1922

Cost practices and problems in the production of coke

C. C. Sheppard

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Official Publications
Vol. IV DEC. 1, 1922 No. 6

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COST PRACTICES AND PROBLEMS IN THE PRODUCTION OF COKE

Note: This paper is one of a series presented before the Pittsburgh Chapter. These papers dealt with cost accounting in the iron and steel industry from the ore to the finished product. It is the intention of the Publications Department to publish some more of these papers as Official Publications.

The term coking is used to denote the process of preparing, from bituminous or other coal, a fuel adapted for metallurgical and other special uses. The operation consists of expelling by heat the gaseous elements from coking coals, leaving the fixed and deposited carbon, ash, and the residue of sulphur and phophorus. These elements constitute what is known as coke.

Three methods have been, or are being used, in the manufacture of coke. These methods may be referred to briefly in the following terms: 1, Coking the coal in heaps or mounds, in the open air; 2, coking the coal in the beehive or round oven partly enclosed, with the air partially excluded; and 3, coking in retort or closed ovens, with air almost entirely excluded.

The first method has almost entirely disappeared owing to its obvious wastefulness, as well as the evident difficulty in operation and limited production.

The second method is still prevalent in most of our coking fields on account of its moderate costs and simplicity of operation.

The by-product coke oven with its additional apparatus for saving by-products affords many advantages in particular localities and under favorable conditions. While enormous economies may be effected in the production of coke by the recovery of the by-products which are wasted in the beehive oven, yet statistics show that less than 60% of coke manufactured today is produced in the by-product coke ovens. This fact may be readily appreciated if we are cognizant of the enormous expenditure which is required in the construction and installation of plants and equipment necessary for the recovery of these by-products.

By-Product Recovery[1]

The by-product recovery plant serves to clean the gas and to recover from it as by-products, tar, ammonia and benzols. The ammonia may be recovered either in the form of ammonia liquor or as ammonium sulphate.

The hot gas from the ovens is drawn through mains to the primary coolers, where it is cooled and a certain amount of water

[1]As described by The Koppers Co., Pittsburgh.

and tar is condensed. This condensate carries with it a portion of the ammonia present in the gas. The gas is then drawn into exhausters and forced by them through tar extractors where any remaining tar is removed. From the tar extractors the gas passes to the saturators, where ammonia is removed in the form of ammonium sulphate. The gas bubbles through an acid bath in the saturator, and the intimate contact of the ammonia with the acid forms ammonium sulphate, which is precipitated as a salt. This reaction is complete, and all the ammonia remaining in the gas is recovered at this point. The gas then passes through cooling towers, where it is cooled to the proper temperature and then through scrubbers or washers where by direct contact with absorbent oil, benzols are removed from the gas. After the removal of the benzols, a part of the gas is returned to the ovens for heating, and the remainder is ready for distribution for use elsewhere.

The ammonium sulphate formed in the saturator is pumped into drawn tables and then dried by means of centrifugal dryers. After being dried, the salt is carried to a storage pile from which it is delivered for shipment. Ammonium sulphate has many industrial uses, but its most important use is as a nitrogen-carrying fertilizer.

The ammonia liquor condensed in the primary coolers, together with tar from coolers and tar extractors, is drained into a tank where by taking advantage of their differences in specific gravity, the two liquids are separated by decantation. The tar is pumped to a storage tank and is ready for use or shipment.

To enumerate the various uses of coal tar would require a volume in itself. Among the most important, are its uses for fuel, road material, roofing material and as a base for many chemcials and dyes.

The ammonia liquor is pumped also to a storage tank and from there it is taken to stills in which the ammonia vapors are driven off by treatment with steam. These vapors are piped into the stream of coke oven gas just before the saturators, and are converted into sulphate of ammonia in the manner just described. If it is desired, all of the ammonia can be scrubbed from the gas by the use of water, and distilled and delivered in the form of concentrated ammonia liquor.

The absorbant oil in its contact with the gas absorbs and carries away with it the benzols contained in the gas. This oil is pumped to stills and the combined benzols are driven off in a product known as light oil. The scrubbing oil, after it gives up its benzols, is cooled and returned to the scrubbing towers to secure more benzol. The light oil containing benzol, toluol and solvent naphtha is pumped to other stills, and these products are separated by fractional distillation. The products are then known as crude benzol, crude toluol, etc. If it is desired to make pure products, the crude products are washed with sulphuric acid to remove impurities, and then neutralized with an alkali and redistilled Such products are then known as pure benzol, pure toluol, etc. Benzols

have many important uses in the manufacture of chemicals. Toluol was in great demand during the war in the manufacture of the high explosive, tri-nitro-toluene, generally known as T.N.T. Benzol is being increasingly used as motor fuel in the place of gasoline, for it is capable of producing 20% more mileage per gallon than gasoline.

The foregoing is a brief description of the operation of a by-product coke plant. Necessarily, such a plant in its design and construction requires the efforts of all classes of engineering talent. The operation of the plant in itself is relatively simple, and aside from one or two men trained in such work, requires only ordinary labor and men capable of operating simple pieces of machinery and apparatus.

Contained in the raw gases issuing from the carbonization of coal is a compound called benzol. Benzol itself is an indispensable source of nitro-benzene and aniline with its long series of derivations used for dyes, drugs, photographic chemicals, etc. The manufacture of synthetic phenol, which is a close rival of carbolic acid made directly from coal tar, may be considered as an outlet for pure benzol on account of the great increase in the production of the various condensation products of phenol and formaldehyde.

From toluene is obtained such well-known products as benzaldehyde, saccharin and benzoic acid. Metaxylene is the source of rather important series of dye. The study of other materials obtained in smaller amounts in coke oven benzol is believed to suggest other valuable results in the not far distant future.

The Koppers Company has developed a motor fuel from coke oven gas that promises to become quite valuable for this purpose. It is claimed to give 20 to 30 per cent more power and mileage than high grade gasoline, and to cause less carbon trouble than gasoline.

Owing to the rapid depletion of natural gas and the increased cost of manufacturing water gas, coke oven gas becomes of greater importance. It is claimed that coke oven gas can be substituted directly for natural gas or water gas. In the steel mills and industrial plants it is used extensively in heating appliances, the chief question being where it can be used to the best advantage. Because of its high flame temperature and ease of control, and due to the claim that it is a cold, clean gas, it is used in open hearth furnaces, tube mills, soaking pits, billet-heating furnaces, annealing furnaces, galvanizing pots, brazing furnaces, etc.

Coke oven gas is also being used either wholly or mixed with water gas in various cities.

Coal tar recovered in by-product coking is also a valuable material from which are derived many of the basic substances used in making dyes, medicines, explosives, etc. By the process of distillation various grades of oil are driven off, such as light oil, naphthalene oil, heavy oil and anthracene oil.

The residue left in the tar still is coal tar pitch, and its quality depends upon the amount of oil removed during distillation.

From the above description of the physical routine for the

recovery of by-products in the manufacture of coke, it will be seen that it is necessary to first determine an aggregate material value which should be placed upon the gases which are evolved during the processes of carbonization. This problem has been, and is, the real difficulty in ascertaining the basis for establishing values for the material costs in the various finished by-products recovered therefrom.

CLASSIFICATION OF ACCOUNTS

The problem of segregating the direct and indirect costs during the remainder of the processes of refinement is not so difficult, and can be reduced to reasonably accurate results. A suggested classification of accounts, showing titles for departments or processes, together with statistical operating accounts for the recovery or refinement of by-products is shown as follows:

CENTRAL BY-PRODUCT COKE COMPANY
CLASSIFICATION OF ACCOUNTS

Department Code	NAME OF DEPARTMENT
A	General Office
B	Works Office
C	Water
D	Steam
E	Electric Light and Power
F	Stores
G	Laboratory
H	Repair Departments
K	Coke Department
L	Tar Department
M	Oils Department
N	Sulphate of Ammonia Department
P	Gas Department
R	Benzol Department
S	Other Departments as needed

A—GENERAL OFFICE

A	1	Executive Salaries
	2	Accounting Staff Salaries
	3	Traveling Expenses, Executives
	4	Bookkeeping and Clerical Salaries
	5	Maintenance of Office Building
	6	Maintenance of Office Equipment
	7	Depreciation, Office Building
	8	Depreciation, Office Equipment
	9	Stationery and Printing
	10	Dining Room Expense
	11	Toilet Repairs and Supplies
	12	Heat, Light and Power
	13	Telephone and Telegraph
	14	Taxes
	15	Insurance, Officers and Employees
	16	Insurance, Fire
	20	Salesmen's Salaries and Commissions
	21	Salesmen's Traveling Expenses
	22	Advertising
	23	Maintenance of Automobiles

Department Code		
		B—WORKS OFFICE
B	1	Salaries, Superintendence and Engineers
	3	Traveling Expenses
	4	Bookkeeping and Clerical Salaries
	5	Maintenance of Building
	6	Maintenance of Office Equipment
	7	Depreciation, Office Building
	8	Depreciation, Office Equipment
	9	Stationery and Printing
	11	Toilet Repairs and Supplies
	12	Heat, Light and Power
	13	Telephone and Telegraph
	14	Taxes
	16	Insurance, Fire
		C—WATER DEPARTMENT
C	1	Salaries, Superintendence and Engineers
	3	Labor, Pumps, etc.
	5	Repairs to Buildings
	6	Repairs to Machinery and Equipment
	7	Depreciation, Buildings
	8	Depreciation, Machinery and Equipment
	12	Heat, Light and Power
	17	Steam
	18	Small Tools
	19	Lubricants, Waste and Packing
	20	Miscellaneous Materials and Supplies
		D—STEAM DEPARTMENT
D	1	Salaries, Superintendence and Engineers
	2	Salaries, Foreman
	3	Labor, Tenders, Cleaners and Stokers
	4	Labor, Miscellaneous
	5	Repairs to Buildings
	6	Repairs to Cranes
	7	Repairs to Boilers and Stacks
	8	Repairs to Pumps
	9	Repairs to Stokers
	10	Repairs to Turbines, Blowers and Fans
	11	Repairs to Fuel Gas Piping
	12	Repairs to Steam Lines
	13	Repairs to Miscellaneous Equipment
	14	Depreciation, Buildings
	15	Depreciation, Cranes
	16	Depreciation, Boilers and Stacks
	17	Depreciation, Pumps
	18	Depreciation, Stokers
	19	Depreciation, Turbines, Blowers and Fans
	20	Depreciation, Fuel Gas Piping
	21	Depreciation, Steam Lines
	22	Fuel
	23	Water
	24	Electric Light and Power
	25	Tools
	26	Lubricants, Waste and Packing
	27	Boiler Compound
	28	Removal of Ashes and Refuse
	29	Miscellaneous Supplies and Expenses

Department Code		
		E—ELECTRIC LIGHT AND POWER DEPARTMENT
E	1	Salaries, Superintendence and Engineers
	2	Salaries, Foreman
	3	Labor
	4	
	5	Repairs to Buildings
	6	Repairs to Generators
	7	Repairs to Rotaries and Transformers
	8	Repairs to Feed Lines
	9	Depreciation, Buildings
	10	Depreciation, Generators
	11	Depreciation, Rotaries and Transformers
	12	Depreciation, Feed Lines
	13	Water
	14	Steam
	15	Small Tools
	16	Lubricants, Waste and Packing
	17	Power Purchased
	18	Miscellaneous Supplies and Expenses
		F—STORES
F	1	Salary, Superintendence
	2	Salaries, Clerical
	3	Stationery and Printing
	4	Telephone and Telegraph
	5	Insurance, Fire
	6	Heat, Light and Power
	7	Repairs to Buildings
	8	Repairs to Equipment
	9	Depreciation, Buildings
	10	Depreciation, Equipment
		G—LABORATORY
G	1	Salary, Superintendence
	2	Labor
	3	Chemicals
	4	Miscellaneous Materials and Supplies
	5	Repairs to Buildings
	6	Repairs to Apparatus and Equipment
	7	Heat, Light and Power
	8	Miscellaneous Supplies and Expenses
		H—REPAIR DEPARTMENT
		MACHINE, BLACKSMITH, ELECTRIC AND CARPENTER SHOPS
H	1	Repairs to Buildings
	2	Repairs to Machinery and Equipment
	3	Water
	4	Steam
	5	Light and Power
	6	Small Tools
	7	Lubricants, Waste and Packing
	8	Miscellaneous Supplies and Expenses
		K—COKE DEPARTMENT
		OPERATING COSTS
K	1	Coal (proportionate part chargeable to producing coke)
	2	Superintendence and Clerical

Department Code		
	3	Labor, Coal Conveying
	4	Labor, Crushing Coal
	5	Labor, Heating and Assistance
	6	Labor, Charging
	7	Labor, Pushing and Leveling
	8	Labor, Cooling and Transferring
	9	Labor, Coke Conveying
	10	Labor, Screening and Inspecting
	11	Labor, Storing
	12	Labor, Loading
	13	Labor, Repairing Ovens
	14	Materials and Supplies, Repairing Ovens
	15	Repairs to Machinery and Equipment
	16	Repairs to Buildings and Grounds
	17	Water
	18	Steam
	19	Gas (Returned to Ovens)
	20	
	21	
	22	Depreciation, Ovens
	23	Depreciation, Machinery and Equipment
	24	Depreciation, Buildings
	30	Proportion of General Overhead

INCOME AND CREDIT ACCOUNTS

	50	Sales, Coke (at cost if not sold)
	51	Sales, Breeze (at cost if not sold)
	52	Proportionate part of operating expenses charged to coke department which is chargeable to production of raw materials in by-products.

Note: After item 51 and item 52 has been determined, the remainder of the charges to department K will represent the cost of item number 50.

L—TAR DEPARTMENT

OPERATING COSTS

L	1	Coal (Proportionate part chargeable to production of tar as a separate commodity)
	2	Proportionate part of operating expenses from coke department
	3	Materials and Supplies
	4	Salaries and Wages
	5	Repairs to Machinery and Equipment
	6	Depreciation, Machinery and Equipment
	9	Proportion of Plant Overhead
	10	Proportion of General Overhead

INCOME ACCOUNTS

L	20	Sales, Tar

Note: If this department is charged with the total cost of tar as computed and further distillation is contemplated, the cost of tar should be credited with its derivatives at cost value.

M—OILS DEPARTMENT

OPERATING COSTS

M	1	Coal (Proportionate part chargeable to production of oil as a separate commodity)
	2	Proportionate part of operating expenses from coke department
	3	Materials and Supplies

Department Code

4 Salaries and Wages
5 Repairs to Machinery and Equipment
6 Depreciation, Machinery and Equipment
9 Proportion of Plant Overhead
10 Proportion of General Overhead

INCOME ACCOUNTS

20 Sales, Oil
Note: If this department is charged with the total cost of oil as computed and further distillation is contemplated, the cost of oil should be credited with its derivatives at cost value.

N—SULPHATE OF AMMONIA DEPARTMENT
OPERATING COSTS

N 1 Coal (Proportionate part chargeable to production of sulphate of ammonia as a separate commodity)
2 Proportionate part of operating expenses from coke department
3 Materials and Supplies
4 Salaries and Wages
5 Repairs to Machinery and Equipment
6 Depreciation, Machinery and Equipment
9 Proportion of Plant Overhead
10 Proportion of General Overhead

INCOME ACCOUNTS

20 Sales, Sulphate of Ammonia
Note: If this department is charged with the total cost of ammonia as computed and further distillation is contemplated, the cost of sulphate of ammonia should be credited with its derivatives at cost value.

P—GAS DEPARTMENT
OPERATING COSTS

P 1 Coal (Proportionate part chargeable to production of gas as a separate commodity)
2 Proportionate part of operating expenses from coke department
3 Materials and Supplies
4 Salaries and Wages
5 Repairs to Machinery and Equipment
6 Depreciation, Machinery and Equipment
9 Proportion of Plant Overhead
10 Proportion of General Overhead

INCOME ACCOUNTS

20 Sales, Gas
Note: If this department is charged with the total cost of gas as computed and further distillation is contemplated, the cost of gas should be credited with its derivatives at cost value.

R—BENZOL DEPARTMENT
OPERATING COSTS

R 1 Coal (Proportionate part chargeable to production of benzol as a separate commodity)
2 Proportionate part of operating expenses from coke department
3 Materials and Supplies
4 Salaries and Wages
5 Repairs to Machinery and Equipment
6 Depreciation, Machinery and Equipment

Department Code	
9	Proportion of Plant Overhead
10	Proportion of General Overhead

INCOME ACCOUNTS

20	Sales, Benzol

Note: If this department is charged with the total cost of benzol as computed and further distillation is contemplated, the cost of benzol should be credited with its derivatives at cost value.

S—OTHER DEPARTMENTS AS NEEDED

OPERATING COSTS

S	1	Coal (Proportionate part chargeable to production of other departments as needed as a separate commodity)
	2	Proportionate part of operating expenses from coke department
	3	Materials and Supplies
	4	Salaries and Wages
	5	Repairs to Machinery and Equipment
	6	Depreciation, Machinery and Equipment
	9	Proportion of Plant Overhead
	10	Proportion of General Overhead

INCOME ACCOUNTS

20	Sales, Other Departments as needed

Note: If other departments are charged with the total cost of other commodities as computed and further distillation is contemplated, the cost of other commodities should be credited with derivatives at cost value.

It will, of course, be necessary to distribute the operating costs of the non-productive departments to the productive departments. In addition we must also distribute the unabsorbed operating costs of the coke department to all of the other productive departments.

The various methods employed for the distribution of general or overhead expenses as well as expenses of one productive department distributed to other productive departments have been treated at length in various other papers read before the Pittsburgh Chapter, and it is not deemed necessary to discuss this subject in the present paper.

The foregoing classification of accounts does not purport to be exhaustive or typical of a plant completely equipped for the purpose of refining or distilling all of the various by-products which are available.

It is intended, however, to suggest the practicability of obtaining actual cost of labor, indirect material and overhead incident to extraction, treatment and refinement, to the point of completion of the various products contained in the original raw gas drawn from the ovens. The fact is recognized that a large percentage of by-product coke plants are erected for specific and limited purposes, and that frequently but one or two of the by-products are actually recovered. In these cases, the products recovered, of course, must absorb all the costs.

Cost of Producing Coke

The method of arriving at the cost of producing coke is practically the same in all plants. As suggested elsewhere in this paper, the method is not at all satisfactory. The problem is one which is the subject of considerable discussion among producers and their accounting departments. Referring again to the illustration given, the costs consist of the coal at cost price, the cost of carbonization (coking costs), and to these costs are credited the market or sale value of the by-products leaving the excess of these costs over the market value of the by-products as the cost of coke.

It will readily be seen that this method of accounting is subject to criticism, especially in the conversion of coal where coke frequently becomes a by-product, and not the major product. Experience has shown us that the so-called by-products of coke are in many cases or localities considered as having decidedly a greater value than the coke, thus reducing the so-called main product to the class of by-products. A number of plants have been built for the primary purpose of manufacturing gas.

The Beehive Oven

A classification of accounts ordinarily found in coke companies operating the beehive oven would be approximately the following:

Coal at Cost
Superintendence
Labor, Larries
Repairs, Larries
Depreciation, Larries
Repairs, Track and Roadway
Power
Labor, Coal Charging
Labor, Ovens
Repairs, Ovens
Depreciation, Ovens
Labor, Coke Washing
Labor, Coke Drawing
Miscellaneous Materials and Supplies
Proportion of General Overhead
Labor, Coke Storage or Loading

From the above classification, it will be seen that the problem of ascertaining the cost of manufacturing coke by the beehive process is a comparatively simple matter. In other words, the total costs as segregated in the above classification of accounts, divided by the total tons of coke produced, will give the average cost per ton. Unfortunately, however, we have lost large values which were originally contained in the coal charge. In other words, we have lost all of the elements contained in the products of combustion. The compositions contained in the products of combustion, per each ton of coal may be summarized as follows:

Tar, 12 gallons
Sulphate of Ammonia, 26 pounds
Gas, 10,000 cubic feet
Benzol, 3 gallons

Assuming an average market price for these commodities, we have lost in money value approximately $3.35 computed as follows:

12 gallons Tar at 5c. per gallon	$ .60
26 pounds Sulphate Ammonia at 2½c. per pound	.65
10,000 cubic feet Gas at 15c. per thousand feet	1.50
3 gallons Benzol at 20c. per gallon	.60
Total	$3.35

The common illustration which is used by by-product coke manufacturers illustrating the cost of coke, is as follows:

Assuming a plant to be equipped with a capacity for 1,000 tons per day, with the cost of coal f.o.b. ovens at $4.00 per ton, we would have the following example:

Coal, 1,000 tons at $4.00 per ton	$4,000.00	
Carbonizing Costs, 1,000 tons at $1.00 per ton	1,000.00	
TOTAL COST		$5,000.00
BY-PRODUCTS RECOVERABLE		
Tar, 12,000 gallons at 5c. per gallon	600.00	
Sulphate of Ammonia, 26,000 pounds at 2½c. per pound	650.00	
Gas, 7,000,000 cubic feet at 15c. per thousond cubic feet	1,050.00	
Benzol Extraction, 3,000 gallons at 20c. per gallon	600.00	
TOTAL VALUE BY-PRODUCTS RECOVERABLE		2,900.00
FURNACE COKE, 660 TONS AT $3.18 PER TON		2,100.00

In the above example it will be noted that only 70% of the recoverable gas is used in the computation. This is accounted for by an estimate of 30% being returned to the ovens for heating purpose.

The problem of ascertaining the material costs of these various by-products as well as the material cost of finished coke is a problem as yet unsatisfactorily solved.

From the foregoing facts, it will be ready seen that the real difficulty arises when we attempt to apportion the cost of materials contained in the gases evolved from the carbonization of coke and used in the production of these various by-products. In other words, it is claimed there is no uniform basis for apportioning this material cost, either on the basis of weight, volume or heat units. It has frequently been suggested that costs be proportionate to market value. However, serious objections arise when we attempt to use that basis, for the reason that there does not seem to be an equitable relationship between the market value and the proportion of constituent elements.

With due consideration for these claims, it is believed, nevertheless, that there are bases which may be used which are sufficiently reliable.

Weight Plan

One plan is herein offered, which if employed will at least establish a comparable basis for all practicable purposes. This plan we will call the Weight Plan. We will assume the manufacture of coke and four principal by-products, namely: coal tar, benzol, sulphate of ammonia and coal gas. Knowing the weight of the finished product of all these items, per ton of coal, with the exception of gas, we have the following figures for one ton of coal:

	Pounds
Coke	1320.0
Coal Tar	120.0
Benzol	21.9
Sulphate of Ammonia	26.0
Water (Waste)	100.0
Gas (Remainder)	412.1
Total	2000.0

Assuming one ton of coal to cost $4.00, we would have the following schedule showing apportionment of weight and material cost to each product, the apportionment being made in the ratio that each product weight bears to the total product weight:

SCHEDULE SHOWING APPORTIONMENT OF MATERIAL COST VALUE TO EACH PRODUCT PER TON OF COAL

	Yield in lbs. of Recovered Products per Ton of Coal	Distribution of Waste to Recovered Products	Revised Weight of Recovered Products	Material Cost of Each Product on Basis of Weight
Coke	1,320.0	69.47	1,389.47	2.78
Coal Tar	120.0	6.32	126.32	.25
Benzol	21.9	1.15	23.05	.045
Sulphate of Ammonia	26.0	1.37	27.37	.055
Gas	412.1	21.69	433.79	.87
Waste (Water)	100.0			
Total	2,000.0	100.00	2,000.00	4.00

In conformity with our preceding outline, we would now compute the total cost of production for each product manufactured. Selecting any one of these products, coal tar for example, we would complete the computation (assuming missing figures) as follows:

L	1	Material Cost of 120 lbs. (12 gal.) as above	.25
L	2	Proportionate part of operating expenses, coke department	.02
L	3	Materials and Supplies	.02
L	4	Salaries and Wages	.08
L	5	Repairs to Machinery and Equipment	.02
L	6	Depreciation, Machinery and Equipment	.03
L	9	Proportionate Part of Plant Overhead	.03
L	10	Proportionate Part of General Overhead	.03
		TOTAL COST	.48
		Sale price of 12 gallons coal tar at 5c. gal.	.60
		Less Cost of 12 gallons as computed above	.48
		PROFIT ON 12 GALLONS OF COAL TAR	.12

Criticisms of this basis are of course anticipated. However, it is believed that this or the British Thermal Unit basis offer less difficulties and inconsistencies, and at the same time greater constancy, than most plans now under consideration.

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