direct gas and the other for the still vapors, is that the "stink" gases (H_2S, CN, etc.) from the latter are at once eliminated from the system, escaping from the second saturator into the air and thus never coming into contact with the gas.

The temperatures at one plant where this process is in operation were as follows:

	°F.
Gas entering first set of water coolers	212
Gas entering P. & A. tar extractor	113
Gas leaving second set of water coolers	73
Gas entering saturator	77
Gas leaving saturator	100

Experiments for a modification of this process are being conducted along the following lines: The gas from the ovens will be treated in one set of horizontal coolers, P. & A. tar extractors, and another set of horizontal coolers as above described.

In the first set of coolers, however, the ammonia liquor will be used for cooling instead of water. The ammonia liquor will thus become heated to a temperature of about 194° F. in its action of cooling the hot gasses from the ovens.

This preheated liquor, and any vapor which may be evolved, will be run to a superheater and brought to a temperature of about 300° F., which is considered sufficient to decompose the compounds of ammonia (chloride, carbonate, etc.).

The ammonia vapor evolved passes from here directly into the saturator. The superheater will be heated either by combustion of surplus gas from the ovens, or by utilizing the waste heat from the chimney flues.

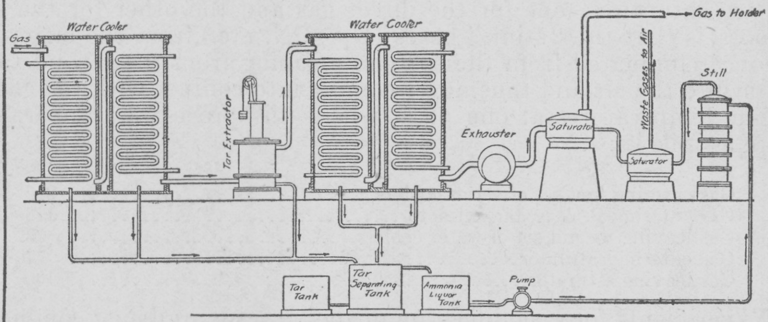
FELD DIRECT SULPHATE PROCESS.

In this process the sulphur in the coke oven gases is utilized to produce most of the sulphuric acid required for the neutralization of the ammonia in these gases. After leaving the ovens, the gases pass through the usual coolers, exhausters, and tar extractors, and are then washed with a solution of ammonium polythionate, which absorbs the ammonia from the gases, forming ammonium thiosulphate and precipitating sulphur according to this reaction:

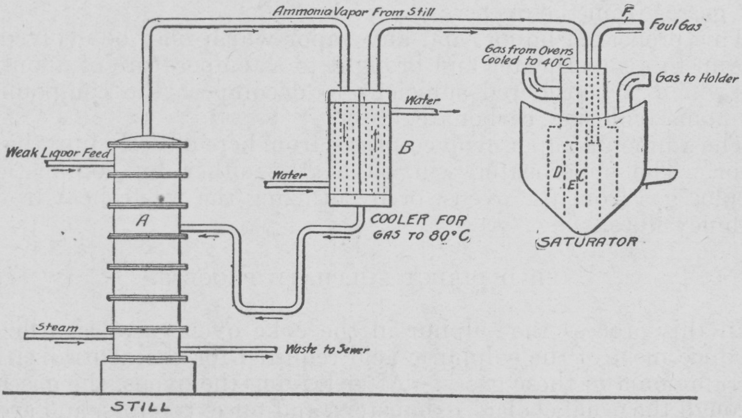
$$(NH_4)_2\,S_4O_6 + 2\,NH_3 + H_2S = 2(NH_4)_2\,S_2O_3 + S.$$

This mixed solution and precipitate is treated in a tank provided with mechanical stirrers with sulphur dioxide formed by burning

COLLIN DIRECT AMMONIUM SULPHATE PROCESS.

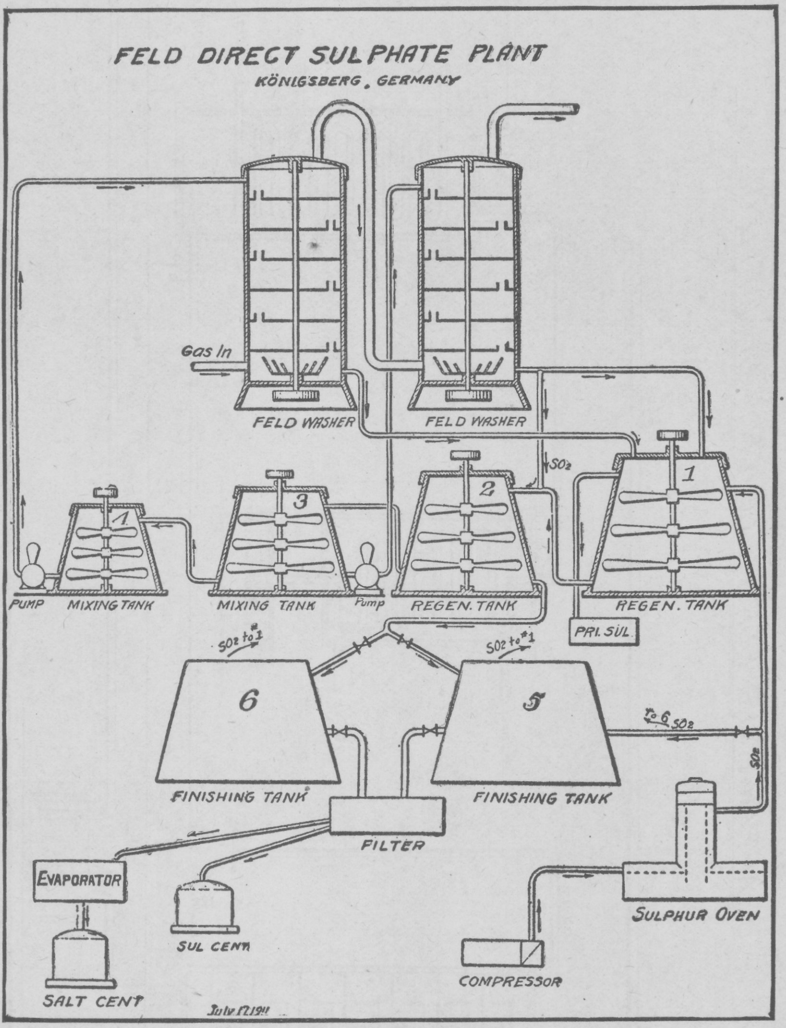


COLLIN DIRECT SULPHATE PROCESS.
AT
KOLNER BERGSCHAFTKARL COLLIERY, GERMANY.



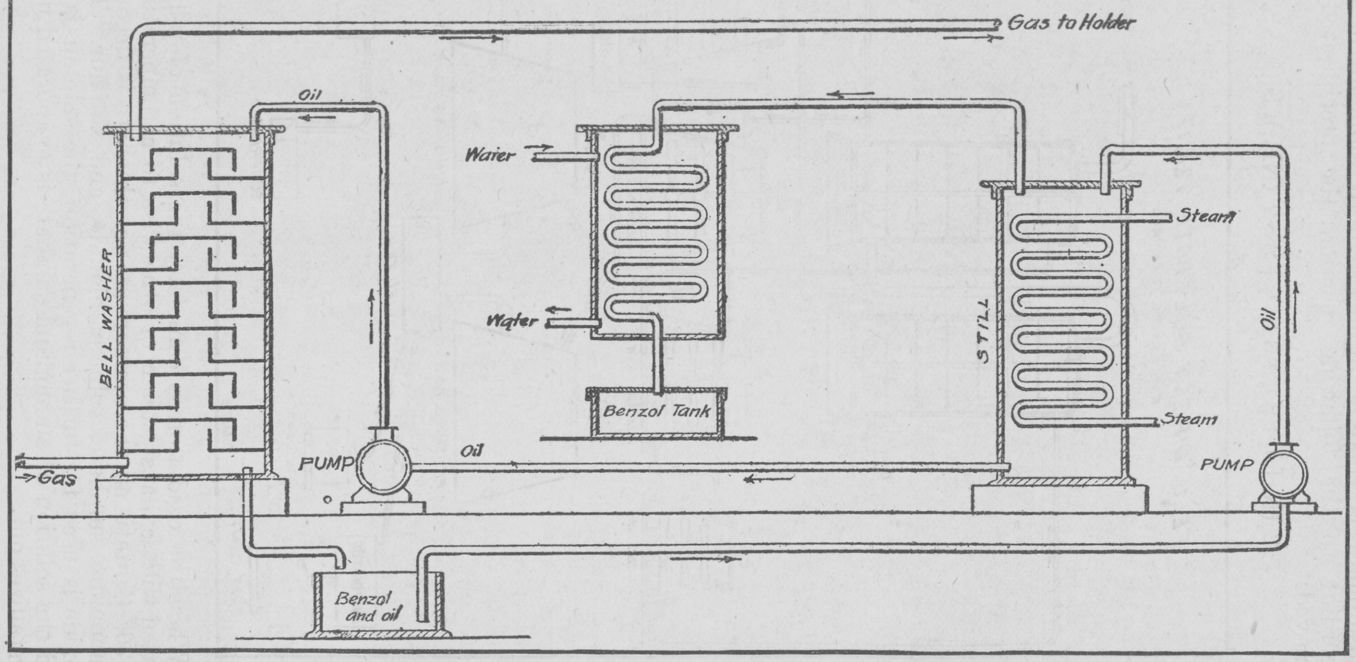
in a suitable oven some of the sulphur previously precipitated; the thiosulphate is thereby regenerated to ammonium polythionate according to the following reaction; the precipitated sulphur is removed:

$$2\ (NH_4)_2\ S_2O_3 + 3\ SO_2 + S = 2\ (NH_4)_2\ S_4O_6 + S.$$



When the oxidation is complete, the solution of polythionate is heated with exhaust steam or otherwise to a temperature of 60° C. to 70° C. until all the ammonium polythionate is decomposed into ammonium sulphate, sulphur dioxide, and sulphur. The sulphur dioxide is used for further regeneration, the sulphur is filtered off, and the solution of ammonium sulphate is evaporated until the salt crystallizes out:

$$(NH_4)_2\ S_4O_6 + \text{Heat} = (NH_4)_2\ SO_4 + SO_2 + 2\ S.$$



APPARATUS FOR RECOVERY OF BENZOL

RECOVERY OF BENZOL.

Benzol is defined as a colorless, inflammable, liquid compound having the chemical formula C_6H_6.

Benzol is recovered from coke-oven gases by scrubbing them with light oil, in washers of various types, after the ammonia has been separated from the gases; that is, after the gases leave the ammonia scrubbers in the indirect process or after the gases issue from the saturator in the direct process. Some benzol is always precipitated with the tar.

The oil used for scrubbing is usually in this country a light oil of specific gravity about 0.8; it should be neither too thin, in which case long enough contact with the gas is not obtained, nor too thick, in which case there is a tendency to solidify.

After scrubbing, the mixture of washing-oil and benzol is conveyed to a still, where the bonzol is driven off, with steam as the heating medium. The benzol so obtained is designated as "crude" benzol, and contains about 50 per cent benzol. This is either shipped as such or is purified by further distillation to various grades of benzol or fractionally distilled with separation of toluol and xylol when required.

The oil used for scrubbing is used over and over again until it gradually becomes too thick by accumulation of naphthalene and tar.

The yield of benzol depends largely on the volatile contents of the coal; usually the higher the volatile matter the higher is the yield of benzol.

USES OF BY-PRODUCTS.

Tar.—This is used largely for two purposes, namely, distillation for production of creosote and light oils and pitch, and for use in road making. Both of these uses of tar have increased very greatly in the last few years and the tendency for still further increase indicates a very large proportion of the future production will be similarly used. Tar is further being used successfully in open-hearth furnaces, replacing producer gas; also in heavy oil engines, providing it does not contain too much free carbon. It has also been burnt with success under boilers through specially devised burners.

Ammonia and ammonium sulphate.—The ammonia, in the form of concentrated ammonia liquor, is used in making anhydrous and aqua ammonia for refrigeration and other purposes, in the production of soda, ash, explosives, and in other lines of chemical manufacture. Sulphate of ammonia is very largely used as a fertilizer, although in some cases it is converted to ammonium hydrate for use in chemical manufacture. When used as a fertilizer it is usually mixed in definite proportions with other fertilizer ingredients, such as acid phosphate, potash, etc., according to the conditions.

Coke dust and coke breeze.—The coke dust is used to advantage in the steel mills in soaking pits, etc. Coke dust up to one-fourth inch in size can also very profitably be burnt in specially designed grates under boilers. The coke breeze is sold for domestic purposes, having been screened and sometimes sized. In locations where coal is cheap the disposal of the coke breeze may at times be somewhat troublesome.

Surplus gas.—The surplus gas obtained from the coke ovens, which has a value of 400 to 650 British thermal units per cubic foot, depending on the coal used, is one of the most valuable by-products. It can be used for all sorts of heating purposes at the steel plant, and its value in replacing coal for all purposes at one of our steel plants is equivalent to approximately one-half million net tons of coal per year, based on 40,500 cubic feet of surplus gas being equivalent to one net ton of coal at that point. This surplus gas is also used for illuminating purposes and can be piped long distances for this purpose. In Europe it is used quite extensively in gas engines. Experiments have also been made using it in the open-hearth furnaces alone or mixed with blast furnace gas, the latter method having been largely adopted in certain parts of Europe ,and I believe ultimately in this country will receive due consideration.

Benzol.—The principal uses of benzol and its products are:

(1) As a motor fuel.
(2) To enrich the illuminating power of gas.
(3) In manufacture of aniline dyes.
(4) As a solvent for rubber and similar substances.
(5) In manufacture of gunpowder.

Production of benzol in Europe has increased enormously in recent years due to its increasing consumption as a motor fuel in place of gasoline. At the same time, the price has steadily increased, more than keeping pace with the increased production.

CONCLUSION.

In conclusion, permit me to express my firm conviction that, when located at points suitable to its requirements, the by-product coke oven is the most satisfactory and economical system yet known for the manufacture of metallurgical coke.

It also furnishes a desirable method for the production of illuminating gas and domestic coke, and we are able to utilize practically all the valuable constituents of coal.

As a great conserver of the national resources of the country's fuel, it should receive the closest study. Take the Gary (Ind.) by-product coke-oven plant as a concrete example: In the last six months of 1912 we actually produced coke at the rate of 2,900,000 tons per year on a mixture of 76.4 per cent Pocahontas and 23.6 per cent high volatile coals. The conservation of coal through producing this amount of coke in by-product ovens instead of beehive ovens amounts to about 1,190,000 tons per year. Furthermore, the actual utilization of the surplus gas for various heating purposes at this plant for the same period is equivalent to an annual saving by replacement of practically 500,000 tons of coal. In other words, in the annual production of 2,900,000 tons of coke at the Gary (Ind.) by-product coke-oven plant a saving of practically 1,700,000 tons of coal, based on above mixture of low and high volatile coals, has been accomplished, which means the conservation of that amount of the coal of our national coal reserves from the operation of that one plant alone. This amount of conservation would not occur in case of using all high volatile coals, because the difference in yield from the low volatile Pocahontas coal when coked in retort ovens as against bee-hive ovens is much greater than is the case with high volatile coals. For instance, if the above-mentioned tonnage of coke had been produced entirely from Connellsville coal, the saving of coal due to the greater yield in retort ovens would have amounted to about 475,000 tons per year. This, with the saving due to replacement of about 500,000 tons of coal by surplus gas would give a total conservation of practically 1,000,000 tons of coal per year when using all Connellsville coal as against 1,700,000 tons of coal per year when using the mixture at Gary, Ind., above referred to.

The coke produced in by-product coke ovens, when properly made, is fully equal in quality to that produced in beehive ovens. It is possible to utilize a larger variety of coals when properly selected and mixed, including coals which up to the present time have been practically regarded as "noncoking coals," and make a highly satisfactory metallurgical coke.

I am distinctly of the opinion that in this country the by-product coke should in most cases be made at the blast furnace plants and not at the coal mines, for in this way it becomes possible to mix coals from various localities to great advantage. I believe that the operation of blast furnaces and coke ovens can be conducted in a more intelligent manner when the coke ovens are located at the blast furnace plant and are under the same management; this also allows a better distributing point for the by-products, such as tar and gas, which can be consumed to great advantage in the works when the blast furnaces are connected with large steel plants.

As to the constructive features of by-product coke ovens, which I have described somewhat in my paper, while we have learned a great deal from the Germans, yet I am frank to say I think we have improved very greatly not only on their construction, but also on their practice, particularly in the amount of output per day per oven, at the same time preserving, if not improving, the quality of the coke by so doing.

As to the possible overproduction of nitrogen, careful study of the whole situation would indicate we need have no apprehension that the supply will exceed the demand. The increasing production of ammonium sulphate is making it possible to supply the farmer with the nitrogen he requires for intensive farming, and as this supply increases he will be able to cultivate his land to better advantage and obtain a larger product per acre. I also believe as the supply increases it will tend to stimulate that demand which at present lies dormant.

In the United States there were produced in 1912 about 200,000 tons of ammonium sulphate and sulphate equivalent. We consumed approximately 230,000 tons, or considerably more than the production. If we recovered the ammonium sulphate from all the 53,000,000 tons of coal coked in this country in that year, it would have amounted to nearly half a million tons, or about twice the present consumption. If the present rate of consumption increases in anything like the ratio for the last 10 years, then the consumption of ammonium sulphate will in a comparatively few years equal the greatest possible production obtainable through the coking of coal, and we all realize that before all of the coal is coked in by-product ovens in this country more than 10 years must have elapsed. The probabilities are that the increase in the demand for ammonium sulphate produced from coal will in time exceed the supply from this source, so that the further supply of nitrogen must come through the use of nitrate of soda from Chile, which has been and still is extensively used, and through other methods of obtaining it, such as from cyanamid, of which approximately 250,000 tons per year are being produced, as well as synthetic ammonium nitrate and sulphate processes, peat, etc. Some of these latter processes, however, can still be stated to be in the experimental stage, even though large amounts of money have already been spent in efforts to develop them. Their value as competitors to the present known and used fertilizers through their ultimate economical production is too uncertain at this time to be discussed by me in detail.

A careful study of what the various Governments are doing, through their agricultural departments, in the way of educating the farmers as to the advantages of artificial fertilizers and a consideration of what is likely to take place in the production of nitrogen from the above sources leads me to believe that the demand for artificial fertilizers for a great many years to come will be in excess of the supply.

Referring once more to the sulphate of ammonia, my conclusions are that the nitrogen in sulphate of ammonia can be produced at a lower cost than in any of the above sources of supply; in other words, that considering all of the above sources of supply, sulphate of ammonia, as made in the by-product coke ovens, will at all times give a handsome return on the money invested.

There is an ever-increasing demand for the surplus gas for the many different uses of heating required in a steel plant or for illuminating purposes which will always cause the surplus gas to remain a by-product of great value.

The use of tar, which formerly was a drug on the market, has of late been greatly stimulated as its advantages for roofing purposes, binder for road building, creosoting, burning in open-hearth furnaces, etc., have become more fully recognized.

Benzol is now extensively used abroad as a motor fuel, and the same conditions are likely to prevail here. Recent tests have shown that benzol is the equivalent of gasoline for this purpose. In fact, better results have been obtained with it in automobiles than with gasoline.

As I previously stated, all of the coke in Germany is made in retort coke ovens and about 80 per cent of these are equipped for recovery of by-products. From the rapid progress that is being made in this country I firmly believe that the time is coming when the same condition will prevail in the United States.

And now, Mr. Chairman, permit me to express my earnest appreciation of the assistance rendered in the study of this whole problem by my associates, particularly the members of the coke committee and the coke-oven superintendents. Their keen study of the different systems, their careful analysis of all conditions connected with operations, have enabled us to reach the present state of perfection of the art, and great credit is due to them for all that has been accomplished so far.

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