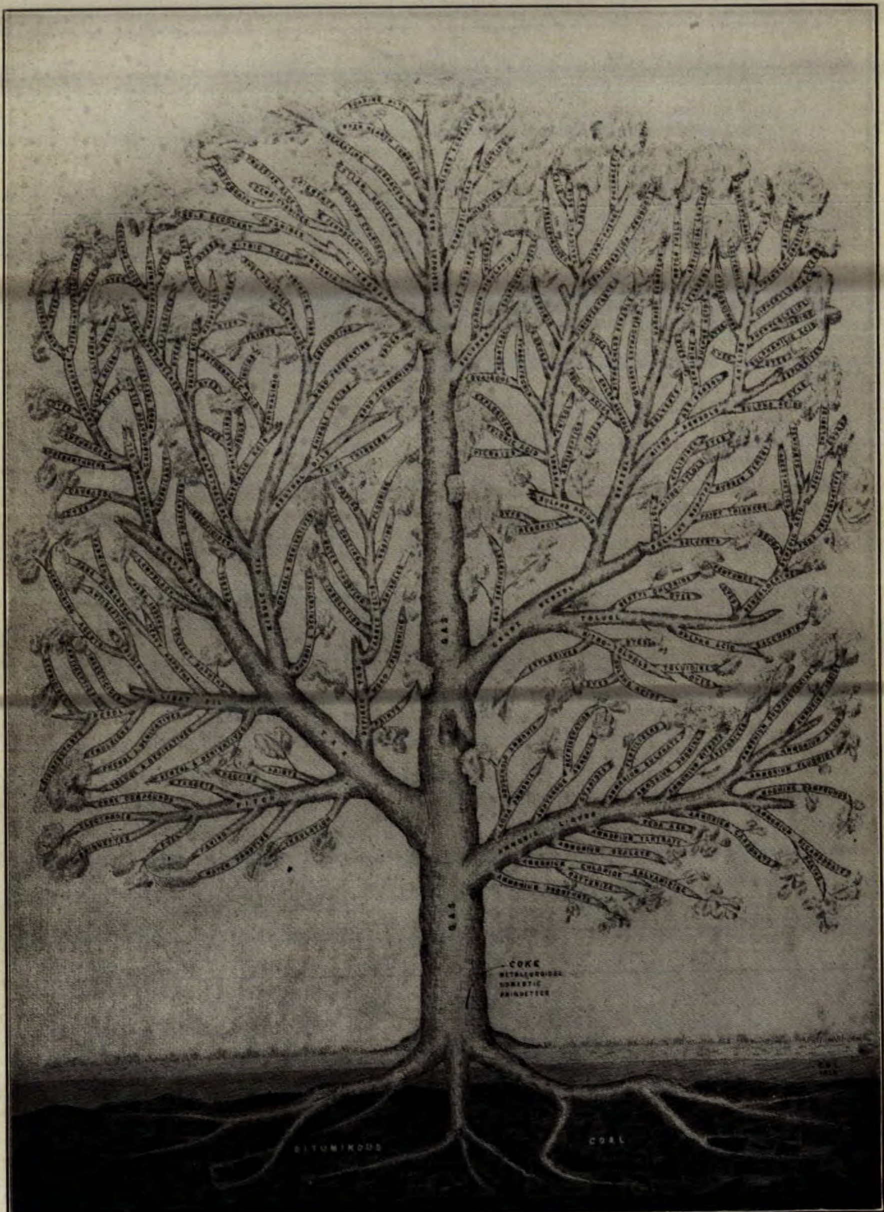


Coal products tree.

CANADA
THE DOMINION FUEL BOARD
IN CO-OPERATION WITH
THE MINES BRANCH, DEPARTMENT OF MINES

Published with the authority of the Honourable Charles Stewart, Minister,
Departments of the Interior and Mines

COKE

As a Household Fuel in Central Canada

BY
J. L. Landt
Consulting Engineer

Dominion
Fuel Board
No. 5

Mines Branch
No. 630

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1925

Dominion Fuel Board

Chas. Camsell, Deputy Minister of Mines..Chairman

John McLeish, Director Mines Branch, Department of Mines......................Vice-chairman

D. B. Dowling, Geological Survey, Department of Mines.........................Member

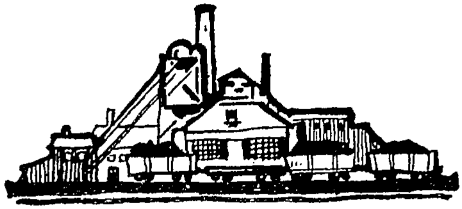
J. B. Challies, Director Dominion Water Power and Reclamation Service, Department of the Interior..Member

F. C. C. Lynch, Director Natural Resources Intelligence Service, Department of the Interior..Member

D. Roy Cameron, Forestry Branch, Department of the Interior...................Member

B. F. Haanel, Chief, Division of Fuels and Fuel Testing, Mines Branch..........Member

C. P. Hotchkiss, Executive Secretary..Member



THE Dominion Fuel Board was formally organized on the recommendation of the Minister of Mines under authority of an Order in Council dated November 25, 1922. The personnel was designed to coalesce the facilities of various Federal services in regard to geological, engineering, and economic studies relating to the fuel problem.

Although the formation of the Board was prompted by the acute fuel situation then prevailing, the duties assigned to it were intended to meet the long-recognized need for a standing organization which would be definitely responsible for ensuring that systematic study of the fuel position of the Dominion be not permitted to lapse on the termination of current emergencies.

The Board is spreading a network of investigation to ascertain the economic value of the different suggested alternatives to alleviate our present unsatisfactory fuel position.

The Honourable Charles Stewart,
Minister of Mines,
Ottawa, Ont.

Sir,—I beg to transmit herewith report on "Coke as a Household Fuel in Central Canada."

I have the honour to be, Sir,

Your obedient servant,

CHARLES CAMSELL,
Deputy Minister of Mines,
Chairman, Dominion Fuel Board.

Foreword

The most urgent phase of the fuel situation in Canada is that of a domestic fuel supply for the province of Ontario and the western part of the province of Quebec. Our dependence on anthracite of foreign origin with which to heat the homes of the people of this part of Canada has been one of the most unsatisfactory situations in the national life of the country, because within recent years the supply of this coal has been uncertain and will become more so as the reserves become exhausted. In addition, the price has shown a marked increase, and the quality has gradually deteriorated.

In searching for a solution to this unsatisfactory condition, the Dominion Fuel Board concluded that the most promising field for investigation lay in the substitution of by-product coke for anthracite in the area affected. The Board consequently engaged the services of Mr. J. L. Landt, an engineer who has had wide and varied experience, not only in investigations of this kind, but in the building and operation of plants for the manufacture of by-product coke, to investigate the feasibility of establishing coke industries at various points in the "Acute Fuel Area" when conditions appeared to warrant such being done. In doing so, the Board felt that several objects might be accomplished; namely—the extension of the market for our own coals from the Maritime Provinces, relief from sole dependence on Pennsylvania anthracite, and the provision of a substitute fuel of equal quality, but at a reduced price.

Additional information relating to certain special investigations made by Mr. Landt in several of our larger cities, which will be of value to those who may consider constructing plants at such points, is available on application to the Board.

The results obtained by Mr. Landt's investigation lead to the conclusion that all the objects indicated may be attained by the building of by-product coke ovens at points such as Montreal, Toronto, and other of our larger cities where the gas market is sufficiently large, and the accompanying report by him is presented with the hope and expectation that the data contained in it will be of value to those companies whose activities are concerned with the production and supply of fuel to the people of this part of Canada.

CHARLES CAMSELL,
Chairman, Dominion Fuel Board.

Letter of Transmittal

DR. CHARLES CAMSELL,
Chairman, Dominion Fuel Board,
Ottawa, Ontario.

SIR,—I beg to submit herewith my report on "Coke as a Household Fuel in Central Canada."

I desire to express my appreciation to you and the members of the Board—to Mr. B. F. Haanel, and Mr. C. P. Hotchkiss for valuable advice and assistance.

The gas companies, officials of the railways, fuel dealers, and financiers have shown great interest by their full and hearty co-operation, and it is my belief that great progress has been made and will continue to be made towards the solution of Canada's fuel problem.

Respectfully yours,

J. L. LANDT,
Consulting Engineer

CONTENTS

	Page
Foreword—Chairman, Dominion Fuel Board	ix
CHAPTER I	
Reasons for the investigation	1
CHAPTER II	
Domestic fuel situation in the "Acute Fuel Area"	3
Coal consumption—Canada	3
Anthracite situation in the United States	9
Bituminous coal fields in the United States	11
Coal fields of Canada	12
CHAPTER III	
Domestic coke	19
Marketing domestic coke	23
Coke sizes	26
Screen sizes	26
Subdivision of coke	27
CHAPTER IV	
Localities investigated	29
CHAPTER V	
Market for coke	34
Domestic	34
Industrial	36
CHAPTER VI	
Market for gas	38
CHAPTER VII	
By-products	44
Ammonia	44
Light oil	46
Tar	48
Breeze	48
Yields of by-products	50
CHAPTER VIII	
Manufacture of gas	53
By-product oven, retort, water gas	53
Liquid purification	65
CHAPTER IX	
By-product coke ovens	66
Semet-Solvay oven	69
Wilputte oven	79
Koppers oven	83
Foundation oven	84
Roberts oven	84
Piette oven	87
CHAPTER X	
Blue gas and producer gas	93

CONTENTS—Continued

PAGE

CHAPTER XI

Recovery systems.... 99

CHAPTER XII

Typical plant.... 110
By-product coke ovens at Hamilton.... 117

CHAPTER XIII

General conclusions: ovens.... 127

CHAPTER XIV

Duty on coal.... 131

CHAPTER XV

Transportation.... 132
Rates.... 132

CHAPTER XVI

Summary.... 136

CHAPTER XVII

Conclusions.... 139

Illustrations

Plate I. Coal products tree.... Frontispiece
II. Bird's-eye view of Wilputte by-product coke oven plant.... xviii
III. Solvay oven battery.... 5
IV. Koppers coke plant—Bethlehem Steel Co., South Bethlehem, Pa.... 7
V. Solvay battery—view from front.... 13
VI. Largest coal-washing plant in the world: exterior view.... 17
VII. Largest coal-washing plant in the world: interior view.... 18
VIII. Coke side of Wilputte ovens.... 20
IX. Discharge side of Solvay battery.... 22
X. Coke wharf, Toledo, Ohio.... 25
XI. Typical pump house installation.... 28
XII. Wilputte ovens—pusher side.... 37
XIII. Interior of Wilputte by-product building.... 40
XIV. Sulphate storage room.... 43
XV. Typical installation of grid scrubbers.... 45
XVI. Typical installation of stills.... 47
XVII. Cooling coils.... 49
XVIII. Condensing coils.... 51
XIX. A and B. Model, typical "D"-shape gas bench.... 54
XX. U.G.I. intermittent vertical retort with detached producer and waste heat boiler.... 56
XXI. A and B. Model, Dods gas oven.... 59
XXII. Discharge side, Solvay ovens.... 61
XXIII. Top, Solvay ovens.... 64
XXIV. Top, Wilputte ovens.... 67
XXV. A and B. Model, Otto-Hoffman oven.... 68
XXVI. A, B, and C. Model, Koppers original patent.... 72
XXVII. A and B. Model, Solvay original patent.... 73
XXVIII. A and B. Model, Solvay original patent.... 74
XXIX. A and B. Model, Solvay double-pass regenerator oven.... 75
XXX. A and B. Model, Solvay vertical sections.... 76

Illustrations—Continued

			Page
Plate	XXXI.	A and B. Model, Solvay single-pass regenerator oven	77
	XXXII.	A and B. Model, vertical sections	78
	XXXIII.	Picture drawing, Wilputte oven	79
	XXXIV.	A and B. Model, Koppers oven	80
	XXXV.	A and B. Model, Koppers new combination oven	81
	XXXVI.	American coke oven, Foundation Oven Corporation	86
	XXXVII.	Roberts oven—American Coke and Chemical Company	88
	XXXVIII.	View of battery, new Koppers ovens	92
	XXXIX.	Typical installation cooling coils and scrubbers	95
	XL.	Distilling columns	98
	XLI.	Ammonium sulphate plant	100
	XLII.	Interior by-product building, Cambria plant, Bethlehem Steel Company	102
	XLIII.	Interior, by-product building, Sparrow Point plant, Bethlehem Steel Company	104
	XLIV.	Light oil stills	105
	XLV.	Boiler stills	106
	XLVI.	View of still tops, cooling rings	108
	XLVII.	Koppers ovens at Youngstown Sheet and Tube Company	112
	XLVIII.	Model, new coke plant at Hamilton	119
	XLIX.	New coke plant at Hamilton	121
	L.	Koppers arrangement for firing ovens with either producer or coke-oven gas	129
	LI.	Coal handling and preparing equipment	130
Figure	1.	Annual consumption of coal and coke in Canada since 1901	2
	2.	Coal and coke curve	15
	3.	Effect of gas price on consumption	39
	4.	Products derived from coal	46
	5.	U.G.I. intermittent vertical retort with attached producer	55
	6.	Solvay flue system	70
	7.	Flue system: Wilputte regenerative coke oven	78
	8.	Flue system: Wilputte gas oven	78
	9.	Flue system: Koppers regenerative coke oven	82
	10.	Flue system: Koppers regenerative coke and gas oven	82
	11.	Flue system: Koppers new combination oven	82
	12.	Flue system: Foundation oven	85
	13.	Heating system: Roberts oven	86
	14.	Heating system: Roberts oven	86
	15.	Flue system: Piette ovens	88
	16.	Amounts of auxiliary fuels required to heat ovens—other data	97
	17.	Flow diagram of Koppers benzol recovery plant	103
	18.	Flow sheet, Hamilton By-product Coke Company, Limited	118

Tables

			Page
Table	I.	Coal consumption in Canada: years	3
	II.	Coal consumption in Canada, 1923: provinces	4
	III.	Total coal production in Canada	4
	IV.	Bituminous coal shipped to Canada from United States	6
	V.	Bituminous coal shipped to Canada from United States	6
	VI.	Anthracite coal shipped to Canada from United States	8
	VII.	Coke shipped to Canada from United States	8
	VIII.	Summary: exports from United States to Canada	8
	IX.	Fuel consumption, other statistics—London-Windsor area	30

Tables—Continued.

X.	Fuel consumption, other statistics—Port Colborne area	30
XI.	Fuel consumption, other statistics—Ottawa area	31
XII.	Fuel consumption, other statistics—Toronto area	31
XIII.	Fuel consumption, other statistics—Hamilton area	32
XIV.	Fuel consumption, other statistics—Montreal area	32
XV.	Fuel consumption, other statistics—Quebec area	33
XVI.	Manufactured gas: city plants in Canada	41
XVII.	Comparison of costs: by-product coke plant and retort plant	57
XVIII.	Characteristics of common industrial gases	62
XIX.	Quality of gas evolved by coke oven: average hourly analysis	63
XX.	By-product coke ovens in North American continent	89
XXI.	Typical plant: estimate for cost and returns of operation	115
XXII.	Manning of 1,000-ton plant	116
XXIII.	Output of proposed new by-product coke plants—other data	137
XXIV.	By-product coke ovens, Canada: approximate figures for establishment of the industry	138

Bird's-eye view of Wilputte by-product coke oven plant, Hamilton. Quenching hood and water tower in left foreground; by-product building in right background.

Coke as a Household Fuel in Central Canada

CHAPTER I

REASONS FOR THE INVESTIGATION[1]

During the past few years, especially during the period 1918-1922, recurrent fuel shortages have seriously affected central Canada. A great deal of inconvenience and discomfort, if not actual suffering, was experienced, in the provinces of Ontario and Quebec. Coal is absolutely essential to the maintenance of life, especially to any nation situated in northern climates. Thus, Canada has been most seriously affected when the domestic supply was cut off. The provinces of Ontario and Quebec, which are devoid of coal measures, are dependent, for industrial and domestic fuels, upon outside sources, Nova Scotia bituminous coals or western Canada coals. It may, reasonably, be stated that Canada has no serious domestic fuel problem other than the one in the provinces of Ontario and Quebec which have thus come to be known as the "Acute Fuel Area."[2]

There is an abundant supply of coals in western Canada, and strenuous efforts are being made by operators of Alberta mines to place their coals on the market in the "Acute Fuel Area" for domestic needs. From a strictly economic standpoint, it would appear foolish to attempt to transport coal or lignites some 2,000 miles under a subsidized freight rate, when the coal fields of Nova Scotia with cheaper water transportation, and the coal fields of the United States, are situated much nearer. At present, therefore, for convenience in discussing the fuel situation, it may be assumed that the sources from which the "Acute Fuel Area" will receive fuel for domestic purposes will be Nova Scotia and the United States.

---

[1] NOTE.—All tonnage calculations in this report are based on short tons (2,000 pounds), unless otherwise mentioned.

[2] See paper—"The Fuel Situation in Canada" by B. F. Haanel—delivered before Canadian Institute of Mining and Metallurgy—spring 1923.

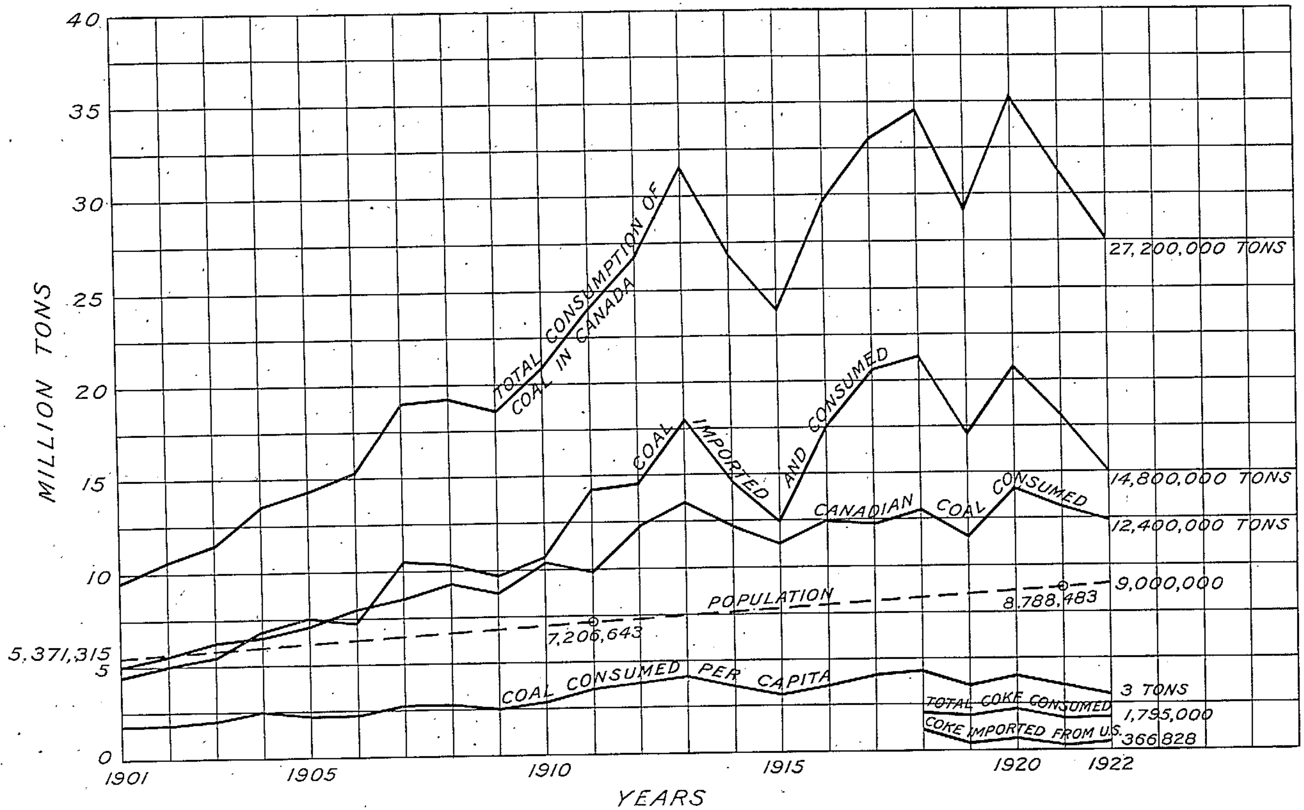


Figure 1. Annual consumption of coal and coke in Canada.

CHAPTER II

DOMESTIC FUEL SITUATION IN THE "ACUTE FUEL AREA"

In order to understand better the fuel situation in Canada, it will be well to look at the general situation and then to examine the conditions in Ontario and Quebec. Figure 1 gives a very comprehensive idea of the consumption of coal in Canada for all purposes, since 1901. The curves, applying particularly to the past few years, show in a broad sense the fluctuations in imports and consumption due to business depression, strikes, or other causes. These data have been gathered from various sources, chiefly from official statistics. Although all these figures are interesting, those in the following table have a more direct bearing on the domestic fuel situation and are very enlightening.

COAL CONSUMPTION IN CANADA

The estimated consumption of coal, based upon production, exports, and imports, as published by the Dominion Bureau of Statistics, is as follows:

Table I.—Coal Consumption in Canada: Years[1]

——	1918	1919	1920	1921	1922	1923
Anthracite	4,900,565	5,057,862	5,040,477	4,664,334	2,734,374	5,167,988
Bituminous	26,644,936	20,832,486	26,467,333	23,229,451	21,375,373	29,271,071
Lignite	3,226,331	2,941,471	3,696,327	3,280,052	3,486,526	3,584,426
Total tons	34,771,832	28,831,819	35,204,137	31,173,837	27,596,273	38,023,485

[1] NOTE:—All tables, calendar years or averages of calendar years.

Assuming that 99 per cent of the anthracite is used for domestic purposes, Canada burns from 4,000,000 to 4,500,000 tons of anthracite a year. The anthracite consumption has been fairly regular, but that of lignite for domestic purposes has been increasing, and in 1921 and 1922 amounted to above 2,000,000 tons each year.

Reports submitted by the retail dealers during past years show that the annual domestic consumption of fuel in Canada is from 6,000,000 to 6,500,000 tons per year.

The following table shows that in 1922 Ontario and Quebec consumed almost 93 per cent of the total anthracite.

Table II.—Coal Consumption in Canada 1923: Provinces

(Short tons)

Province	Anthracite	Bituminous	Lignite	Total
Nova Scotia	53,739	3,791,303	....	3,845,042
New Brunswick	90,343	795,020	....	885,363
Prince Edward Island	4,303	83,680	....	87,983
Quebec	1,816,409	4,700,770	....	6,517,179
Central Ontario	3,062,208	11,742,856	51,331	14,856,395
Head of lakes and Manitoba	138,414	2,537,958	701,615	3,377,987
Saskatchewan	2,291	121,192	1,338,610	1,462,093
Alberta	107	3,519,224	1,419,539	4,938,870
British Columbia and Yukon	174	1,979,068	73,331	2,052,573
Total tons	[1] 5,167,988	[2] 29,271,071	3,584,426	38,023,485

[1] Of which United States supplied 4,906,222 tons, and Great Britain 261,659 tons.
[2] Of which United States supplied 17,248,298 tons, and Great Britain 268,810 tons.

Any curtailment of anthracite has thus been a great factor in producing a serious situation in the "Acute Fuel Area."

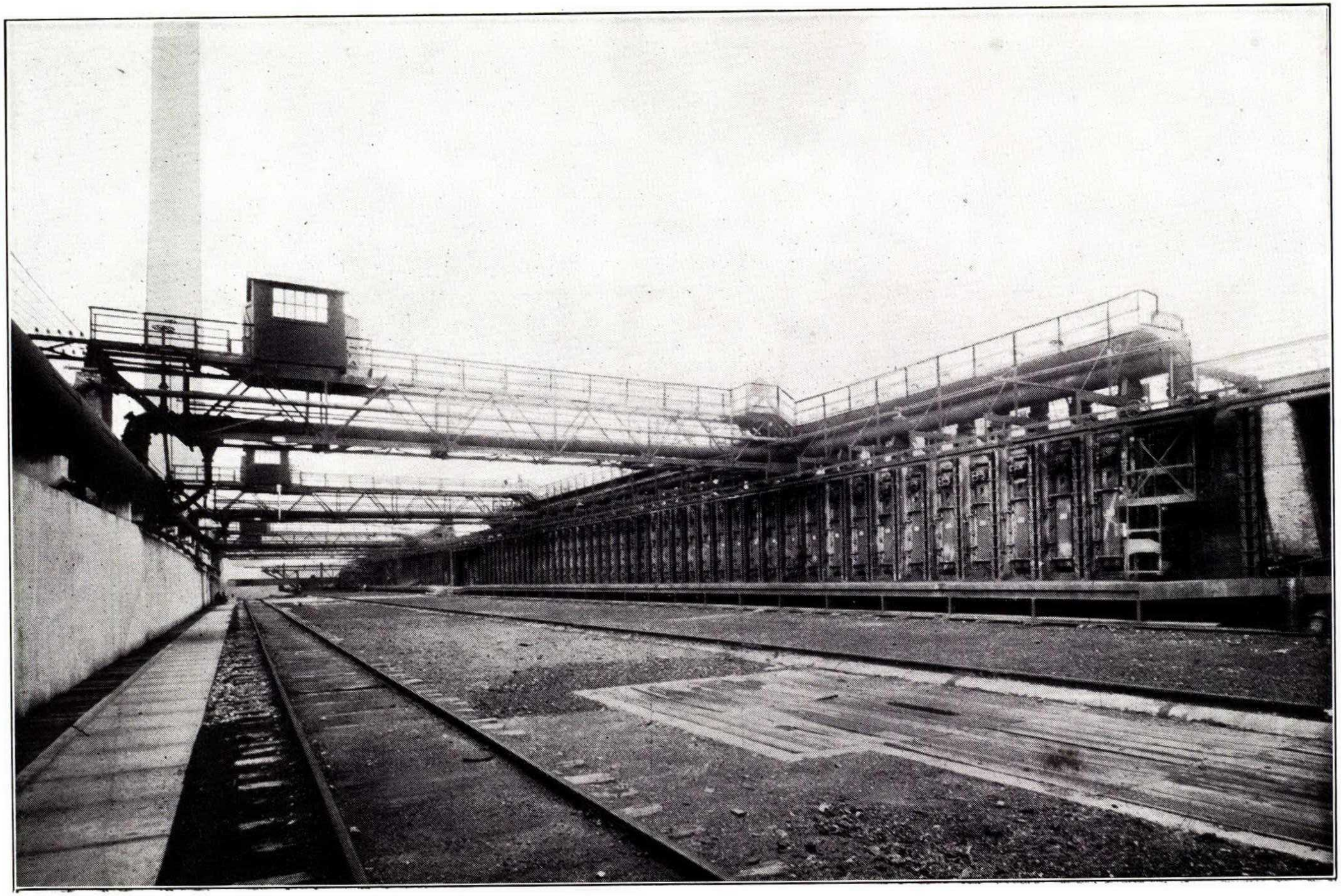
From Table III it will be seen that the coals classed as anthracite which are produced in Canada play a very small part in domestic consumption. Quebec and Ontario use none of the lignites, but depend mainly on imported anthracite for their domestic supply.

Table III.—Total Coal Production in Canada

(Short tons)

—	1918	1919	1920	1921	1922	1923
Bituminous	10,892,046	10,629,697	13,122,924	11,680,477	11,630,488	13,408,369
Anthracite	85,579	73,839	127,513	96,964	40,417	107
Lignite	2,941,471	2,882,710	3,696,327	3,280,052	3,486,526	3,582,095
Total tons	13,919,096	13,586,246	16,946,764	15,057,493	15,157,431	16,990,571

The influence that bituminous coals exert in the domestic fields is somewhat problematical, for in times of anthracite shortage many bituminous coals, such as Pennsylvania, Pocahontas, and other low and high volatiles, are used as substitutes. Bituminous coal plays a very important part in controlling the price of coke, and the distribution and prices of such coal are shown in Tables IV and V.



Solvay oven battery.

Table IV.—Bituminous Coal Shipped to Canada from United States

(Gross tons per U.S. Foreign Commerce and Navigation)

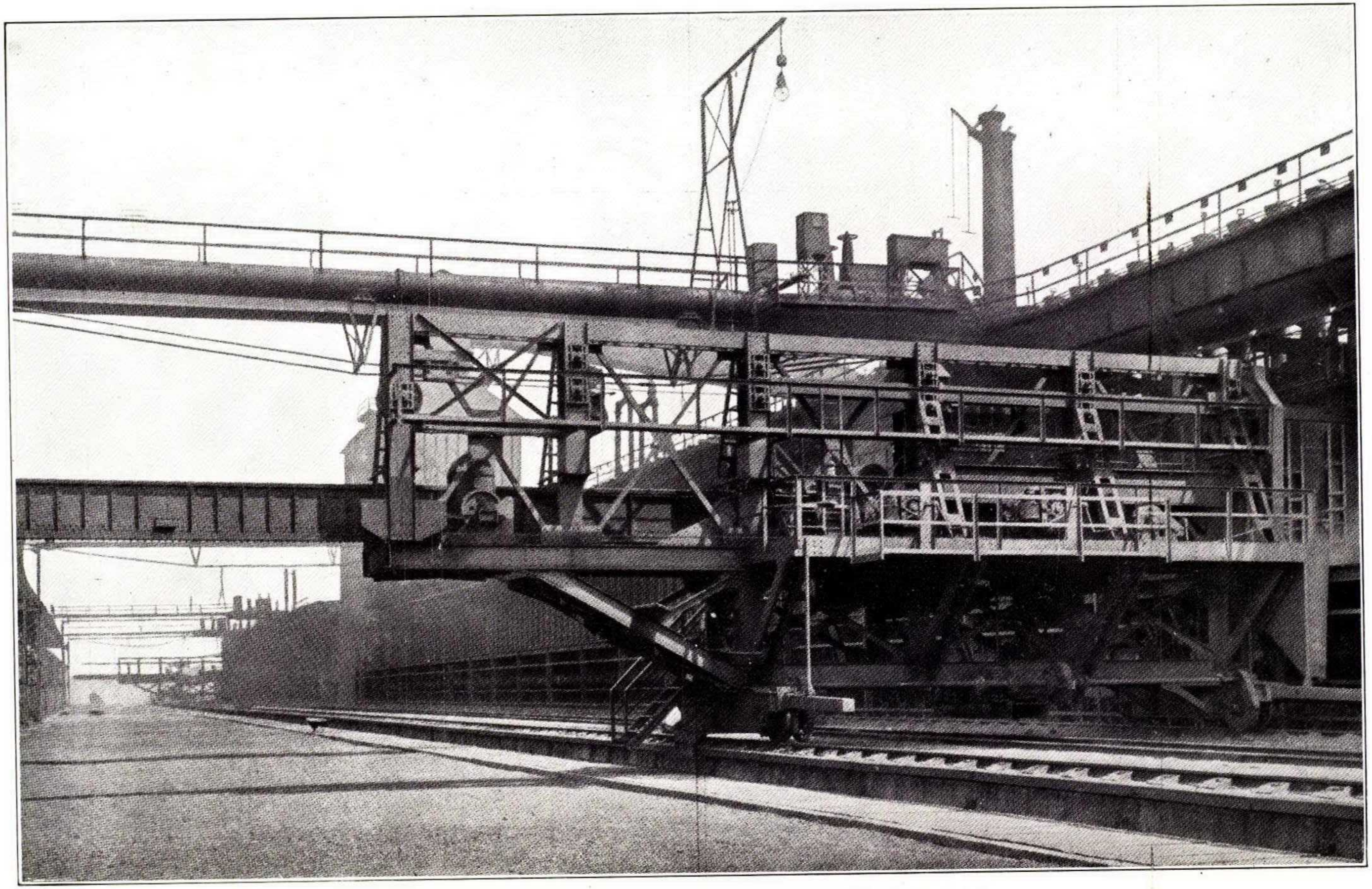
Customs districts	1918	1919	1920	1921	1922	1923
Buffalo	3,591,277	2,193,852	3,219,005	2,926,663	2,690,841	3,453,419
Dakota	20,365	34,064	21,174	52,247	23,170	78,557
Duluth-Superior	26,417	43,637	81,104	106,357	55,493	55,731
Michigan	1,837,875	1,013,014	1,591,462	1,196,883	1,250,094	1,719,923
Ohio	7,261,663	5,260,883	6,393,548	5,210,272	3,822,580	6,242,068
Rochester	1,076,474	488,156	898,772	418,571	451,317	655,366
St. Lawrence	2,239,737	1,574,782	2,215,670	1,919,168	1,274,161	2,483,862
Vermont	125,717	40,798	65,084	27,149	6,765	14,216
Maine and New Hampshire	71	11,879	302	218	269	10,293
Massachusetts	1,489	2,489	40	3,100	25	303
Montana and Idaho	....	....	....	6,630	....	....
Total above districts	16,181,085	10,663,554	14,486,161	11,867,258	9,574,715	14,713,738
Total to Canada	16,191,364	10,669,490	14,491,252	11,961,405	9,675,310	14,713,738

Table V.—Bituminous Coal Shipped to Canada from United States—Average Prices at Border per Gross Ton

—	1919	1920	1921	1922	1923
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
January	3 72	4 23	6 41	4 87	6 28
February	3 67	4 22	6 03	5 30	6 49
March	4 33	4 24	5 88	5 24	6 46
April	4 28	4 50	5 29	4 51	6 02
May	3 73	4 63	4 90	4 48	5 26
June	3 62	5 26	4 41	5 09	5 04
July	3 61	6 22	4 46	5 36	4 92
August	3 67	6 66	4 24	6 81	4 87
September	3 71	6 72	4 60	6 70	5 04
October	3 74	6 79	4 55	6 23	5 07
November	4 01	6 60	4 83	6 47	4 91
December	3 94	6 52	4 62	6 41	5 14

These prices are the average for all bituminous grades, including steam, coking, and gas coals. A good by-product coking coal costs 15 to 25 cents more per ton at the mine than a good steam coal, and a good gas coal costs from 50 to 75 cents more than the coking grades under normal conditions. At present, prices are somewhat distorted, with gas coal selling for far more than seems warranted.

Tables VI, VII, and VIII show the imports of anthracite and coke from the United States into Canada by districts and totals.



Koppers coke plant, Bethlehem Steel Company, South Bethlehem, Pa.

Table VI.—Anthracite Coal Shipped to Canada from United States

(Gross tons per U.S. Foreign Commerce and Navigation)

Customs districts	1918	1919	1920	1921	1922	1923
Buffalo	2,331,662	2,341,091	2,341,556	2,261,386	1,233,731	2,339,029
Dakota	1,654	4,742	6,931	23,734	9,098	36,044
Duluth-Superior	335	16,634	6,694	8,058	3,573	20,251
Michigan	11,574	530	1,401	2,884	3,417	7,047
Ohio	34,925	56,264	24,907	22,042	11,975	35,474
Rochester	608,121	514,817	550,231	381,667	244,502	457,530
St. Lawrence	1,291,585	1,335,903	1,437,883	1,205,777	731,269	1,470,640
Vermont	20,424	21,086	21,147	18,148	7,024	12,610
Maine and New Hampshire	9,227	1,312	753	773	725	364
Massachusetts	....	2,596	1,051	878	636	362
Total above districts	4,309,507	4,294,975	4,392,554	3,925,347	2,245,950	4,379,351
Total to Canada	4,379,177	4,344,564	4,435,966	4,035,014	2,296,830	4,379,351

Table VII.—Coke Shipped to Canada from United States

(Gross tons per U.S. Foreign Commerce and Navigation)

Customs districts	1918	1919	1920	1921	1922	1923
Buffalo	517,296	191,842	278,892	94,087	184,817	357,676
Dakota	2,353	4,891	4,220	7,207	25,307	22,624
Duluth-Superior	551	664	4,446	1,299	2,999	2,584
Michigan	335,744	92,776	200,556	77,594	129,476	173,189
Ohio	159,164	21,135	16,473	5,482	3,356	58,588
Rochester	5,613	3,479	3,217	891	245	1,580
St. Lawrence	33,745	37,964	17,476	14,795	8,998	33,702
Vermont	4,544	1,252	2,403	1,548	8,073	14,016
Maine and New Hampshire	1,500	1,029	1,430	308	2,466	4,137
Massachusetts	....	....	....	....	....	25
Total above districts	1,060,510	355,032	529,113	203,211	365,737	668,121
Total to Canada	1,071,430	356,333	530,485	203,251	366,811	[1]668,121

[1] It is significant that imports of coke for 1923 were almost double those of 1922.

Table VIII.—Summary: Exports from United States to Canada

(Gross tons per U.S. Foreign Commerce and Navigation)

—	1918	1919	1920	1921	1922	1923[1]
Anthracite	4,379,177	4,344,564	4,435,966	4,035,014	2,296,830	4,329,394
Coke	1,071,430	356,333	530,485	203,251	366,811	665,247
Total	5,450,607	4,700,897	4,966,451	4,238,265	2,663,641	4,994,641
Bituminous coal	16,191,364	10,669,490	14,491,252	11,961,405	9,675,310	15,048,444

[1] Saward's Annual.

Table VIII (Continued)—United States Exports of Coal and Coke to Canada 1922 and 1923: Calendar Years

(Gross tons per U.S. Foreign Commerce and Navigation)

—	Anthracite		Bituminous		Coke	
	1922	1923	1922	1923	1922	1923
To:						
Maritime Provinces	88,998	124,526	59,649	143,124	4,382	12,410
Quebec and Ontario	2,194,814	4,270,718	9,541,518	14,764,913	333,808	630,498
Prairie Provinces	12,864	55,250	60,877	118,205	28,230	25,089
British Columbia and Yukon	154	3,825	13,266	22,202	346	56
	2,296,830[1]	4,454,319	9,675,310[1]	15,048,444	366,811[1]	668,053

[1] Saward's Annual.

The domestic fuel consumption of Ontario and Quebec is about 4,000,000 tons a year, made up as follows:

	Tons
Anthracite	3,500,000
Coke (imported)	150,000
Coke (gas works)	200,000
British coals	100,000
Lignites and others	50,000
	4,000,000

It can readily be understood why serious suffering and discomfort were prevalent in the "Acute Fuel Area" when more than half the supply was cut off and there were no other fuels available.

Manitoba is using more and more Alberta coals for all purposes. Saskatchewan is using lignites, British Columbia has her own coal. The Maritime Provinces have their own coal fields and in addition can import from Great Britain.

Almost all the anthracite and coke imported from the United States was consumed in Quebec and Ontario, so that by-product coke plants wisely situated in those provinces would have a potential market of from 3,000,000 to 4,000,000 tons annually.

ANTHRACITE SITUATION IN THE UNITED STATES

In order to understand the fuel situation in Canada, especially in the "Acute Fuel Area," the reader should have a general idea of the conditions governing the production and sale of fuel in the anthracite and bituminous coal fields of the United States from which Canada draws part of her coal supply.

The recurring fuel shortages in Canada, especially since 1918, were not due to a lessened production of bituminous coals in the "States," but to industrial disorders in the anthracite field. Strikes almost always occur in regions where the demand keeps pace with production, where it is impossible to increase production to meet the demand, or where curtailment in many cases means actual suffering. Realizing these facts, the miners are insistent, and the operators adamant, and the public suffers.

The life of the anthracite fields in Pennsylvania is estimated, at the present rate of production, at 75 to 100 years. Canada must, therefore, look for some substitute for anthracite, since exports of this coal from the United States cannot continue indefinitely.

Furthermore, it is very improbable that anthracite coal will ever become much cheaper than at present because: there is no over-production; there is no irregularity of production (except as occasioned by strikes, etc.); overhead and production costs are mounting; resources are rapidly diminishing; an embargo may be proclaimed.

Anthracite is in steady demand the whole year round; in winter moving by rail to points comparatively near the mines, and in summer to more remote points both by rail and through the Great Lakes by boat. Owing to the fact that there is no over-production, the mines work full time winter and summer; nor is the demand affected by business conditions, as is the market for bituminous coal, of which 90 per cent is consumed in industries.

The mining of anthracite is a very costly and elaborate undertaking, the coal being from 500 to 2,000 feet deep and the larger part of it being mined at 1,000 feet. Figures recently published show that for each ton of anthracite produced 11 tons of water are pumped from the mine, half a ton of rock and dirt is hoisted, and 7 feet of timber is used. Each minute in the day 2 tons of air is forced into the mines for ventilation.

The anthracite field lies in a comparatively small area in Pennsylvania and is divided into the Northern, Middle, and Southern fields, or, as generally termed, the Wyoming, Lehigh, and Schuylkill regions.

Mining in the Wyoming and Lehigh fields is relatively simple, but in the Schuylkill field where steeply pitching, overturned, and badly faulted beds of varying thickness occur, the engineering problems are tremendous. The two former fields have limited reserves; the last contains almost all the coal that will be produced in the next seventy-five years. This means a lower yield of domestic coal or at least a larger production of steam sizes, which must compete in price with bituminous coals.

There are approximately 150,000 men employed in the anthracite industry, but only about 42,000 of these are actually mining the coal. The rest serve the needs of the miners. In 1922 the cost of producing 1 ton of anthracite stove size was approximately as follows:

	Per gross ton	Per net ton
Labour	$5 30	$4 73
Supplies	1 35	1 21
General expenses	0 75	0 67
Total mine cost	7 40	6 61
Operators profit and royalties	0 70	0 62
Price f.o.b. mines	8 10	7 23

The producer charges more for the prepared sizes to offset the prices received for the steam sizes. The average profit of the operator is somewhere between 40 cents to 60 cents per ton on total production, but even if this profit were eliminated the price to the consumer would be reduced less than 5 per cent after freights and dealer's margin have been added.

As the supply of anthracite diminishes prices will become so prohibitive as to place it altogether in the luxury class. There seems little likelihood of reducing the cost of anthracite at the mines even if the industrial situation be improved by government regulation or possibly government ownership. Miners' wages—the main factor—are not likely to come down, and with high transportation rates and dealers' margin, the ultimate price will turn the public to cheaper fuels.

BITUMINOUS COAL FIELDS IN THE UNITED STATES

There are in the United States about 8,000 bituminous coal mines, with an estimated annual capacity of 850,000,000 to 1,000,000,000 tons, which is 300,000,000 to 450,000,000 tons more than the yearly consumption. The present bituminous fields of Pennsylvania, West Virginia, Kentucky, Ohio, and Illinois have sufficient reserves of coking coals to last 1,000 years or more.

The condition of the bituminous industry where the mines are operating only one-half to three-fourths of the time has turned attention in the United States and Canada towards coke as a solution of the domestic fuel problem. As a matter of patriotic interest, engineers have been increasingly insistent that the wasteful methods of coking coal be eliminated, and how successful have been their efforts can best be judged by the fact that of the 36,526,000 tons of coke produced in the United States in 1922 only 8,033,000 tons were produced from beehive ovens.

In every district in the bituminous fields good coking coals are available; of these, a large quantity, although unsuitable for metallurgical coke, are ideal for domestic coke, and being in less demand, are sold at lower prices.

Over-development of these fields induces the belief that for a great many years prices, except as affected by business conditions, labour disorders, etc., are unlikely to rise. Canada's demand, being so small compared with the potential output of the states mentioned, cannot materially diminish the supply.

There is, however, one class of bituminous coal—the so-called gas coal—used extensively in the gas industry, which may be difficult to secure in adequate quantity.

Bituminous coals may be classified according to the amount of volatile matter present, as follows:

14–18 per cent volatile matter	low volatile
18–25 " "	medium volatile
25–35 " "	high volatile
35–up " "	high volatile or gas coals

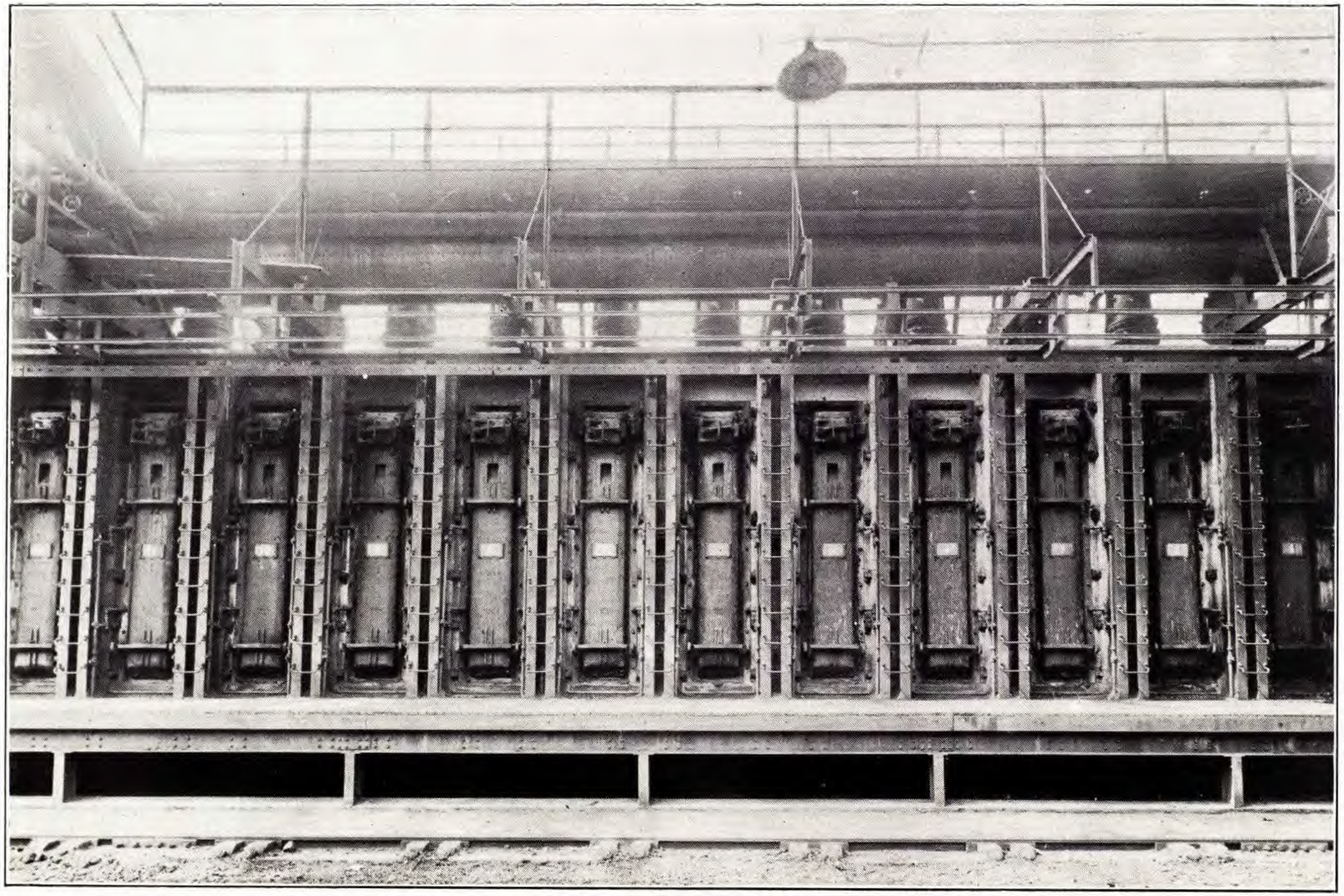
Most of the good grades of gas coals used in central Canada come from the Westmoreland, Youghiogheny, and Clearfield districts and are very closely controlled by small groups of operators. This control has maintained prices far above those asked for coking or other bituminous coals, and there seems little chance of these prices being lowered. The by-product oven for manufacturing domestic coke is independent of either gas or low volatile coals, but can take advantage of market conditions, all of which means cheaper fuel to the ultimate consumer.

COAL FIELDS OF CANADA

Canada, as previously stated, is amply supplied with coal in the eastern and western provinces. Nova Scotia can increase her output well above the 6,000,000 ton mark, but it may be difficult for her to meet all future demands. New Brunswick, too, is producing coals for various purposes and is developing the North Minto district. These fields have good coking coals, part of which can be marketed for coking purposes as far east as Montreal. West of Montreal, however, the coal must be transferred to smaller vessels, causing transportation charges to mount rapidly. If the waterways were developed so as to admit of large vessels from Nova Scotia entering lake Ontario, these coals could probably be marketed in Hamilton, Toronto, and other cities bordering on that lake. Present rail freights exclude these coals from markets west of Montreal.

British Columbia has coal suitable for all purposes. Alberta is producing fuel for her own needs and for those of Manitoba and Saskatchewan. The development of numerous new mines in the western coal fields has created another problem, that of marketing the full output.

The sources of supply for coking coals for use in the "Acute Fuel Area" are the United States and Nova Scotia. Nova Scotia has plenty of coals which will produce good coke for domestic purposes and a more limited supply which will produce a good metallurgical coke. A coke suitable for metallurgical purposes is not necessarily a suitable domestic coke. The determining factor is the fusibility of the ash. For metal-



Solvay battery, view from front.

lurgical purposes, coke containing a low fusible ash is desirable, as the liquid ash, or, as commonly known, slag, can be tapped from the furnaces and easily disposed of, but the domestic user experiences difficulty with low fusible ash, which forms troublesome clinkers.

The Mines Branch, Department of Mines, will shortly issue a report on the coals of New Brunswick and Nova Scotia which will be of considerable interest from the standpoint of the by-product coke oven and will enable an intelligent selection of coals to be made for various purposes.

The coals of New Brunswick are high in both ash and sulphur. The high ash in these coals means a high ash coke (probably 25 to 30 per cent ash) which is undesirable, especially if the ash be low fusing. A high sulphur content is also undesirable, for some of the sulphur in any carbonization process passes off in the gas as a sulphur compound, and must be eliminated before the gas can be sold for domestic purposes. Coals should not have a sulphur content above 2 per cent if a good city gas is to be made without increasing unduly the cost of purification.

As a rule sulphur exists in the coals of Nova Scotia and New Brunswick in the form of pyrites (Fe S) and the iron of the pyrites unites with the silica of the ash, forming ferrous silicate—a substance of extremely low fusibility. Thus ash of this character, in addition to sulphur, may make the coal unsuitable for carbonization. High ash content also detracts from the heating value of the coke. In order to give an approximate idea of the heating value of fuels, Figure 2, the coal and coke curve, is presented. From this curve, with the proximate analyses of the fuel given, a very close approximation of the heating value in B.T.U.'s may be obtained.

The coals of Nova Scotia vary greatly in character, some being high in ash, low in sulphur, and vice versa—others high in both ash and sulphur, and others low in both. The fusibility of the ash also varies. But it is apparent that certain of these coals can be used. The ash should not run below 2,200°F. in fusibility in fuels to be used for domestic purposes, and although some of the Nova Scotian coals run much lower than this they might make a very satisfactory domestic coke. The Mines Branch has conducted a series of tests at the new coke oven plant at Hamilton—coking Nova Scotia and New Brunswick coals.

There is no reason why the coals of eastern Canada should not produce a satisfactory product that can be profitably marketed, providing the price of the coal compares favourably with that of other coals. In other words, if coke produced from these coals can be sold at a price which will give heat units equivalent to other fuels, it will rapidly come into favour. It may become economical and feasible to wash some of these coals so as to reduce the ash and, chiefly, the sulphur content. The most important

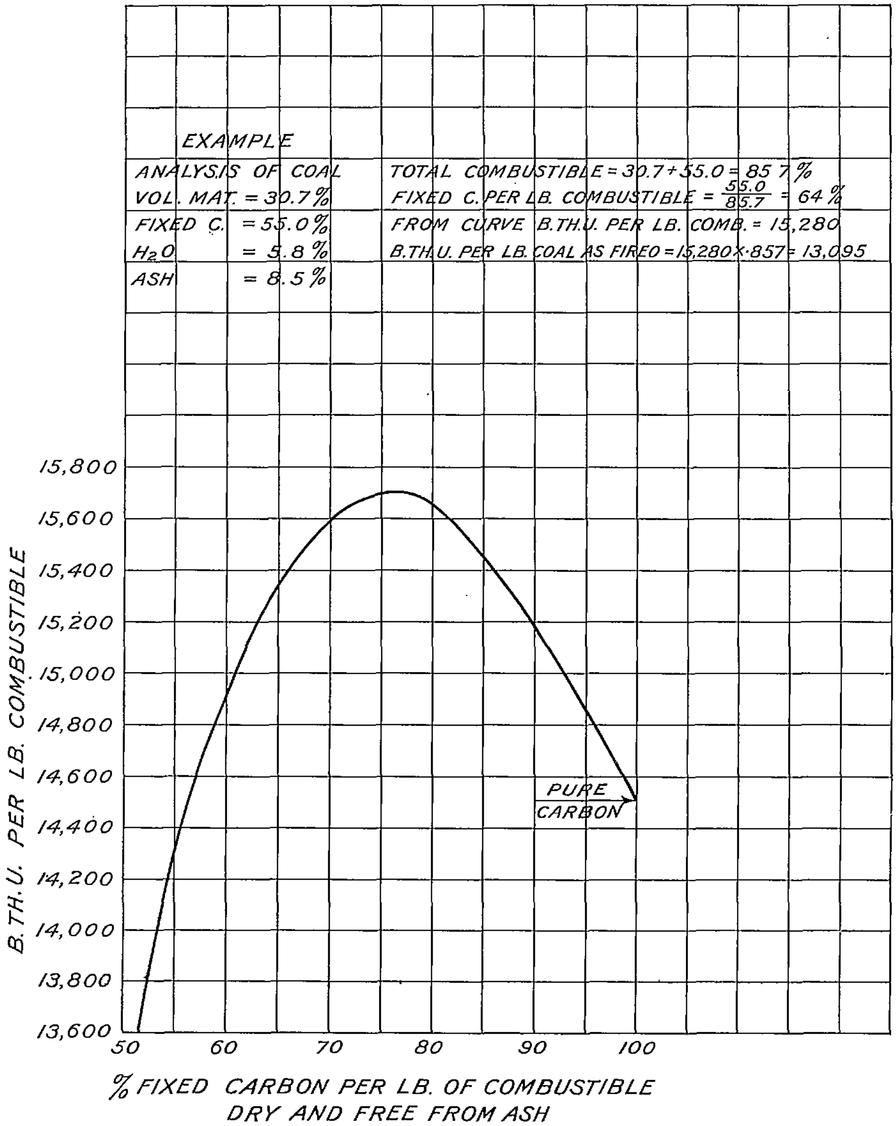


Figure 2. Coal and coke curve for determining approximate heating value from proximate analysis.

impurities in coke are ash, sulphur, and phosphorous. The whole of the ash in coal carbonized remains in the coke. The sulphur in the coal is divided into two classes: (a) fixed sulphur (chiefly $CaSO_4$) which remains in the coke, and (b) free sulphur (chiefly pyrites) which is evolved in the gas in the form of H_2S, C_2S, etc. All the phosphorous remains in the coke, but this is unimportant in domestic coke.

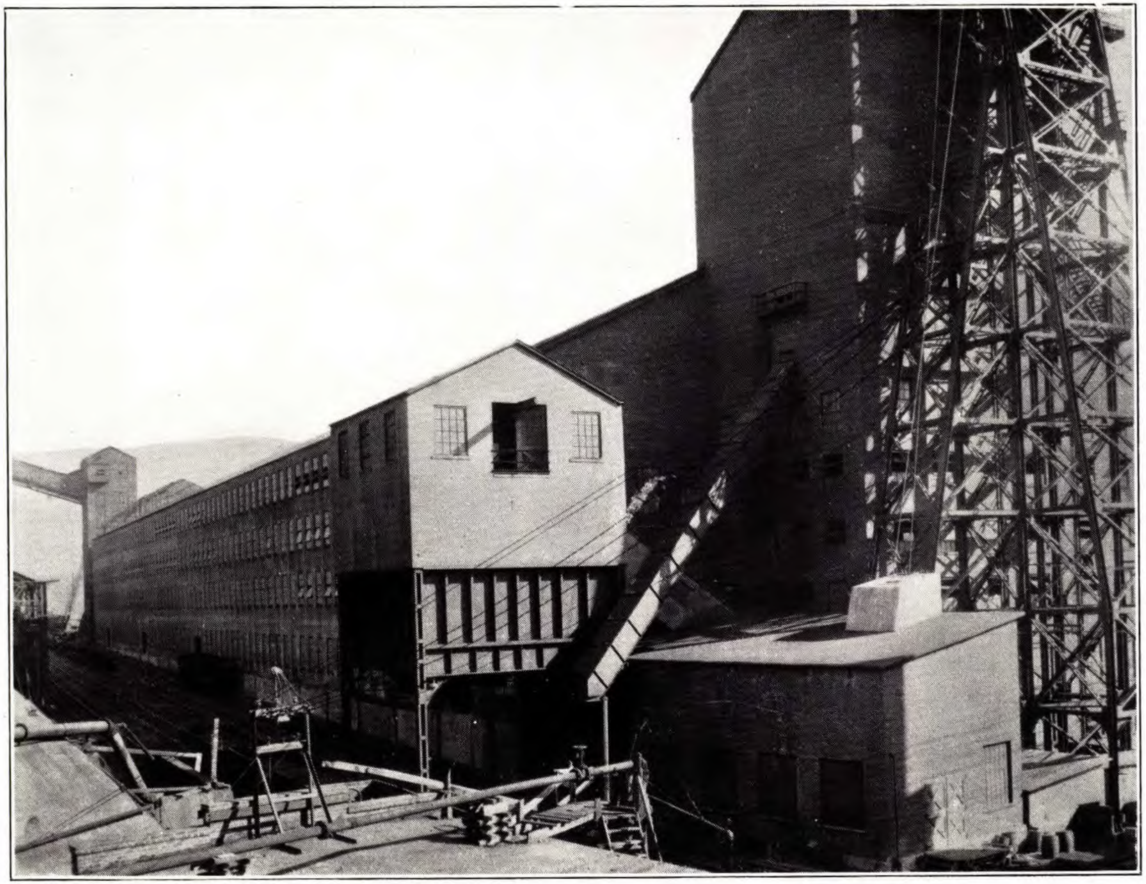
Coal-washing plants can be installed, maintained, and operated at a cost of approximately 50 cents per ton, including losses. The washed coal must be moved during the summer on account of the water content, but this is not serious, as most of the coal should move when vessel transportation can be taken advantage of.

The washing of coals will become of increasing importance, and a description of a recent notable installation of a washing plant will, therefore, prove of interest.

Plates VI and VII show views of the coal-washing plant of the Bethlehem Steel Company at the Cambria plant, Johnstown, Pa. This plant, the largest of its type, has a capacity of 4,000 gross tons per 10-hour day. It was designed to remove about 20 per cent of the ash and 50 per cent of the sulphur, and the draining pits are so arranged that only 6 per cent to 8 per cent water remains in the coal. Tests have shown that these figures have been consistently maintained or even exceeded.

The mine-head shaft delivering the coal directly into the washing plant is 405 feet high and carries a double skip hoist. Each skip lifts 8 tons at a time and 6,000 tons can be lifted per 10-hour day. From the skip the coal passes through two 12-foot by 17-foot Bradford breakers, whence the coal is loaded into cars for shipment or sent to the adjacent washery. This building is 565 feet long by 100 feet wide and contains seventy-two Campbell washing tables which receive the raw coal and deliver it into ten draining pits, which have a combined capacity of 16,000 tons. From the pit the coal is reclaimed by two bridges with continuous bucket diggers and is sent to the mixing plant, where it is mixed as desired for use in the coke ovens. Refuse from the washing tables falls into collector bins and thence into railway cars. The refuse is sent to the boiler house and used with coke breeze under the boilers. Nine men can efficiently operate this plant. The washing loss runs from 12 per cent to 15 per cent by weight, but only 5 per cent to 7 per cent of combustible is lost.

PLATE VI



Largest coal-washing plant in the world; exterior view. Note mine shaft head at right.

Largest coal-washing plant in the world: interior view. Note drainage bins.

CHAPTER III

DOMESTIC COKE

Coke is the solid residue resulting from the dry distillation of bituminous coking coals. The change from coal to coke can be illustrated by showing a typical analysis of a by-product coking coal and the coke resulting therefrom.

Proximate Analysis

—	Coal as charged	Commercial coke
	Per cent	Per cent
Water	2·0	3·00
Volatile matter	30·0	0·75
Fixed carbon	58·2	83·60
Ash	8·0	11·40
Sulphur	1·8	1·25
	100·0	100·00

It will be noted that in coking the coal, almost all the volatile matter, which is the smoke-producing element in bituminous coal, has been driven off in the form of gas and tar oils. The sulphur has been reduced and the carbon content increased. The ash has increased in proportion to the volatile matter in the coal. From the gas, which was the volatile constituent of the coal, many valuable products are obtained. The coking of coal conserves the by-products and also releases the carbon, which is valuable only for the purpose of producing heat.

Coke is subject to a great many variations and the quality depends to a great extent upon human skill. By-product coke, produced by latest methods, makes a domestic fuel of higher grade than the anthracite which is marketed today, and is a fuel excellently suited for burning in present equipment in general use.

The coking process was at first conducted in bee-hive ovens. The product from these is satisfactory for certain purposes (metallurgical), but the process is very uneconomical, on account of the wasting of the gases and their valuable by-products, as well as part of the fixed carbon of the coal charge. This waste led to the development of the modern by-product oven, which affords the possibility of using (by mixing) a great variety of coals, and yet produces a product of uniform quality. The by-product process is more flexible in the coking operation and is capable of improving the quality of the coke by variations of temperature and coking time to an extent impossible in either beehive or retort practice.

View along coke side of Wilputte ovens, showing the coke-quenching car, coke guide, door machine, and clay carrier.

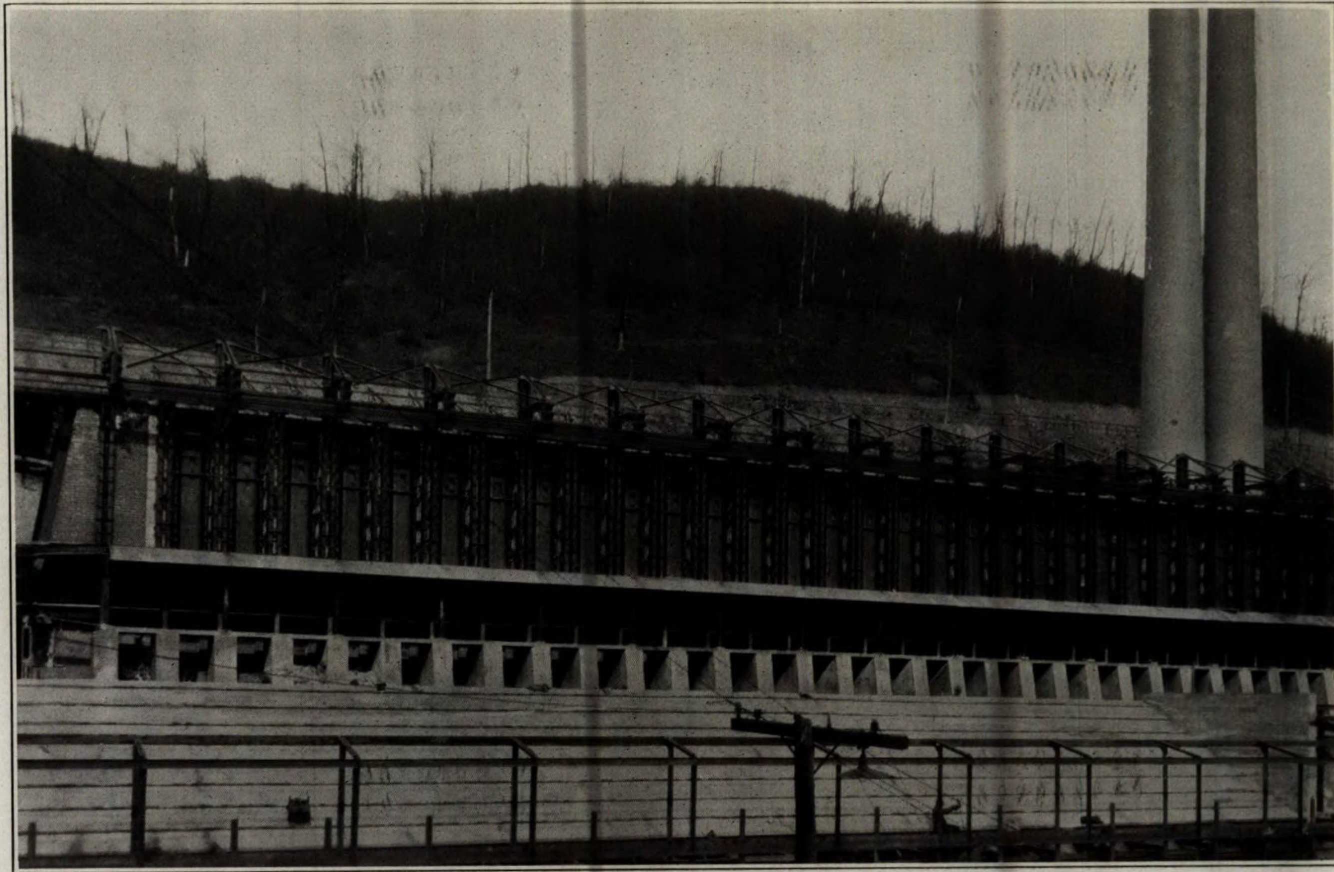
By-product coke is harder than that produced in the retort, stands handling better, and is, physically, as near as possible to anthracite. From a given coal, retort and by-product coke are almost alike chemically, but the vast difference in physical characteristics makes by-product coke more suitable for the domestic equipment now in use.

Coke as a domestic fuel is no longer a matter of conjecture. People have been educated to its advantages and it has become a favourite household fuel. Manufacturing processes have been continually improving during the past few years. At least five cities in the New England States (where, due to a shortage of anthracite, as much if not more suffering occurred than elsewhere) are negotiating for by-product coke plants as they are determined to make themselves independent of anthracite. Providence, R.I., already has a plant, its output finding a ready market and its development dependent only on the demand for gas.

Utica, N.Y., is constructing a by-product coke oven plant. The history of Michigan, and especially the cities of Detroit, Chicago, Providence, Minneapolis, St. Paul, and many others, bears testimony to the growing popularity of by-product coke.

In Canada, almost all the domestic coke produced has been by the retort method. Such coke is a very satisfactory domestic fuel, but it has been limited in quantity and commonly sold only in the immediate vicinity of the plant, as it does not stand transportation well. The producers of this coke have dealt very fairly with the public as regards prices, service, etc., and their customers are naturally well satisfied. Most of the by-product coke used in Canada has come from the United States and has sold, in general, at several dollars per ton above retort coke, but at a slight margin under anthracite. Coke ovens cannot be established in every city in central Canada, and can be economically operated—selling coke and gas at fair prices—only where there is a market for the gas. It follows that where this demand does not exist, the retort finds its place and the domestic fuel therefrom will be suitable and satisfactory. There is a market in Canada for all the coke for domestic fuel that the country can produce, both by coke oven and retort.

Coke has received much adverse criticism through ignorance, and situations arising from depressed business conditions. Producers of metallurgical coke have been accustomed, during business depressions, to flood the market with poor coke not uniformly sized, full of dust, and entirely unsuited for domestic purposes. It would be as reasonable to expect good results from this coke as from anthracite uncleaned, unprepared, and unsized. When business was good, the coke manufacturer allowed his domestic trade to dwindle, and obtained higher prices from other sources. This recurrent withdrawal from the market is a short-sighted policy and has caused intense dissatisfaction.



Discharge side of Solvay battery.

MARKETING DOMESTIC COKE

There is probably no feature, in Canada's efforts to attain fuel independence, more important than the marketing of domestic fuel. The ordinary citizen must use anthracite unless he can be assured of a regular and ample supply of an alternative fuel. Moreover, he must also receive fair treatment as regards service, quality, preparation, collections, etc. The lack of such treatment has hitherto been one of the chief obstacles in marketing coke. In spite of this fact, coke has become very popular in certain districts. But intense dissatisfaction has been caused by the withdrawal of coke from the domestic market in order to secure better prices from other sources. Some of the factors governing the sale of coke for domestic purposes are similar to those governing the sale of gas, viz., storage, investment, territory to be served, etc. The demand for coke for heating purposes is seasonal and, therefore, unless coke can be delivered at a rate approximating that of production, considerable storage space is required, which entails more capital expenditure.

Fortunately, the by-product oven can produce, as desired, either a heavy, dense coke for domestic purposes, or an open, porous coke for metallurgical and industrial purposes. Also, when the gas demand in summer diminishes, less coke can be produced. Owing to the fact that cleaner and better prepared coke can be procured during the summer, householders and industrial consumers should stock coke during the summer. As an inducement to the fuel-buying public, it has been suggested that at least a part, if not all, the saving to the producer effected by not having to stock coke in quantity be passed on to the consumer. In fact, several large Canadian dealers suggested that the fuel could be paid for over a period of time, like many other products. American dealers and producers have publicly stated that their Canadian business was most attractive because the domestic market in northern latitudes is far more stable than industrial markets, and should not be abandoned for occasional higher prices.

In developing a market for coke where anthracite is the chief competitor, the *sizing* of coke is of primary importance. Quality is, of course, important also, but no matter how high the quality, coke cannot be successfully burned unless properly sized for the equipment in which it is to be used.

One of the criticisms regarding coke is that it burns out the grates. Dealers and others can inform the public as to the true facts by publishing instructions regarding the use of coke. If the consumer will follow the instructions, he will, provided the quality of the coke has been maintained, actually use less coke than coal. Many people are ignorant as to the size of their fire boxes and as to other conditions, and careful investigation should be made so that the proper grade of coke be purchased. It is of interest to note that one company which sells about 15,000 tons yearly to the domestic trade in Canada, reports percentages as to sizes purchased, as follows:

	Per cent
Egg	20
No. 1 nut	50
No. 2 nut	30
	100

In the case of a plant producing coke on only a small scale, it is as a rule more convenient and economical to contract for its distribution; but where large plants are concerned, it is in most cases advisable to run a distribution department.

The size and style of delivery equipment, local laws regarding the dumping of fuel on sidewalks, and many other details, are important in giving good service at lowest cost. The principal factors in marketing coke may be summed up as follows:

Locate the market
- (a) Sales research or engineering

Interest market in product
- (a) Advertising
  - (1) Planning
  - (2) Production
  - (3) Statistical

Classify prospects
- (a) Credit

Consummate sales
- (a) Sales

Deliver product
- (a) Traffic

Collect bills
- (a) Collection

Keeping market satisfied
- (a) Trouble department or through sales department

A good domestic trade is worth more over a term of years than an industrial trade and it is, therefore, sound policy to deliver good quality and keep customers satisfied.

Whether the producing company should handle retail sales will depend on local conditions. A careful investigation of the methods of Canadian dealers, their margins of profit, service, and financial standing shows that it will probably be better to leave the sale and distribution of domestic coke in their hands. There may be other objections to the producing company entering the retail field. Representative dealers in the larger cities of Ontario and Quebec expressed the opinion that they would like to handle domestic coke provided they were assured of a regular supply, the same margin of profit, and fair treatment on the producers' part, so that they in turn can modify their yards and equipment for the

Quenching car unloading at coke wharf, Toledo Furnace Company, Toledo, Ohio.

lowest possible cost of operation consistent with good and satisfactory service. Investigations show that about $3 covers dealer's profit, operating costs and bad debts, and overhead.

In order to promote the sale of coke and allow the dealer some return for the expense of modifying his equipment, it may be desirable to increase this figure temporarily. Dealers are, as a whole, operating on smaller percentages of profit than almost any other class of retailers. Large profits are made only when large tonnages are handled and sold. It can be safely said that the co-operation of producers, dealers, and consumers will result in popularizing coke, for it is as satisfactory as anthracite, has equivalent or higher heating value, and as a rule sells for less money.

In 1923 a bill was passed in Pennsylvania to permit the adulteration of coal in amounts dependent on the size. Such a bill could be passed only if there were a marked decline in the supply of high-grade anthracite.

COKE SIZES

The following are the approximate sizes of coke as known to the trade:

Screen Sizes

Furnace coke	All over $\frac{3}{4}$ inch	square openings
Foundry "	All over 3 or 4 inches	" "
Egg[1] "	Through 3 inches or 3·5 inches over $1\frac{5}{8}$ inches	" "
Stove[1] "	Rather indefinite size between egg and nut	
Nut[1] "	Through $1\frac{5}{8}$ inches over $\frac{7}{8}$ inch	" "
Pea[1] "	Through $\frac{7}{8}$ inch over $\frac{1}{2}$ inch	" "
Buckwheat[2] coke	Through $\frac{1}{2}$ inch over $\frac{1}{4}$ inch	" "
Rice[2] "	Through $\frac{1}{4}$ inch over $\frac{1}{8}$ inch	" "
Breeze[3]	Usually through $\frac{3}{4}$ inch or $\frac{1}{2}$ inch to dust	

For Canada the following domestic sizes are recommended, as they are sufficient for all practical purposes:

Screen Size

Egg coke	Through 3·5 inches over $1\frac{5}{8}$ inches	Square openings
or	Through 3 inches over $1\frac{1}{2}$ inches	" "
Nut "	Through $1\frac{5}{8}$ inches or $1\frac{1}{2}$ inches over 1 inch	" "
Pea "	Through 1 inch over $\frac{1}{2}$ inch	" "
Breeze[3]	All through $\frac{1}{2}$ inch	" "

It has been suggested that instead of calling the sizes egg, nut, and pea, they be called large, medium, and small.

---

[1] Domestic sizes.
[2] Industrial sizes.
[3] Suitable for steam-making purposes.

Subdivision of Coke

As pointed out elsewhere in this report, it may in some cases be desirable to produce metallurigical coke, and the approximate percentages of each kind are given below—yields are for a normal coking time.

		Per cent
Foundry coke	All over 3·5 inches screen	50
Egg "	Through 3·5 inches over 1⅝ inches screen	30
Nut "	Through 1⅝ inches over 1 inch screen	10
Pea "	Through 1 inch over ½ inch screen	6
Breeze	Through ½ inch to dust	4

If all the coke is made for domestic purposes, scalping and crushing the oversize will divide it as follows:

	Per cent
Egg	65
Nut	20
Pea	8
Breeze	7

Typical pump-house installation.

CHAPTER IV

LOCALITIES INVESTIGATED

An extensive survey of conditions was made in Quebec, Montreal, Ottawa, Toronto, and Port Colborne. To a lesser extent investigations were carried on regarding markets, etc., in Hamilton, London, and the "Border" cities. Gas companies, wholesale and retail coal and fuel dealers, financiers, engineers, and others were consulted and all evinced great interest in the proposition. Prospective purchasers of by-products and coke were also consulted and a large majority were enthusiastic. Oil refiners were a little afraid that motor benzol would compete with gasoline; coal dealers that regular supplies of coke would not be available, and *anthracite* operators in the United States were afraid of losing their large, satisfactory domestic fuel market. In most cases, these fears are baseless.

The cities chosen are those where the domestic gas demand is sufficient to warrant installation of ovens and successfully support a by-product coke plant. Other localities such as the "Border" cities, can erect plants as soon as the industrial or domestic gas demand is sufficient. The district between Bridgeburg and Windsor has for a long time been served by natural gas, but the supply is rapidly diminishing and the territory will soon have to depend on manufactured gas.

Port Colborne presents a problem of great interest. Within 7 miles of this town, so favourably located on Welland canal, are many industries which are most interested in obtaining gas. The industrial demand alone is approximately 20,000 M cubic feet per day without considering the sale of gas to two natural gas companies, whose supply is now insufficient to meet the winter demands. With cheap lake transportation of coal and the large market for coke in the Colborne-Windsor area, conditions are most favourable for the installation of a coke plant. Even if a coke plant were erected in each of the centres investigated, the demand for domestic fuel would be only half supplied in the Acute Fuel Area.

86227—4

Table IX.—Fuel Consumption—Other Statistics—Towns and Cities

London-Windsor Area[1]

Cities	County	Population	Approximate railway miles from London, Ont	Approximate tons domestic fuel used
London	Middlesex	61,000	....	83,000
St. Thomas	Elgin	16,000	16	23,000
Chatham[2]	Kent	13,300	64	2,600
Wallaceburg[2]	Kent	4,000	87	500
Leamington[2]	Essex	3,700	101	800
Amherstburg[2]	"	2,800	118	1,200
Sandwich[2]	"	4,450	113	1,050
Windsor[2]	"	38,600	111	11,000
Ford[2]	"	5,900	112	1,800
Walkerville[2]	"	7,100	110	2,100
Sarnia[2]	Lambton	15,000	61	4,200
Petrolia[2]	"	3,150	51	1,150
Strathroy	Middlesex	2,700	20	400
St. Marys	Perth	4,000	23	8,500
Stratford	"	16,000	33	20,000
Ingersoll	Oxford	15,500	19	6,000
Woodstock	"	10,000	28	18,000
Tillsonburg[3]	"	3,000	46	2,800
Simcoe[3]	Norfolk	4,000	70	3,200
Goderich	Huron	4,100	67	5,000
Paris[4]	Brant	4,500	47	3,600
Brantford[3 4]	"	31,000	55	40,000
Miscellaneous	....	....	....	32,000
	....	259,800	....	271,900

[1] NOTE.—Excluding competing cities, London-Windsor district has a potential minimum market of approximately 195,000 tons of domestic fuel.
[2] Compete with coke from Detroit.
[3] Compete with coke from Port Colborne.
[4] Compete with coke from Hamilton.

Table X.—Fuel Consumption—Other Statistics—Towns and Cities

Port Colborne Area[1]

Cities	County	Population	Approximate railway miles from Port Colborne	Approximate tons domestic fuel used
Port Colborne	Welland	3,450	....	2,500
Welland	"	9,000	7	7,000
Thorold	"	5,000	18	4,100
St. Catharines	Lincoln	20,000	22	25,000
Niagara Falls	Welland	15,000	21	14,000
Dunnville	Haldimand	3,250	19	2,100
Simcoe[2]	Norfolk	4,000	60	3,200
Tillsonburg[2]	Oxford	3,000	84	2,800
St. Thomas[2]	Elgin	16,000	104	23,000
Ingersoll[2]	Oxford	5,500	99	6,000
London[2]	Middlesex	61,000	118	83,000
Merritton	Lincoln	2,550	20	1,000
Grimsby[2]	"	2,000	37	4,850
Beamsville[2]	"	1,300	33	200
Port Dalhousie	"	1,200	25	3,000
Humberstone	Welland	1,200	2	150
Bridgeburg	"	2,400	20	950
Brantford[2]	Brant	31,000	57	40,000
Miscellaneous	....	....	....	21,000
	....	186,650	....	243,850

[1] NOTE.—Excluding competing cities, Port Colborne has a potential minimum market for 80,800 tons of domestic fuel.
[2] Compete with coke from Detroit or Hamilton.

Table XI.—Fuel Consumption—Other Statistics—Towns and Cities

Ottawa Area[1]

Cities	County	Population	Approximate railway miles from Ottawa	Approximate tons domestic fuel used
Ottawa	Carleton	108,000	....	175,000
Hintonburg	"	5,600	4	
Carleton Place	Lanark	3, 50	32	1,100
Perth	"	3,800	54	4,000
Smiths Falls	"	6,800	42	3,500
Belleville[2]	Hastings	12,200	132	18,000
Napanee[2]	Lennox and Adding on	3,000	111	5, 00
Kingston[2]	Frontenac	22,000	111	35,000
Gananoque	Leeds	3,600	104	1,150
Brockville	"	10,050	70	15,000
Prescott	Grenville	2,700	61	4,000
Cornwall	Stormont	7,500	56	8,500
Rockland	Russell	4,500	25	900
Hawkesbury[3]	Prescott	5,550	5	950
Arnprior	Renfrew	4,950	59	2,000
Pembroke	"	7,900	94	2,610
Hull, Que	Hull	24,300	2	25,000
Aylmer, Que	"	3,000	10	500
Buckingham, Que	Papineau	3,850	21	250
St. André-Avelin, Que	"	3,000	52	350
Miscellaneous	....	....	....	18,000
		250,250	....	322,050

[1] NOTE.—Excluding competing cities, Ottawa has a potential minimum market for approximately 263,000 tons of domestic fuel. [2] Compete with coke from Toronto. [3] Compete with coke from Montreal.

Table XII.—Fuel Consumption—Other Statistics—Towns and Cities

Toront Area[1]

Cities	County	Population	Approximate railway miles from Toronto	Approximate tons domestic fuel used
Toronto	York	522,000	....	600,000
Newmarket	"	3,700	38	6,2 0
Brampton	Peel	3,000	17	7,900
Barrie	Simcoe	7,000	68	8,500
Orillia	"	8,800	0	9,0[illegible]0
Oshawa	Ontario	12,000	29	11,000
Lindsay	Victoria	7,600	58	6,800
Bowmanville	Durham	3,300	39	7,600
Port Hop	"	4,500	56	5,700
Cobourg	Northumberland	5, 00	62	2,500
Peterborough	Peterborough	21,000	6[illegible]	31,000
Trenton	Northumberland	5,900	94	4,000
Belleville[2]	Hastings	12,200	105	18, 0[illegible]
Picton	Prince Edward	3,500	125	5,000
Campbellford	Northumberland	3,200	97	1,500
Oakville[3]	Halton	3,300	18	2,000
Guelph[3]	Wellington	18,500	44	28,000
Galt[3]	Waterloo	13,500	55	14,000
Waterloo[3]	"	6,000	58	6,000
Kitchener[3]	"	22,000	56	20,000
Preston[3]	"	5,700	51	7,000
Miscellaneous	....	....	....	22,000
		692,[illegible]00	....	823,700

[1] NOTE.—Excluding competing cities, Toronto has a potential minimum market for approximately 720,000 tons of domestic fuel. [2] Compete with coke from Ottawa. [3] Compete with coke from Detroit-Hamilton.

Table XIII.—Fuel Consumption—Other Statistics—Towns and Cities

Hamilton Area[1]

Cities[2]	County	Population	Approximate railway miles from Hamilton	Approximate tons domestic fuel used
Hamilton	Wentworth	115,000		160,000[6]
Dundas	"	5,000	4	8,000
Guelph[3]	Wellington	18,500	33	28,000
Galt[3]	Waterloo	13,500	36	14,000
Waterloo[3]	"	6,000	52	6,000
Kitchener[3]	"	22,000	50	20,000
Preston[3]	"	5,700	40	7,000
Paris[5]	Brant	4,500	33	3,600
Brantford[4]	"	31,000	25	40,000
Niagara Falls[4]	Welland	15,000	35	14,000
Welland[4]	"	9,000	38	7,000
Stratford[5]	Perth	16,000	65	20,000
St. Marys[5]	"	4,000	63	8,500
Simcoe[4]	Norfolk	4,000	44	3,200
Woodstock[5]	Oxford	10,000	52	18,000
Ingersoll[5]	"	5,500	61	6,000
Tillsonburg[4]	"	3,000	57	2,800
Thorold[4]	Welland	5,000	29	4,100
London[4]	Middlesex	63,000	80	83,000
St. Thomas[5]	Elgin	16,000	82	25,000
St. Catharines[4]	Lincoln	20,000	33	25,000
Miscellaneous				20,000
		371,700		521,200

[1] NOTE.—Excluding competing cities, Hamilton has a potential minimum market for approximately 170,000 tons of domestic fuel.
[2] NOTE.—Approximately 70,000 tons of coke is also sold in above cities.
[3] Competes with coke from Toronto.
[4] Competes with coke from Port Colborne.
[5] Competes with coke from London-Windsor district.
[6] As reported by retailers and distributors.

Table XIV.—Fuel Consumption—Other Statistics—Towns and Cities

Montreal Area[1]

Cities	County	Population	Approximate railway miles from Montreal	Approximate tons domestic fuel used
Montreal and environs, including St. Henri, Verdun, Hochelaga, Lachine, Maisonneuve, Mile End, Westmount, Outremont, etc.	Hochelaga	740,000	10–20	800,000
Valleyfield	Beauharnois	9,250	39	3,000
St. Jérôme	Terrebonne	5,500	35	1,200
St. Johns	St. Johns	7,750	25	2,750
Granby	Shefford	6,800	45	1,400
Magog	Stanstead	5,150	82	1,650
Sherbrooke	Sherbrooke	23,500	100	9,000

Table XIV.—Fuel Consumption—Other Statistics—Towns and Cities—Con.

Montreal Area[1]—Continued

Cities	Counties	Population	Approximate railway miles from Montreal	Approximate tons domestic fuel used
St. Hyacinthe	St. Hyacinthe	11,000	33	9,400
Longueuil	Chambly	4,700	5	3,000
St. Lambert	"	3,900	6	900
Sorel	Richelieu	8,200	40	4,000
Joliette	Joliette	9,150	31	2,150
St. Cuthbert	Berthier	3,550	41	550
Three Rivers[2]	St. Maurice	22,400	75	3,100
Shawinigan Falls	"	10,600	95	1,900
Grand-Mère[2]	"	7,650	101	2,150
Richmond	Richmond	6,000	74	2,500
Cap-de-la-Madeleine	Champlain	6,750	78	2,050
Miscellaneous				28,000
		893,450		879,200

[1] NOTE.—Excluding competing cities, Montreal has a potential minimum market for 870,000 tons of domestic fuel.

[2] Compete with coke from Quebec.

Table XV.—Fuel Consumption—Other Statistics—Towns and Cities

Quebec Area[1]

Cities	Counties	Population	Approximate railway miles from Quebec	Approximate tons domestic fuel used
Quebec	Quebec	95,300		75,000
Beauport	"	3,250	5	350
Levis	Levis	10,500	1–20	1,550
St. Casimir	Portneuf	3,000	47	300
La Perade	Champlain	3,000	54	300
Three Rivers[2]	St. Maurice	22,400	78	3,100
Grand-Mère[2]	"	7,650	81	2,150
Shawinigan Falls[2]	"	10,600	87	1,900
St. Hyacinthe	St. Hyacinthe	9,500	32	1,850
Thetford Mines	Megantic	7,900	85	800
Black Lake	"	2,650	89	275
St. Victor-de-Tring	Beauce	2,100	75	150
St. Ephrem-de-Tring	"	3,500	81	850
St. Mary	"	2,550	46	625
Montmagny	Montmagny	4,150	48	1,100
Cap St. Ignace	"	4,500	54	900
Rivière-du-Loup	Temiscouata	7,700	118	1,350
Cap-de-la-Madeleine[2]	Champlain	6,750	77	2,050
Victoriaville	Arthabaska	3,800	68	1,000
Mégantic	Frontenac	3,150	125	700
Miscellaneous				25,000
		213,950		121,300

[1] NOTE.—Excluding competing cities, Quebec has a potential market for approximately 110,000 tons domestic fuel as a minimum.

[2] Compete with coke from Montreal.

CHAPTER V

MARKET FOR COKE

DOMESTIC

Ontario and Quebec consume from 4,000,000 to 4,500,000 net tons of domestic fuel, of which over 90 per cent is imported. The following tables, prepared from reports of retail dealers, show how some of the cities and towns consumed fuel. These tables are also used in conjunction with transportation problems.

Table	IX.	London-Windsor district
"	X.	Port Colborne area
"	XI.	Ottawa "
"	XII.	Toronto
"	XIII.	Hamilton
"	XIV.	Montreal "
"	XV.	Quebec "

Where two or more plants compete, it is hoped that by a zoning system or other means a great deal of the overlapping will be eliminated. In order to arrive at the total potential market the overlapping territories were assigned arbitrarily to definite areas, as if no competition would exist. The approximate domestic consumption of fuel by areas is as follows:

Area	Tons
Quebec	121,300
Montreal	870,000
Ottawa	322,000
Toronto	720,000
Hamilton	260,000
Port Colborne	135,000
London	200,000
	2,628,300

From Table XXIII—showing the size of the proposed plants as determined from the gas loads—it will be seen that even if London built a plant, coke from Toronto, Port Colborne, or Hamilton could enter the area, for the London plant could not supply the demand.

The Hamilton plant produces approximately 325 tons of coke per day, of which only about one-half is sold as domestic. After providing for industrial demands it could supply coke that would replace only about 20 per cent of the total fuel sold in the city. If the plant sold the entire output as domestic, the amount of fuel replaced would be about 65 per cent. With the public properly educated to the use and advantages of coke, it is not improbable that this could be done. In any event, domestic coke will probably be moved from Port Colborne, west to the London district and even farther if competition from the States can be met.

Toronto is in much the same position as Hamilton. Should a Toronto plant put out all coke as domestic, it would have to sell about one ton per capita to dispose of all its coke in the city and vicinity.

Ottawa cannot come anywhere near supplying the demand for domestic fuel and is favourably located with respect to her market.

Montreal is in a similar position and with proper effort could dispose of the coke within her own limits. Montreal will probably have to meet keen competition from anthracite, but as only a part of the gas load would, at the start, be taken care of by coke oven gas, the percentage of replacement would be quite low until the market could be worked up.

Quebec is in a like position as regards coke, and should have no difficulty in disposing of her output.

It may be as well to repeat the warning—on which the Dominion Fuel Board is insistent—that within the next few years the United States cannot permit, and probably will not allow, the exportation of anthracite. But Canada can, with the aid of coke, make herself independent of anthracite.

Although there is room for a plant in all the cities mentioned, the first plants built will have the advantage of picking the cream of the market. Engineers agree that the consumption of domestic fuel in the cities averages about one ton per capita per annum. The per capita consumption of anthracite in Canada is about 0·55 net tons. Including all fuels (bituminous coals, coke, lignites, etc.) used for all purposes the per capita consumption is approximately 3·5 net tons. The per capita consumption of anthracite in Ontario is approximately one ton per annum; in Quebec it is 0·57 net tons.

To summarize from Tables IX to XV inclusive, the total market is about 2,628,000 tons, all within comparatively short railway hauls. If plants were built in all the localities investigated, 1,376,300 tons of domestic coke could, on the present gas consumption, be produced; in other words, the "Acute Fuel Area" could obtain 52 per cent of its domestic fuel requirements with coke. The amount of domestic coke which might be produced in the "Acute Fuel Area" is shown in Table XXIII as 935,000 tons or 35·5 per cent of the domestic requirements. A certain amount of industrial business is desirable to compensate for the summer decline in domestic coke sales. Although it is unlikely that all the cities mentioned as favourable will erect ovens, Canada could soon be much less dependent on imported coal, if the larger cities manufactured coke.

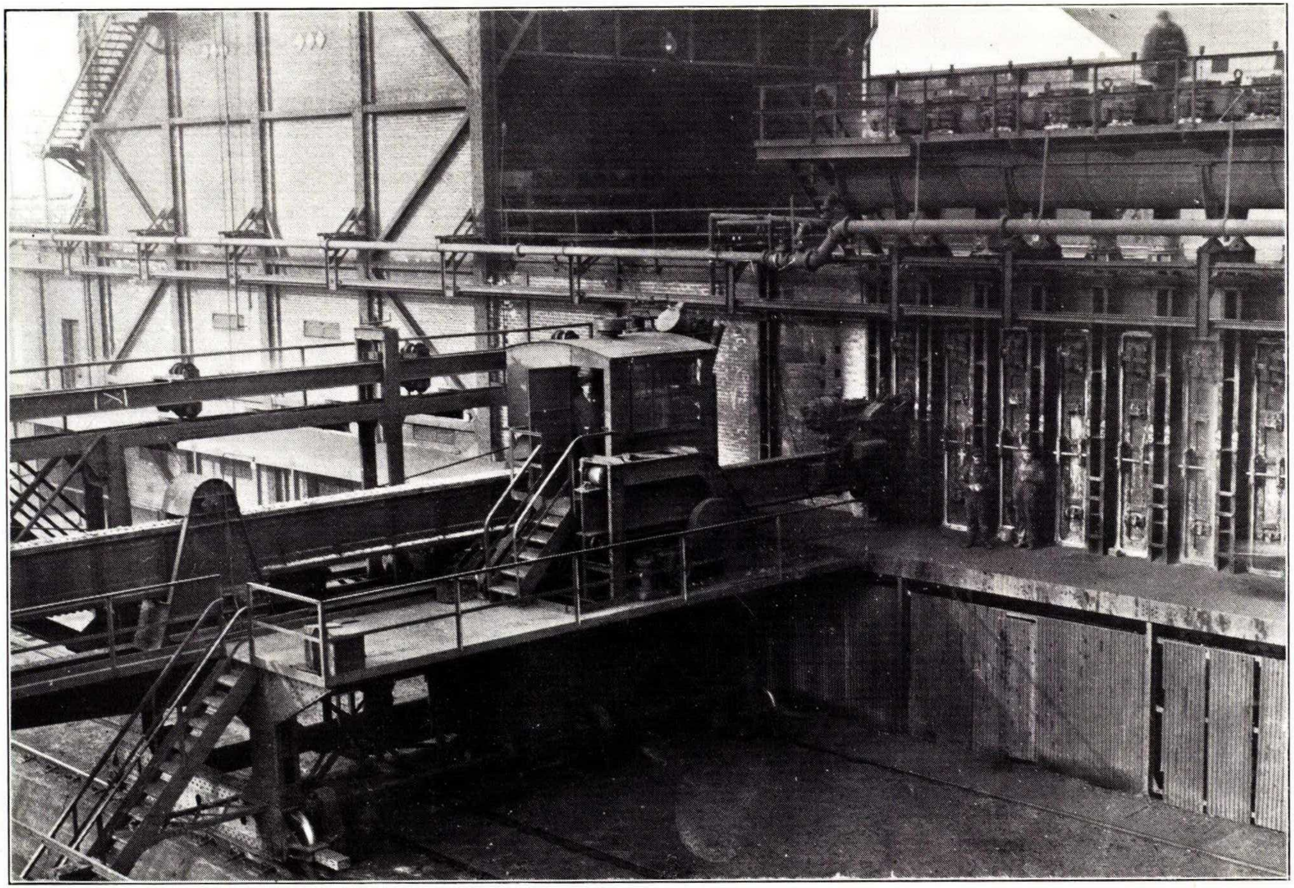
INDUSTRIAL COKE

The industrial market is divided into several classes according to the purpose for which the coke is needed. As regards blast furnaces, most of the plants either have coke ovens which supply their own needs, or—as at Port Colborne—contemplate the erection of such ovens. Other furnaces depending on foreign sources for coke are not steady operators.

	Tons
Ontario—	
Mining, milling, smelting, and refining (nickel—nickel copper, etc.)	75,000
Foundries and machine shops	65,000
Miscellaneous	15,000
	155,000
Blast furnace coke about 130 to 150,000 tons (imported)	130,000
	285,000
Quebec—	
Foundries and machine shops	40,000
Mining and milling	12,000
Carbide	32,000
Miscellaneous	13,000
	97,000

From the above table it appears that, excluding blast furnace coke, the present industrial market in the "Acute Fuel Area" is about 250,000 tons per year.

From the average imports of coke of all classes it appears that the domestic coke imported is approximately 150,000 tons per year.



Pusher side of Wilputte ovens, showing coke pusher in foreground and part of coal bin beyond.

CHAPTER VI

MARKET FOR GAS

In order to obtain an approximate idea as to the market for gas in the "Acute Fuel Area," the writer chose for investigation those cities where the domestic demand for gas appears to warrant the installation of coke ovens. The only exception was Port Colborne, where conditions are peculiar, owing to the demand being almost entirely industrial.

The localities investigated included Quebec, Montreal, Ottawa, Toronto, and Port Colborne, and to a lesser extent Hamilton, where a coke plant is already in operation. Although these cities were the only ones where an intensive study was made, the principle outlined would apply to other cities where a sufficient demand for gas, either domestic or industrial, exists. Other cities, such as Windsor and London, Ont., might find conditions suitable for coke ovens. Cities and towns between Port Colborne and Windsor have for years been supplied with cheap natural gas, but the diminishing supply will concentrate attention on manufactured gas. This whole territory is well covered with pipe-lines that could be made available for transporting the gas.

Table XVI shows the existing markets for gas in the cities mentioned; the tonnage of coal required to produce that gas if it be all coke-oven gas; the amount of coke produced, etc. Table XVI gives a brief list of the plants in Canada making gas, names of the companies, approximate production, and the price of gas to the consumer.

In Table XXIII, the figures shown are based on coke oven gas supplying the entire demand, a part of the present equipment to be held in reserve or to take care of extreme peaks or demands for gas. It is probable, however, that to establish the industry most economically only single units should be erected until such time as older equipment can be scrapped and markets built up for the products. The per capita consumption of gas varies greatly according to locality, and is largely governed by the price (*See* Figure 3).

The establishment of by-product coke ovens will not necessarily reduce the price to any great extent, for the price of gas depends upon the price of coke. Wherever a fair price for gas is charged, coke for domestic purposes can be sold at considerably less than anthracite. Many cities in Canada charge a very fair price for gas; in others it is exceptionally high, and it is the latter cities that should benefit by the establishment of coke ovens.

Engineers, generally, are of the opinion that the smallest unit of coke ovens which can be economically operated is one that has an output of "surplus" gas of not less than 600,000 cubic feet of gas per day. But where sufficient industrial gas can be sold ovens may be successfully installed even though the domestic consumption be low. Where gas consumption is small and gas is manufactured by old or expensive processes attention should be turned toward the retort. The retort produces gas and a good domestic coke and meets the requirements of smaller communities.

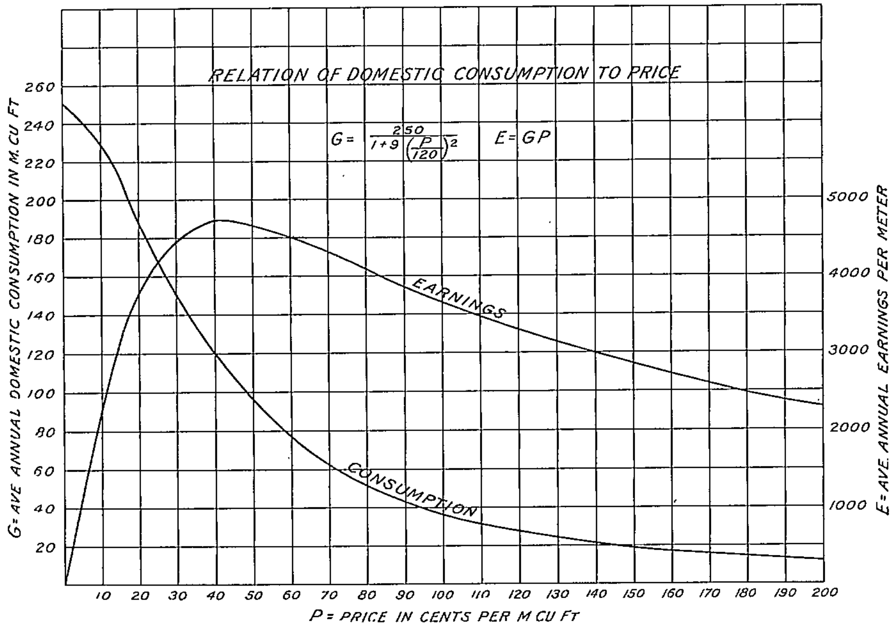
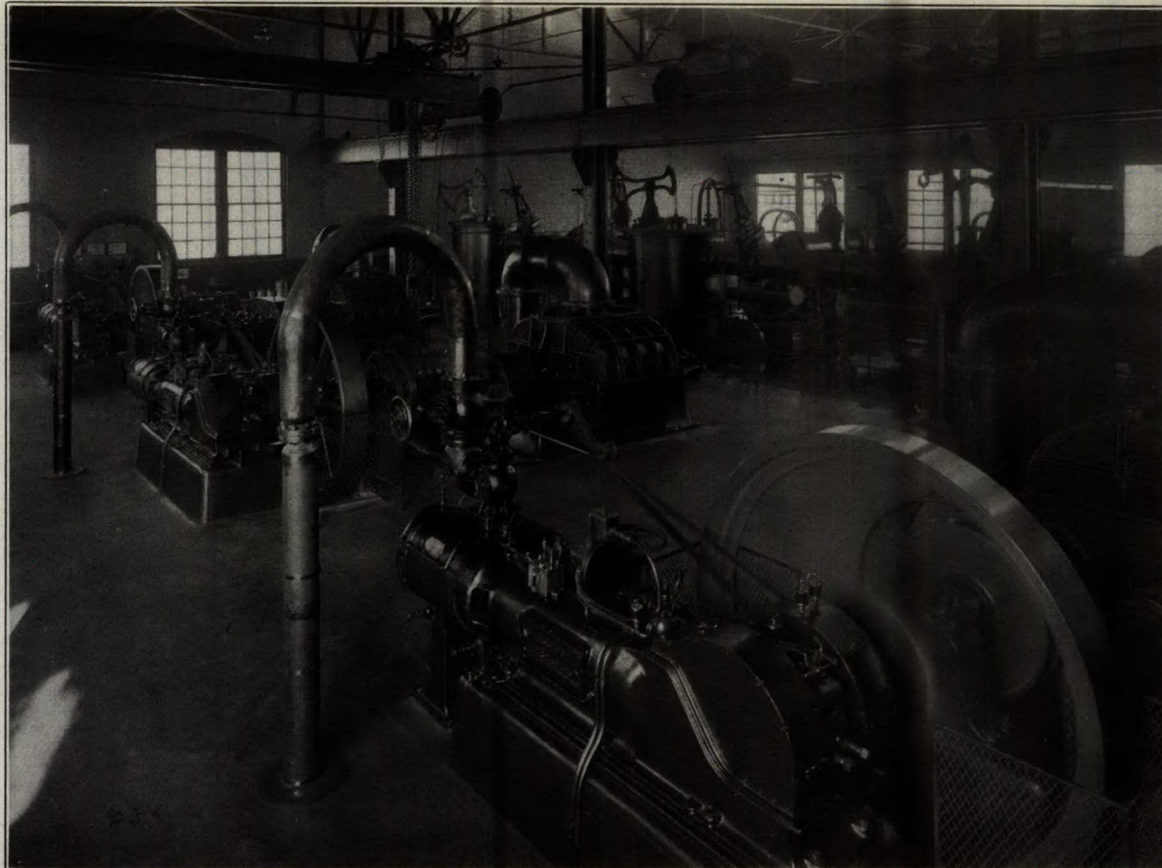


Figure 3. Effect of gas price on consumption.

The coke oven, however, because it produces larger quantities and a better quality of coke, is strongly advocated for Canada, and is being widely adopted in the United States.

Figure 3 shows a curve which illustrates the experience of a large company, operating several subsidiary companies, distributing domestic and industrial gas. It shows clearly the effect of price upon consumption. Although this chart is not strictly applicable to conditions in Canada, it gives a good general idea of what may be expected under varying price conditions, and points the moral that gas, sold as cheaply as is consistent with the market price of the by-products, is to the benefit not only of the public, but also the producer.



Interior of Wilputte by-product building, showing gas exhausters in foreground with tar extractors and saturaters in background.

Table XVI.—Manufactured Gas: City Plants in Canada

City	Name of company	Approximate production	Processes	Gas price per M cu. ft.
		M cu. ft.		$ cts.
St. John, N.B.	New Brunswick Power Co.	52,000 p. an. 140 p. day	Coal Horizontal	2 50 net
Halifax, N.S.	Nova Scotia Tramways and Power Co.	95,000 p. an. 260 p. day	Coal gas Inclined retorts	1 76 net

Ontario

City	Name of company	Approximate production	Processes	Gas price per M cu. ft.
Barrie	Barrie Gas Co., Ltd.	10,500 p. an. 29p. day	Lowe	2 25 net
Belleville	Belleville Gas Dept., Municipal Plant	26,000 p. an. 70p. day	Coal and Lowe	1 75 net
Brockville	Public Utilities Commission	46,000 p. an. 126p. day	Lowe	2 00 net
Cobourg	Hydro-Electric Power Commission of Ontario	7,500 p. an. 20p. day	Coal gas	2 50 net
Guelph	Board of Light and Heat Commissioners Municipal Plant	95,000 p. an. 260p. day	Coal H. retorts and car water gas	1 30 net
Hamilton[1]	United Gas and Fuel Co[2].	550,000 p. an. 1,500p. day	Coal H. retorts and car water gas	1 25 net
Kingston	Public Utilities Commission, city of Kingston	87,500 p. an. 240p. day	Car water gas	1 75 net
Kitchener	Kitchener Light Commissioners	77,000 p. an. 210p. day	Coal gas and water gas	1 80 gross
London	City Gas Co.	350,000 p. an. 950p. day	Coal gas and Lowe.	1 25 gross
Oshawa	Hydro-Electric Power Commission of Ontario	27,000 p. an. 74p. day	Lowe	2 15 gross
Ottawa	The Ottawa Gas Co.	530,000 p. an. 1,450p. day	Coal gas	1 45 net
Owen Sound	Public Utilities Commission, Owen Sound	23,000 p. an. 63p. day	Oil gas and coal gas.	1 80
Peterborough	Hydro-Electric Power Commission of Ontario	57,000 p. an. 156p. day	Lowe Merrifield	2 00 net
Port Hope	Port Hope Gas Co.	5,000 p. an. 14p. day	Coal	2 00 to 1 25 net
St. Thomas	Light, Heat, and Power Dept., St. Thomas Municipal Plant	78,500 p. an. 215p. day	Coal and Lowe	1 75 net
Stratford	Stratford Gas Co.	28,000 p. an. 77p. day	Coal	1 20 to 1 00 net
Toronto	Consumers Gas of Toronto	5,000,000 p. an. 13,500 p. day	Lowe and Coal	0 90 0 85 net 0 80 50c. service charge
Waterloo	Waterloo Water and Light Commission Municipal Plant	14,000 p. an. 38p. day	Water gas	2 90 net

[1] Potential localities for by-product coke-oven plants are printed in italics.
[2] Hamilton is now operating a battery of Semet-Solvay ovens. The gas load is approximately 3,000 M cu. ft. per day, or 825,000 M cu. ft. per annum.

Table XVI.—Manufactured Gas: City Plants in Canada—Continued

Quebec

City	Name of company	Approximate production	Processes	Gas price per M cu. ft.
		M cu. ft.		$ cts.
Montreal...........	Montreal Light, Heat, and Power Consolidated	4,000,000 p.an. 11,000p.day	Coal and water gas.	1 10
Quebec.............	Quebec Railway, Light, Heat, and Power Co., Ltd.	220,000 p. an. 600p.day	Lowe............... Car water gas	1 55 net
Sherbrooke.........	City Gas and Electric Dept., Municipal plant	50,000 p. an. 137p.day	Lowe...............	1 58 net
Sorel...............	Gas Dept., Municipal Plant.	3,500 p. an. 10p.day	Coal...............	2 60 net

British Columbia

City	Name of company	Approximate production	Processes	Gas price per M cu. ft.
Nelson.............	City Gas Dept., Municipal Plant	5,100 p. an. 14p.day	Coal...............	2 25 to 1 85
New Westminster...	New Westminster Gas Co.	12,000 p. an. 33p.day	Coal...............	2 50 to 2 25
Vancouver..........	Vancouver Gas Co., Ltd....	470,000 p. an. 1,280p.day	Coal and Lowe......	1 50 to 0 75
Victoria............	Victoria Gas Co., Ltd.......	82,000 p. an. 225p.day	Coal............... G.W. vertical	2 00 to 1 25

Manitoba

City	Name of company	Approximate production	Processes	Gas price per M cu. ft.
Brandon............	Canada Gas and Electric Corp.	40,000 p. an. 110p.day	Coal...............	2 10
Winnipeg[1]..........	Winnipeg Electric Railway Co.[1]	510,000 p. an. 1,400 p.day	Coal gas and car water gas	2 50

[1] Winnipeg has let the contract for a battery of Koppers ovens to go in run in 1924, when it is expected the gas load will be approximately 1,500 M cu. ft. per day, or 410,000 M cu. ft. per annum.

Sulphate storage room, Colorado Fuel and Iron Company, Pueblo, Col.

CHAPTER VII

BY-PRODUCTS

AMMONIA

Ammonia, as produced by the by-product coke oven, is commonly made in one of two forms—aqua ammonia (NH_3 gas in water) or ammonium sulphate ($(NH_4)_2 SO_4$). Ammonia from the retort is mostly produced as liquor.

The chief use of ammonia as sulphate is as a fertilizer. Unfortunately Canada, and especially the western part, has not been educated in the use and value of sulphate as a fertilizer. The nitrates of Chile and manufactured fertilizers of other kinds are readily available to Canadian farmers and at present are perhaps preferred. There is no question of the value of ammonium sulphate as a fertilizer as has been shown in the United States, where, although more than fifty coke plants are now producing sulphate, it is proposed to harness several vast waterpowers for the production of this substance. There is a ready market at fairly good prices for all the ammonia which can be produced in Canada either as liquor or sulphate.

Those plants contemplating the manufacture of sulphate would naturally be those advantageously located as regards water transportation, so that they can take advantage of the steady demands from the West Indies, South America, etc. Furthermore, an educational campaign, if properly conducted, should create a demand for home consumption.

Aqua ammonia can be produced at the coke plant as a finished product for household purposes, as "powder[1]" liquor for the explosive industry; as anhydrous or pure aqua ammonia for refrigerating purposes; as a base for washing compounds; battery compounds, etc. Although at present Canada's demand for ammonia liquor could not absorb the entire production of the proposed coke plants, only slight quantities would have to be exported.

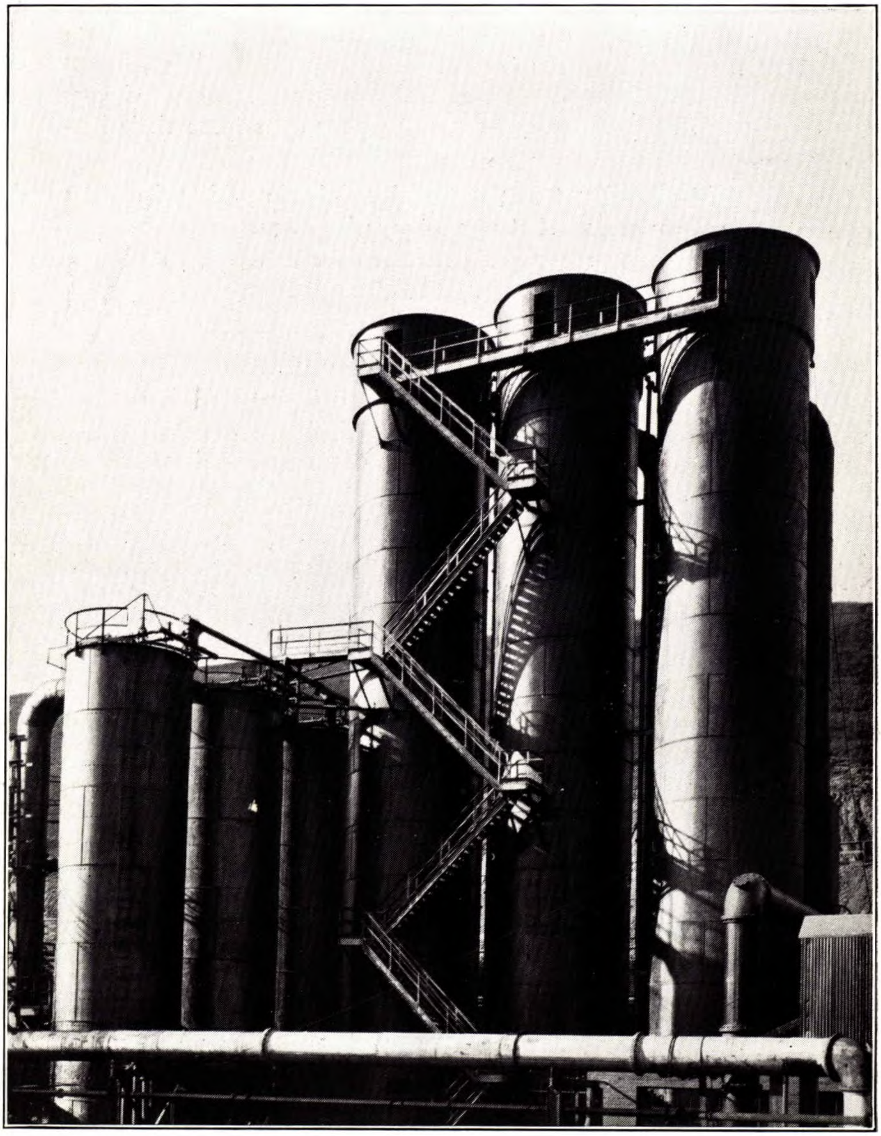
Ammonium sulphate sells at 2 to 4 cents per pound at the plant; at the time of writing the price is from 2·25 to 2·50 cents.

Ammonia liquor sells from 7 to 13 cents per pound—the present market being 7 to 10 cents, depending on the grade.

Ammonia, especially sulphate, has no large markets in Canada, but the entire output of liquor that could be produced by the proposed plants could be exported at attractive prices.

[1] "Powder" liquor is a trade name of a grade used by manufacturers of high explosives.

PLATE XV



Typical installation of scrubbers in coke-oven plant.

LIGHT OIL

Light oil, as produced at many coke plants, is known before refining as crude light oil or crude benzol, and is generally refined into four main substances known as benzol, toluol, xylol, and solvent naphtha, from which so many luxuries and drugs, dyes, explosives, etc., are made. Contrary to general opinion, many of the so-called coal tar dyes have their inception in light oil.

Crude light oils after treatment with sulphuric acid and caustic soda are often placed on the market as motor spirit or motor benzol—it being superior to gasoline on account of its higher heating value. Its importance in the motor world will increase as the oil supplies diminish.[1]

Light oil, from a national standpoint, is specially valued for the manufacture of explosives. A nation dependent on outside sources for these light oils has little chance of waging war successfully as these oils form the base of all higher explosives.

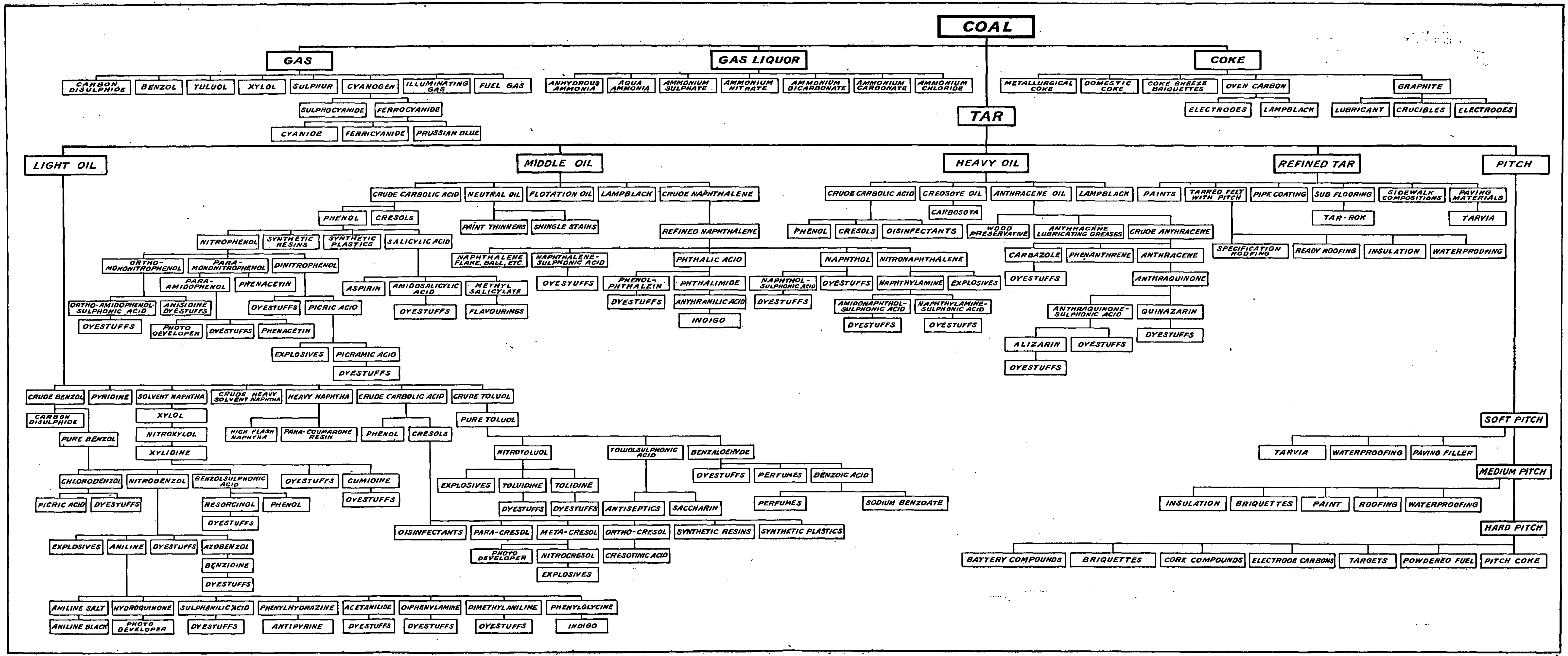
Coke plants, of 500 tons carbonizing capacity per day, or less, may not find it profitable to recover light oils, except in the most favourable circumstances. Ordinarily these small plants would leave the light oil in the gas, thus increasing the yield and heating value. Unless the production of light oil is about 1,500 gallons per day, the cost of equipment and overhead cuts deeply into the profit.

In Canada, refiners of gasoline naturally look with disfavour upon the introduction of motor spirit, as they have already extended their plants to cope with the gasoline demand for some years to come. In cities where motor benzol might be produced, gasoline would meet very strong competition and, possibly, might in time be displaced. The value of motor benzol as compared with the other by-products is comparatively small, and for this reason benzol can be sold very cheaply without especially affecting profits of the plant.

Although, in certain cases, benzol might drive out gasoline, it appears that from the standpoint of the coke-oven operator it would be better to concentrate on the manufacture of by-products from light oils and produce as little motor spirit as possible. This follows from the fact that gasoline and motor benzol bring, in normal periods, a much lower price than the "pure products". For example, when gasoline retails at 25 cents per gallon, motor spirit nets the producer from 18 to 20 cents, but benzol brings 35 to 45 cents, toluol and xylol 30 to 40 cents, and solvents 25 to 35 cents. The operator would probably produce motor spirit only when the market for pure products was depressed.

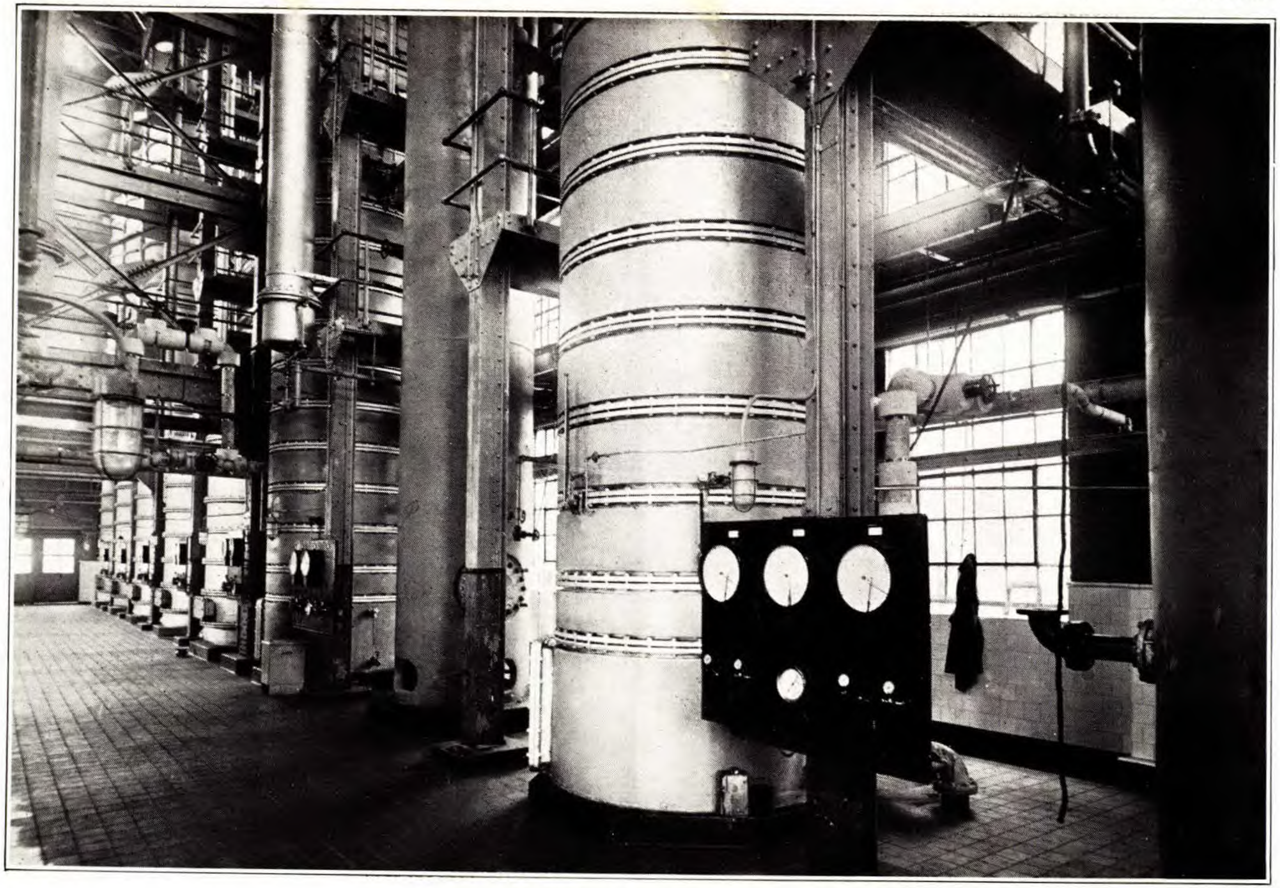
[1] For a complete list of the various products obtained from light oil *See* Plate I and Figure 4.

PRODUCTS DERIVED FROM COAL



Published by permission of The Barrett Co., N.Y.

Figure 4. Products derived from coal.



Typical installation of stills.

TAR

Tar is a very complex body, containing carbon, hydrogen, sulphur, phosphorous, oxygen, etc., and from these almost an infinite number of compounds can be formed. The composition of tar from any particular coal depends almost entirely on the temperature at which the tar is produced. Tar made at low temperatures contains very little benzol or phenol; tar produced at high temperatures contains much more of these aromatic compounds, and it is these compounds that give value to the tar and make low temperature distillation at present unprofitable. Tar consists roughly of: water and light oil; middle oil; heavy oil; anthracene oil; pitch.

Light oil as extracted from tar has the same uses and value and is of similar nature to the light oil previously discussed.

The middle oil yields phenol and cresol derivatives, naphthaline, etc., from which are made wood preservatives, shoe polish, dyes, paints, etc.

Heavy oil also is used for wood preservatives, etc., and from this oil the valuable anthracene oil is obtained.

Anthracene oil is used for the manufacture of lubricants, but is perhaps of most value to the dye industry in the form of carbazol, anthraquinone, etc.

Pitch, the residue left from the distillation of tar, has extensive use in paving materials, water-proofing materials, insulation, core compounds, electrodes, etc.

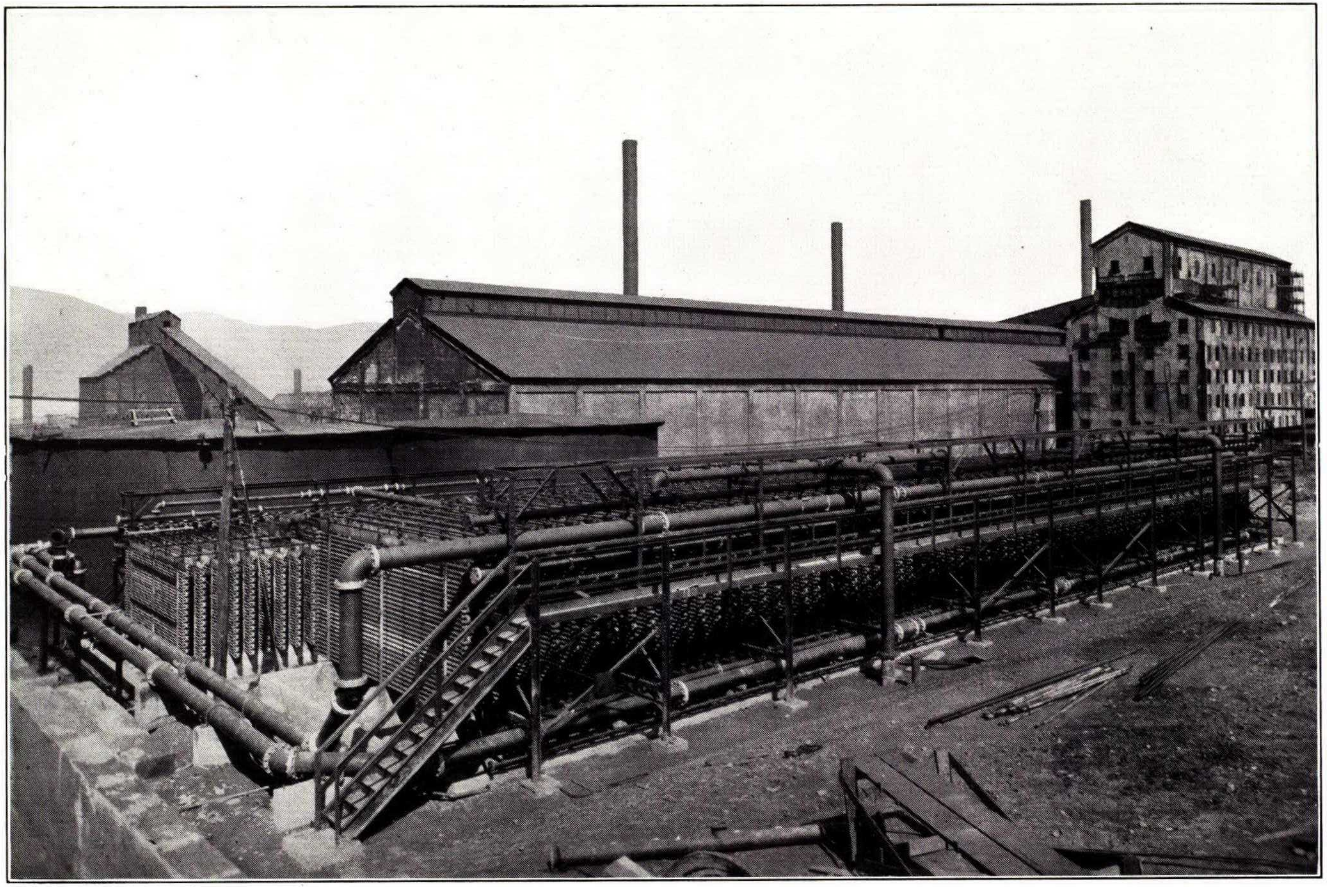
Tar, in refined state, without extraction of the products, is used for road building, water-proofing, etc.

For Canada, tar has another use of significant importance, and that is for fuel purposes. Tar has a higher heating value per gallon than fuel oil and for that reason commonly sells at from 1 to 3 cents a gallon more, and is never difficult to market. From a conservation standpoint it may not be advisable to urge the burning of tar because many valuable products are lost, but this objection might be overcome by the extraction of valuable oil (anthracene, etc.), leaving just enough of the lighter oils in the tar to render it fluid and workable.

Tar in the crude state, containing not more than 2 per cent water, ready for the refiner, sells for 6 to 10 cents per imperial gallon.

BREEZE

Breeze is composed of coke dust or finer pieces of coke resulting from the screening of the major sizes. As known to the trade, breeze is all the fine coke passing through a $\frac{1}{2}$-inch or $\frac{3}{4}$-inch square opening screen. Further subdivision is made in some cases, dividing the coke into buckwheat and rice sizes, although there is not much demand for these except for special purposes. Until the advent of the regenerator oven breeze was somewhat a drug on the market. Although breeze could be successfully



Cooling coils.

used under hand-fired boilers, the boilers could not be forced to rating and there were many difficulties due to clinker, etc. The market for breeze for the manufacture of carbides, carborundum, electrodes, etc., was limited to special grades. With the development of the regenerator oven, however, it became necessary to utilize the breeze and hence the Combustion Engineering Corporation brought forth the Coxe stoker, which was immediately successful in burning breeze, anthracite culm, and other low-grade fuels. Perhaps its greatest success has been with coke breeze. Ratings on boilers of over 200 per cent are common practice and this otherwise almost valueless fuel has now become valuable. Efforts in the past at briquetting, etc., were mostly complete failures and there is practically no fuel of such description being produced today.

Breeze, running high in ash, sulphur, and water, thus came into its own as a boiler fuel. The composition of breeze is dependent upon the methods of the plant where it is produced, but is roughly:

	Per cent
Ash	5 to 40
Sulphur	2 to 5
Water	10 to 20
Volatile matter	0·5 to 2
Carbon	72·5 to 33
	100·0 to 100

Calorific value—9,000 to 12,000 B.T.U.

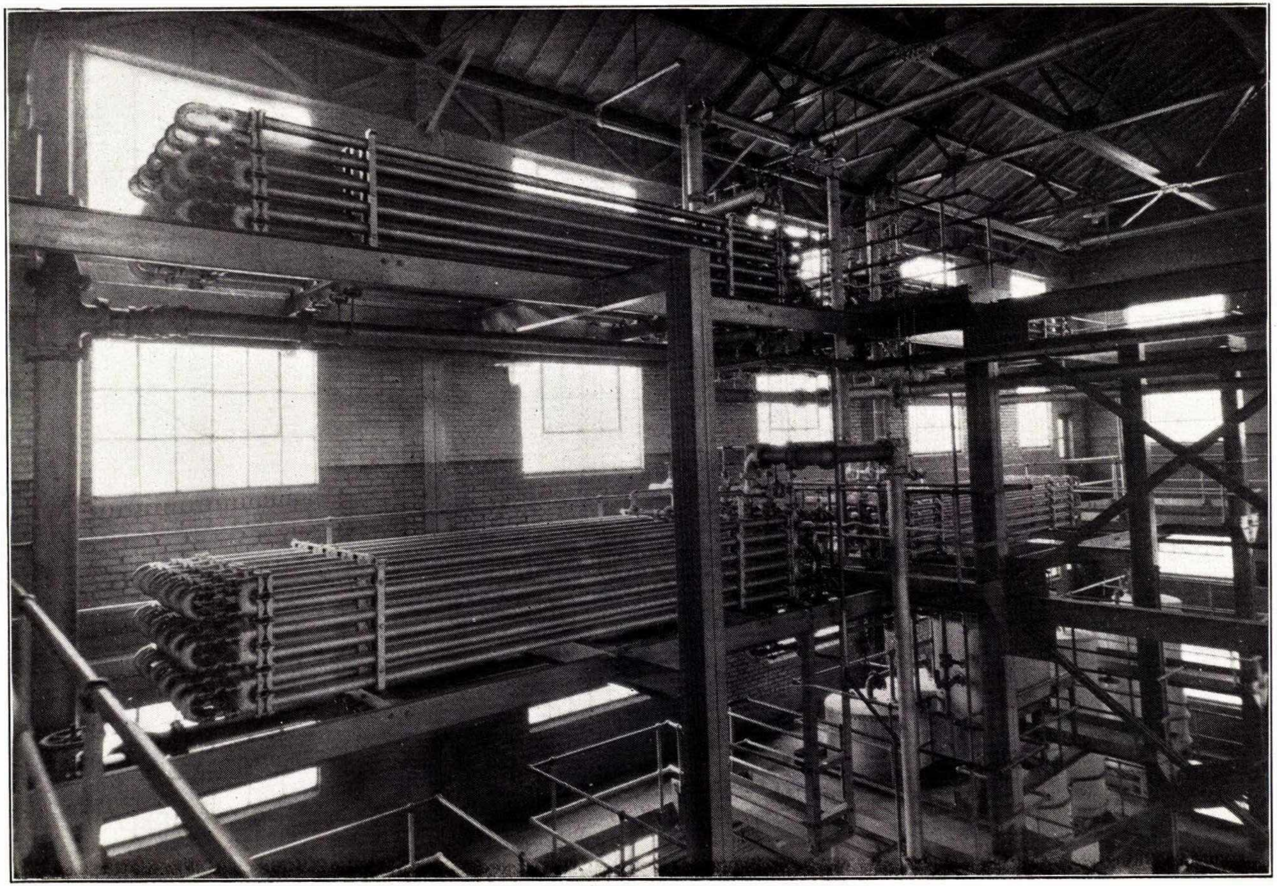
For boiler purposes breeze is usually assigned a value based on its B.T.U. value when compared with the heating value of a good grade of steam coal. Usually this will run from 70 to 80 per cent of the price of steam coal.

In later years breeze has become more important owing to the perfection of the gas producer, which it is claimed by some manufacturers will use as high as 50 per cent breeze when mixed with pea or nut coke. Producer gas, when used for the auxiliary firing of coke ovens, can thus be made more cheaply. Owing to these developments the economic importance of breeze to the coke plant is evident.

Usually at the coke plant only enough breeze is made to take care of the steam requirements, and where there is any surplus it is sold as steam fuel or used in gas producers or generators.

YIELDS OF BY-PRODUCTS

Yields of by-products are dependent largely upon the quality of coal used, but also on the methods of recovery. Regulation of oven heats, especially in the top of the oven, is most important in order to facilitate the formation of some products and prevent the cracking or destruction of others. In many plants the by-product apparatus is inadequate and recovery has naturally been low.



Condensing coils, light oil.

A well-operated plant will recover 95 per cent of the oils, and practically all the tar and ammonia in *the gas*. This efficiency is that of the by-product apparatus, not the oven. The by-product oven recovers only about 25 per cent of the nitrogen in the coal. This is owing to heat conditions in the ovens which are unfavourable to the formation of ammonia or cyanogen compounds. Actual yields per ton of coal carbonized will run about as follows:

NH_3 (figured as sulphate); lbs.	26 to 30
Light oil; imp. gals.	3 to 3·5
Tar, imp. gal	8 to 12
Breeze, per cent.	3 to 6

Although ammonia yields are somewhat dependent on the coal used, tar and light oils are most affected. Breeze yield is a function of the mixing coals and the coking time and heat treatment. In general, plants manufacturing ammonia liquor instead of sulphate will recover a little less ammonia, for it is not profitable to remove all the ammonia from coke-oven gas, too much water being required for absorption, and the distillation of these weak liquors would cost more than the additional ammonia recovered is worth.

Cyanides, alcohol, and other products have also been recovered from coke-oven gas and may soon be produced in large quantities if the demand be sufficient to make operations profitable.

CHAPTER VIII

MANUFACTURE OF GAS

BY-PRODUCT OVEN, RETORT, AND WATER GAS

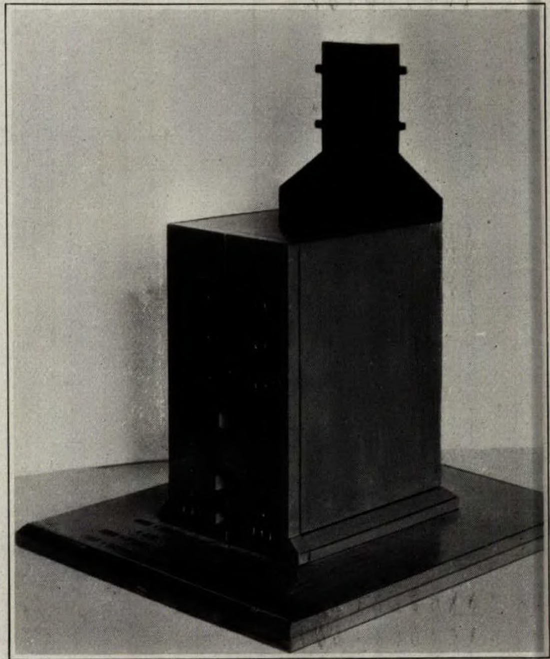
"Town" gas is manufactured by three methods, the by-product recovery coke oven, the retort system, and the water-gas system. Each of these has its own special field, and it is only when the fields overlap or an attempt is made to substitute one system for another that controversy arises as to their merits. It may be well in this connexion to comment briefly on low temperature carbonization and complete gasification. American gas engineers doubt if either process will ever be perfected. Low temperature carbonization aims at the production of a maximum quantity of oils—the quantity and quality unknown—at the expense of coke and gas. Attempts at complete gasification have not been successful. These processes have little to offer, either in the gas or domestic fuel field, and the opportunity for expansion of gas plants lies in the adoption of the by-product coke oven in rightly chosen localities.

The cost of making gas by the water-gas process, known as carburetted water gas, for city purposes, greatly exceeds the cost of gas made by either the retort or coke oven methods. But, the water-gas system has its place in very small plants or to take care of peak loads in localities where there is a great variation in load.

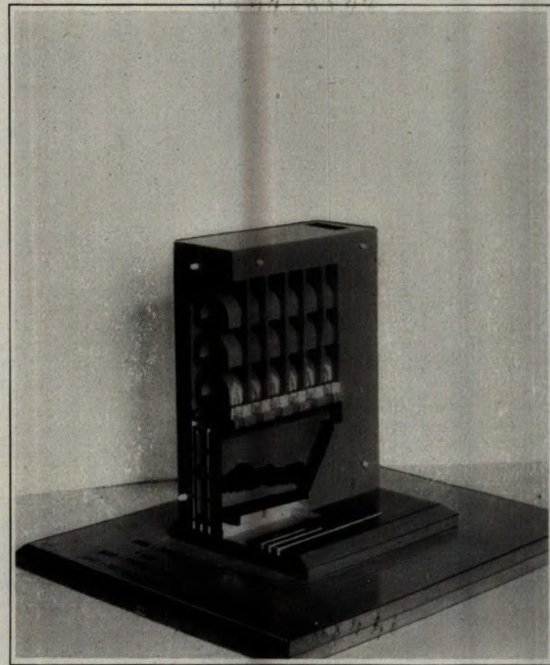
Water gas or straight blue water gas is useful as an ordinary fuel for heating coke ovens (*See* Chapter X).

In order to present fairly the respective advantages and disadvantages of the coke oven and retort methods data were obtained of modern retort plants in the United States. The plant selected as representative is one showing the best continuous practical results and is of the intermittent vertical type (*See* Figure 5 and Plate XX). This plant has been in operation for about five years, and is exceptionally well managed. In order to compare the results of this plant with a coke-oven plant of similar gas capacity, certain figures had to be changed to put the plants on a comparable basis. The coke-oven plant was producing gas of a high B.T.U. content and extra credit for gas produced was given and comparison was made on the basis of gas containing 550 B.T.U.'s per cubic foot.

Table XVII is a comparison of operation costs and returns of both plants, each capable of producing 6,000 M cubic feet of gas per day. No account has been taken of flexibility of the coke ovens when using auxiliary fuels such as blue or producer gas, but this matter is discussed elsewhere in this report.



A. Model, typical "D"-shape gas bench.



B. Model, vertical section through typical "D"-shape gas bench.

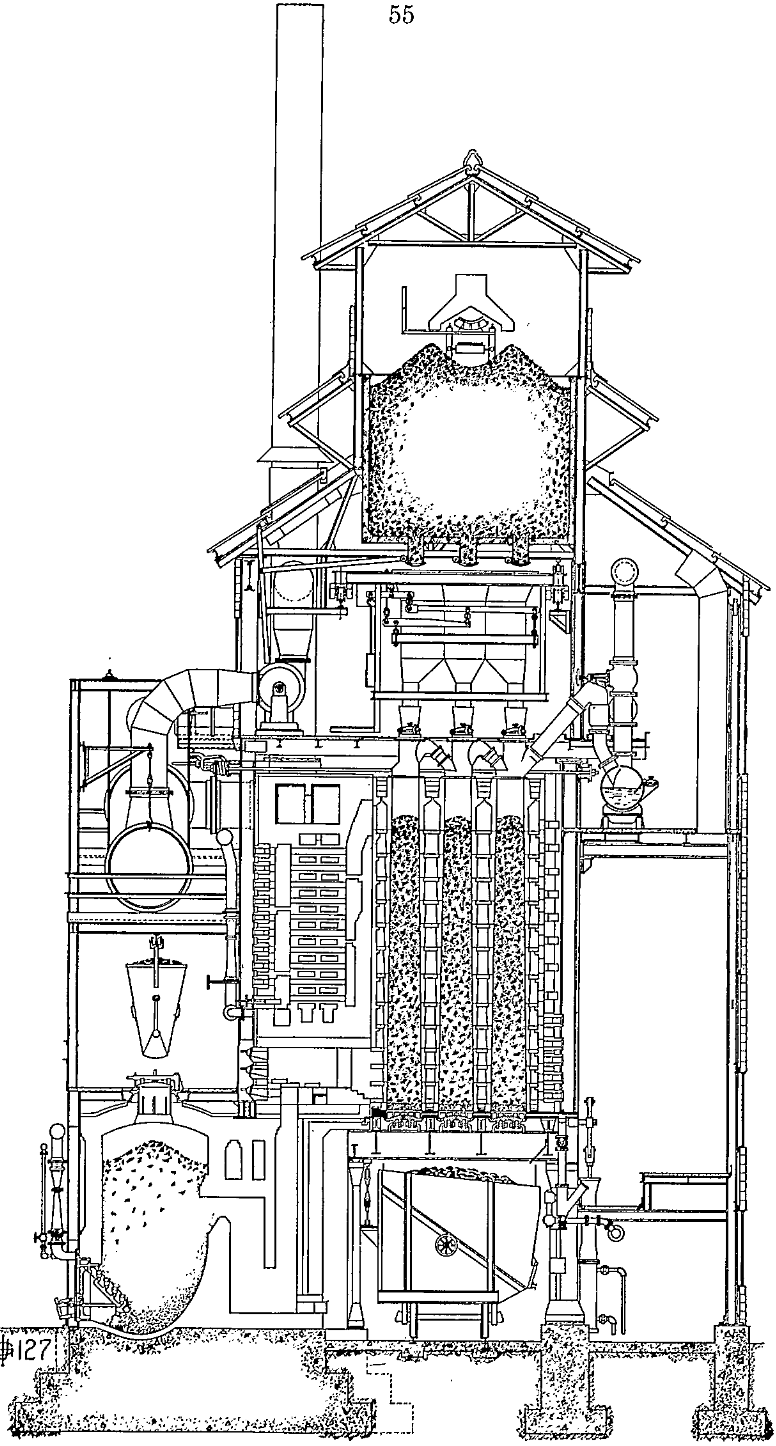
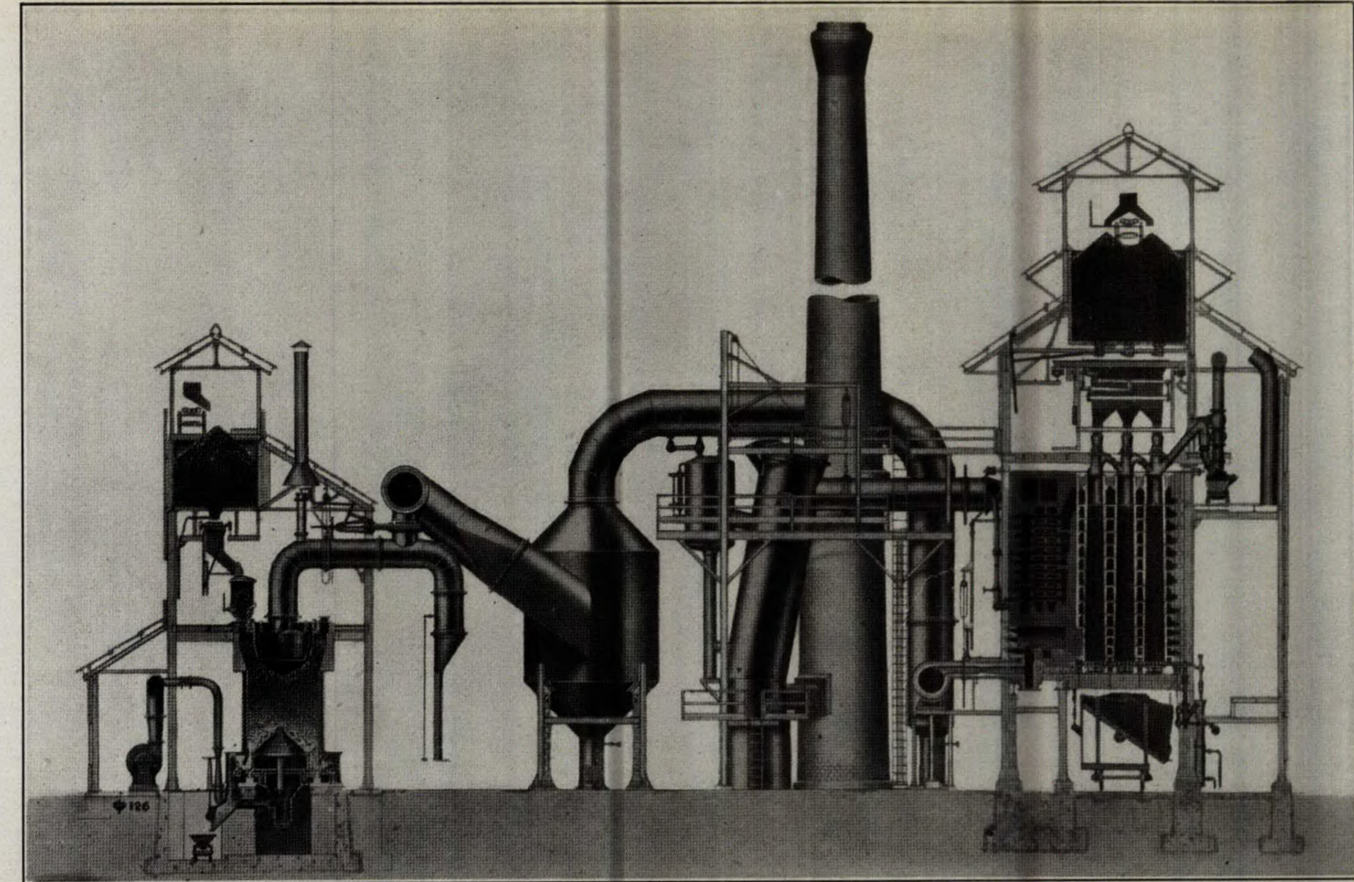


Figure 5. U.G.I. intermittent vertical retort system with attached producer.



U.G.I. intermittent vertical retort system with detached producer and waste heat boiler.

Table XVII.—Comparison of Costs By-Product Coke Plant and Retort Plant (6,000 M Cubic Feet Gas per Day)

—	By-product plant	—	Retort plant
Dry coal per day in tons	860		545
Commercial coke per day—70% from dry coal	600	50% from dry coal	283 (Saleable coke)
Operating labour—hours per ton dry coal	1·5		1·95
Repair labour—hours per ton dry coal	0·30		
B.T.U. in gas per cubic foot	550		550
	Per ton dry coal		Per ton dry coal
Total operating expense includes supervision, labour, repairs, power, water, etc	$2.00		$2.00
Insurance..... 0·5% on $2,500,000	0·04	0·5% on $2,000,000	0·053
Taxes......... 1·0% on 2,500,000	0·08	1·0% on 2,000,000	0·106
Depreciation. 6·0% on 2,500,000	0·48	6·0% on 2,000,000	0·636
7·5%	0·60	7·5%	0·795
Total expense	2·60		2·795
Cost of coal	6·35		7·350
Total cost	8·95		10·145
Returns from by-products— Yields		Average price for the year	Returns from by-products Yields
NH_3—lbs. per ton 6·5	0·53	$0·082	0·455 5·57
Tar—gals 9·0	0·33	0·037	0·490 12·22
Benzol—gals 3·0	0·71	0·230	0·570 2·40
Coke 70%	5·77	8·250	4·540 55%
Total credits	7·34		6·055
Net cost	1·61		4·09
	7 M cubic feet surplus gas yield per ton coal		11 M cubic feet surplus gas yield per ton coal
Cost of gas per M cubic feet	0·230		0·350

To produce the 6,000 M cubic feet of gas, the retort carbonizes about 545 tons of coal per day, the coke oven about 860, the retort producing about 285 tons of saleable coke, the ovens about 600 tons. The retort plant uses about 325 pounds coke per ton of coal carbonized, this coke being converted into producer gas which fires the retort. This coke contains about 17 per cent ash and 7 per cent water and in size is everything passing through a 1¼ inch screen. The plant, therefore, has a high efficiency.

The man hours of labour required for operating the retort plant are average ones over a period of one year; the man hours for the ovens are conservatively taken, for many plants of similar capacity are consistently bettering these figures.

Including supervision, labour, repairs, power, water, etc., the conversion or operating cost has been taken at $2 per ton of coal carbonized in each plant. The retort plant actually operated for over a year at a cost of slightly over $2. The coke-plant costs will run considerably less than $2 and the figure for same base rate for labour used in the retort plant would give the coke-oven plant a cost of about $1.80 per ton.

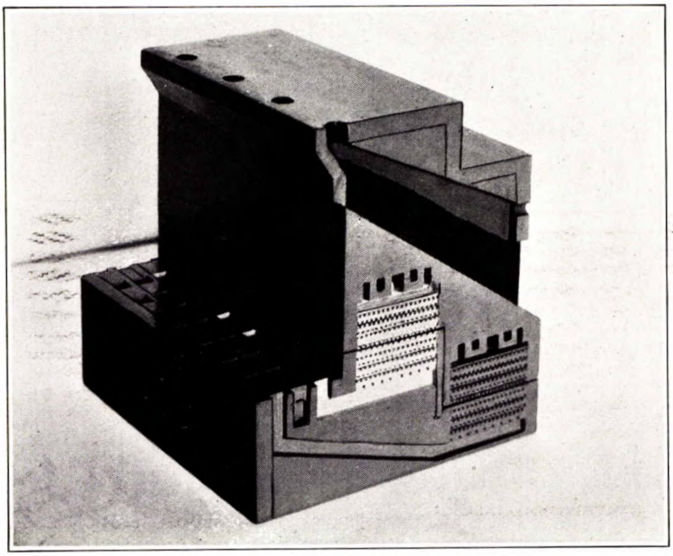
The retort plant cost slightly over $2,000,000; a coke plant of capacity shown can be built for $2,500,000. Fixed charges included in the total expense have been taken as shown on the cost sheet, based on the respective valuations of retort and coke plant. All figures are based on the cost per ton of dry coal carbonized. In comparing retort and oven plants, it is customary to figure the cost of the coal the same for any given locality. This, however, is not strictly fair. Recent tests have proved that the retort operates best on *screened lump* gas coal.

The price of gas coals has been considerably above that of a good coking coal, because gas coals are comparatively scarce and the production is largely controlled. Moreover, screening of coal to produce lump sizes costs money—not alone for labour but because the rejects from the screens sell at comparatively low prices.

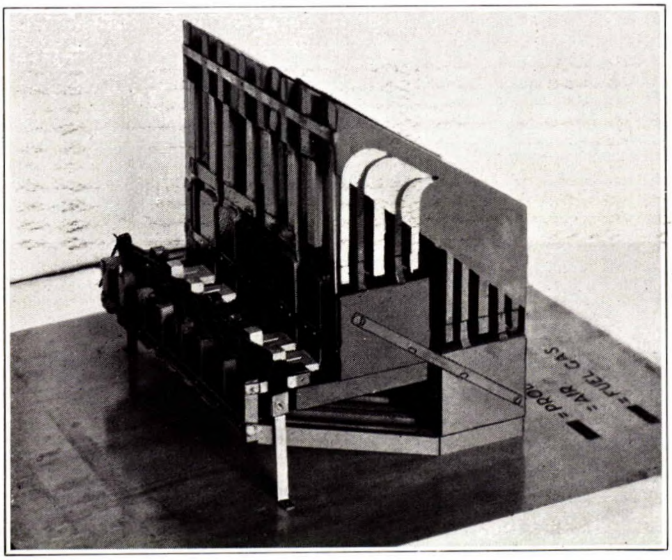
On the cost sheet, the figure shown for the coal price paid by the retort plant was the average price for one year. But a good coking coal, suitable for *metallurgical* coke, was available in the same locality at approximately $1.50 per ton less, and coking coals suitable for good domestic coke were available at still lower figures. In other words, the coke oven is not dependent on any particular coal, but can use the lower grades.

In order to place the comparison on an equitable basis, a spread of only $1 per ton is shown. As regards by-products, the coke oven will produce more ammonia, light oil, and saleable coke; the retort produces more tar and gas. The coke-oven builders excel in recovering and refining by-products, but if retort builders install adequate by-product recovery apparatus, the quality and quantity produced should be about the same as from the coke ovens. The extra cost of the apparatus would put the capital expenditure of both plants on the same basis.

The yields shown for the retort, on the cost sheet, are the average for a year, the plant having been in operation about five years; those for the coke oven are consistent yields after several years of operation. The retort produces more gas per ton of coal than the oven because it is fired with coke or gas made from coke, thus leaving all gas coming from the coal available for sale. The retort usually uses higher grades of coal than the coke oven and gas coals yield greater amounts of tar. Coke ovens when carbonizing gas coals immediately register the higher tar yield. The coke oven is heated usually with a part of the total gas produced, conserving the coke for sale. It is this feature of the coke oven which is of prime importance to Canada.



A. Model, Dods gas oven, vertical section through coking chamber and regenerators.



B. Model, Dods gas oven, core pattern of regenerators and heating flues.

The yield of gas shown for the retort is the average yield for the year, figured on a 550 B.T.U. basis; that for the coke plant is based on average practice for coke plants using a 30 per cent volatile coal. A certain Canadian coke plant has consistently, over a period of years, used only 35 per cent of the total gas to heat the ovens, and for monthly periods has used only 30 per cent. The average amount of fuel gas used on modern coke plants will vary from 35 to 50 per cent depending on the quality of coal, coking time, etc.

A comparison of the two plants shows the relative difference in the cost of gas, excluding interest on capital invested. The cost of gas naturally varies with the cost of coal, but after the cost has been determined, as in data shown, an additional charge of 1·6 cents per 1,000 cubic feet should be added to the cost of the coke-oven gas to represent 7 per cent interest on the difference in capital. For example, interest at 7 per cent on $500,000 is $35,000 per year, or 1·6 cents per 1,000 cubic feet of gas. Assuming that the retort produces as much ammonia and light oil as the coke oven, and 4 gallons of tar per ton more than the coke oven, and substituting December 1923 price for tar, then the retort would have about 50 cents more in by-product credits than is shown on the data sheet. This is about 4·3 cents per 1,000 cubic feet and the cost of gas from the retort on this basis is 30·7 cents, hence there is a difference of 6 cents or 7 cents in the cost of gas made by the two methods under the hypothetical conditions outlined. A difference of 5 cents per 1,000 cubic feet in the cost of gas represents in this case about $110,000 per year, or 10 per cent interest on an investment of $1,100,000. Moreover, no consideration has been given to the quality of coke which in the case of the coke oven will fetch slightly higher prices.

Although analyses of coke from the retort using gas coal, and coke from the coke oven using a fair grade of coking coal, are similar, there is a great difference in the physical characteristics. Retort coke makes a satisfactory domestic fuel, but, being much softer than oven coke, will not stand shipment and is, consequently, saleable only in the vicinity of the plant. Oven coke, when made for domestic purposes (not coke which is the reject from metallurgical screening) is hard, occupies less volume than retort coke, is much denser, and is physically nearest to anthracite. It stands transportation, weathers better, is generally cleaner and free from dust.

The superiority of by-product coke is evident from the fact that by slight changes in coking time and treatment of the coal, it can be produced for metallurgical or other industrial purposes. This enables the operator, during the warmer months when the domestic trade is slack, to market his output as industrial coke. The usual practice in the retort plant during

Discharge side, battery of Solvay ovens.

those months is to slow down, using part of the coke to make carburetted water gas and stocking the remainder—a very expensive expedient, which results in raising the average cost of gas over the year.

The retort, unquestionably, can easily hold its own with the coke oven on plants producing not over 1,500,000 cubic feet of gas per day, and to a lesser degree with coke ovens on plants producing from 2,000,000 to 2,500,000 cubic feet per day. But in larger plants such as those proposed for Montreal and Toronto, the coke oven can produce gas more cheaply. Where possible, retorts should replace water gas, and coke ovens should replace the retort. From the standpoint of national expediency, the more coke produced the better, for the larger the production the nearer will Canada be to domestic fuel independence.

Many gas works operators object to a large production of coke, claiming no desire to enter the coke business. With the broad market existing for domestic fuel, and with the fuel dealers ready to co-operate, there is no reason why plant owners should go into the retail business. The entire output of contemplated plants can be sold on favourable contractual terms.

In the quality of gas made by the retort and coke oven, there is very little difference. The characteristics of various industrial gases is shown in the following table:

Table XVIII.—Characteristics of Common Industrial Gases

—	Blue gas	Carburetted water gas	Oil gas	Coke oven and coal gas	Producer gas
Illuminants	None	*10·0*	5·0	3·0	None
Marsh gas, CH_4	2·0	13·0	*26·0*	*33·0*	3·2
Hydrogen, H_2	*50·0*	*34·0*	*55·0*	*50·0*	11·7
Carbon monoxide, CO	*39·0*	*31·0*	8·0	5·0	*23·1*
Carbon dioxide, CO_2	5·0	4·0	2·0	2·0	4·7
Oxygen, O_2	0·5	1·0	trace	1·0	0·5
Nitrogen, N_2	3·5	7·0	4·0	6·0	*56·8*
Specific gravity	0·53	0·66	0·37	0·40	0·8
B.T.U.	310	585	595	580	153

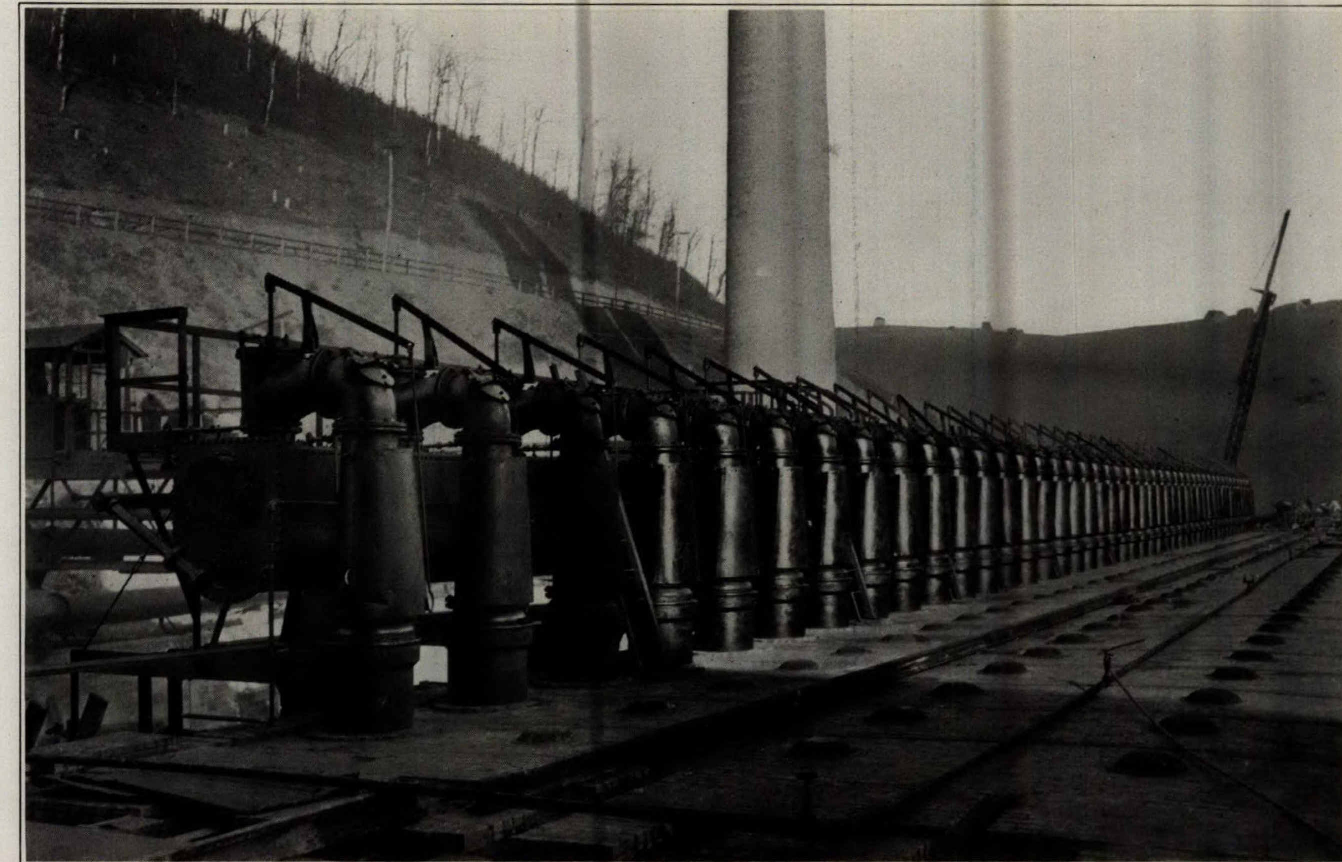
Predominating characteristics of each gas are shown in italics.

Table XIX gives the average hourly analysis of the gas from a single coke oven. The test was conducted over a period of four days. The oven, 16 inches wide, was run on seventeen-hour coking time, and was coking a mixture of West Virginia and Kentucky coals.

Owing to the fact that the larger part of coke-oven gas is evolved during the first part of the coking period the average B.T.U. content of the gas is much higher than the average of the B.T.U. values shown in the following table. In the heat balance shown in Chapter IX, on ovens, the nitrogen content of the gas average for one month's run was only 4 per cent. The coke oven can compete where the market for gas is limited. Winnipeg, Man., Utica, N.Y., and Battle Creek, Mich., all have comparatively small gas requirements, but have discarded the retort plant for "town" gas and have substituted the by-product recovery coke oven. In Buffalo, N.Y., however, a retort and water-gas plant is now under construction. Conditions here, however, are against the coke oven. Some retort coke will be made, which will be used in water-gas machines for producing upwards of 10,000,000 cubic feet of gas per day during the winter, and this system is employed in conjunction with rapidly diminishing natural gas supply. In this city, the daily demand for gas varies from 10,000,000 feet in summer to 70,000,000 in winter. The retort and water-gas plant was selected because it is easy to close down in summer and start up again in winter.

Table XIX.—Quality of Gas Evolved by Coke Oven: Average Hourly Analysis

Time	C_6H_6	CO_2	C_2H_4	O_2	CO	H_2	CH_4	N_2	Comb.	Calculated		Observed		Candle power
										B.T.U.	Sp.gr.	B.T.U.	Sp.gr.	
1st hour...	1·1	2·1	4·5	0·3	6·2	41·2	38·3	6·3	91·3	641	0·449	639	0·447	16·34
2nd hour..	0·8	2·0	4·0	0·2	5·3	45·5	36·2	6·0	91·8	633	0·425	616	0·428	15·61
3rd hour..	0·8	2·0	3·6	0·2	5·0	45·6	35·6	7·2	90·6	598	0·432	586	0·423	13·78
4th hour..	0·7	1·8	3·4	0·2	4·7	49·5	34·0	5·7	92·3	591	0·390	582	0·388	13·45
5th hour..	0·7	1·8	3·4	0·2	5·2	47·6	34·0	7·1	90·9	586	0·421	585	0·408	13·84
6th hour..	0·6	1·8	2·9	0·2	5·6	48·8	33·7	6·4	91·6	573	0·426	563	0·405	13·06
7th hour..	0·6	2·1	2·5	0·1	5·8	49·1	32·8	7·0	90·8	558	0·413	556	0·397	12·71
8th hour..	0·5	1·9	2·2	0·2	6·4	51·1	31·5	6·0	91·6	548	0·395	532	0·397	12·10
9th hour..	0·2	2·1	1·5	0·2	6·4	51·7	31·7	6·2	91·5	531	0·386	534	0·387	10·64
10th hour.	0·2	1·9	1·5	0·2	6·4	52·7	31·3	5·8	92·1	530	0·380	530	0·390	10·32
11th hour.	0·2	2·0	1·4	0·2	7·1	52·8	31·3	5·0	92·8	529	0·382	516	0·377	10·33
12th hour.	0·2	1·5	1·3	0·3	6·9	53·3	31·2	5·1	93·1	529	0·370	528	0·368	10·37
13th hour.	0·3	1·6	1·7	0·2	6·9	53·2	31·2	4·9	93·3	538	0·380	530	0·376	10·24
14th hour.	0·3	1·2	1·3	7·3	7·0	54·8	30·3	4·8	93·7	529	0·361	528	0·363	9·36
15th hour.	0·2	1·2	1·1	0·2	6·8	58·1	27·5	4·9	93·7	498	0·343	490	0·344	8·50
16th hour.	0·2	0·7	0·9	0·2	6·1	62·1	24·8	5·0	94·1	488	0·318	487	0·317	7·70
17th hour.	0·1	0·7	0·6	0·1	5·1	65·9	21·4	6·1	93·1	450	0·298	478	0·294	7·41



Top, battery of Solvay ovens.

LIQUID PURIFICATION OF GAS

In the so-called liquid purification, soda ash (Na_2Co_3) is used for the removal of sulphur from the gas. Not all the sulphur is extracted, only from 80 to 90 per cent, the remainder being taken out in the usual manner by regular purification apparatus. Both favourable and unfavourable comments have been made, but it has been pretty well established that corrosion of apparatus, one of the apparent difficulties, is not caused by HCN, but carbon dioxide (CO_2) dissolved in water. At present the chief interest for Canada in this process is that criticisms are made that good results are not obtained in cold weather, and that efficiency of recovery is low, because the process is of combined temperature and chemical nature. However, rapid strides are being made in the development, and in the future this system may prove to be better, and more economical than those systems in present use.

CHAPTER IX

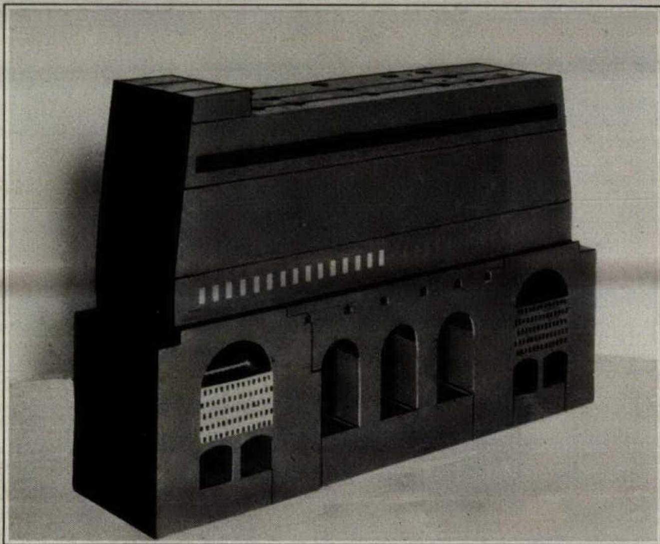
BY-PRODUCT COKE OVEN

In the latter part of the seventeenth century, attempts were made in England to make tar and coke; a century later attempts were made in Germany to replace charcoal—the chief fuel used for the manufacture of iron—with coke. But it was not until 1860 that practical success was attained, and tar and ammonia were recovered. Since that time, there have been in Europe various kinds of by-product ovens, such as the Coppee, Otto, Collin, Huessener, Simon-Carves, Koppers, Simplex, Semet-Solvay, etc. In 1893 the first coke ovens with by-product recovery were introduced in America and such rapid advances have been made that American design and practice now excel those of Europe. The ovens hereafter discussed are those of companies building or operating their ovens on this continent; other types have become obsolete. A partial list of by-product coke ovens in the North American continent is given in Table XX. The ovens in general use today are the Semet-Solvay, Koppers, and Wilputte, but the Roberts, Piette, and Foundation ovens have certain features which make them of special interest. The claims for type and style of each oven as hereafter presented are those put forward by the builders.

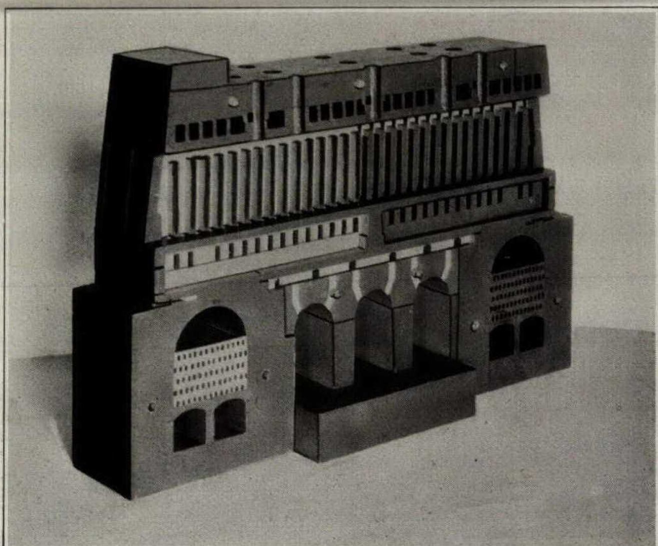
A by-product coke oven is a rectangular chamber surrounded by a system of flues which aims at accurately controlling the heat. By this means better coke and by-products are obtained, and in this respect the coke oven differs materially from the retort. As a rule all ovens are tapered to permit easy pushing of the coke. On account of the taper, vertical flue ovens have more flues on the coke side of the oven than on the pusher side in order to coke the greater thickness of coal.

The two principal flue systems are the vertical and the horizontal. In some cases one set of flues heats two adjacent oven chambers; in other cases each side of the oven chamber has its own flue system. A further distinction in ovens may be made, namely, the waste heat or recuperative type and the regenerative type. Waste heat ovens use cold air for combustion of fuel gas; recuperative ovens supply partly heated air and the regenerative oven uses highly preheated air (about 1,100°C.). For the past ten years in America the last type has almost exclusively been built, because of the greater yield of surplus gas, greater efficiency, and the advent of the modern stoker for burning breeze. The regenerative oven is also more flexible in operation and lends itself better than other types to the use of auxiliary fuels.

Top of Wilputte ovens with coal bin in centre background under which stands the four-hopper larry car.



A. Model, Otto-Hoffman oven, vertical section through coking chamber and omnibus regenerators.



B. Model, Otto-Hoffman oven, vertical section through vertical heating flues and omnibus regenerators.

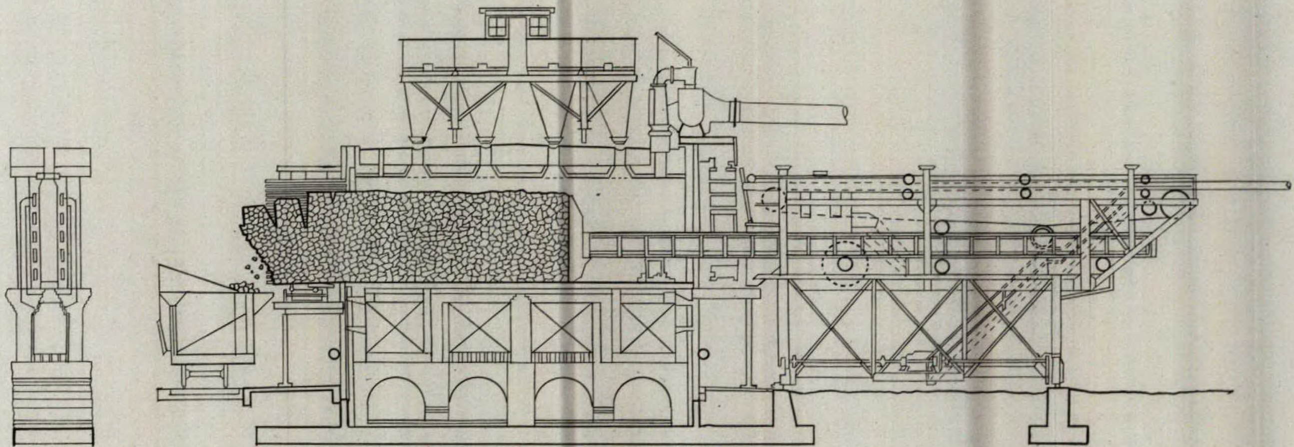
In America the ovens are built with silica brick instead of with clay brick, silica having several times more refractoriness and conductivity than clay.

A coke oven should be simple in design, and its working parts should be accessible. Facilities for inspection and regulation of the ovens should be such that work can be continued with least interference and discomfort to workmen. The ovens should be substantially built so that wear and tear will be at a minimum when operating at high speeds. A high quality of brick is essential. The main desirable features of an oven are: maximum output of coke; maximum yield of by-products; low fuel gas consumption; low maintenance costs and long life; ease of regulation and control; uniform heating of walls.

SEMET-SOLVAY OVEN

This regenerative oven—and practically no other type is being built on the North American continent—does not have the sole flue used in older types, but waste gases from the flues pass directly into the two-pass regenerators (*See* Figure 6), and has its horizontal flues independent of the walls and roof, so that the flues can be rebuilt without affecting the main structure.

Each oven has its own heating system divided from those of the adjacent oven by solid walls, so that the hot flue brickwork is relieved of the weight of the top brickwork and the charging larry. Each oven being independent can be repaired without distrubing the operation of adjacent ovens. Gas admission is made to the flue on the face of the oven above the platform and a peep-hole is provided at each end of every heating flue, through which conditions can be observed without inconvenience. On either updraft or downdraft the air supplied to the first burner is greatly in excess of theoretical requirements, and gas, admitted at convenient points in the flues, allows combustion to progress gradually with a minimum of burnt products, thus securing perfect distribution of heat over the oven wall. Reversals in direction of flow of waste products usually occur about every fifteen minutes, without the fuel gas being cut off, thus simplifying the operation of oven regulation. The amount of gas admitted to the flues at various points is regulated by orifices inserted in the burner piping, and once the battery has been adjusted the coking time is varied by simply changing the pressure in the fuel gas main. The use of auxiliary fuel entails no changes in design, because blue gas has the same relative efficiency as coke oven gas, and it is, therefore, unnecessary to provide double regeneration. This type of oven is best adapted for blue gas.



Section through oven chamber.

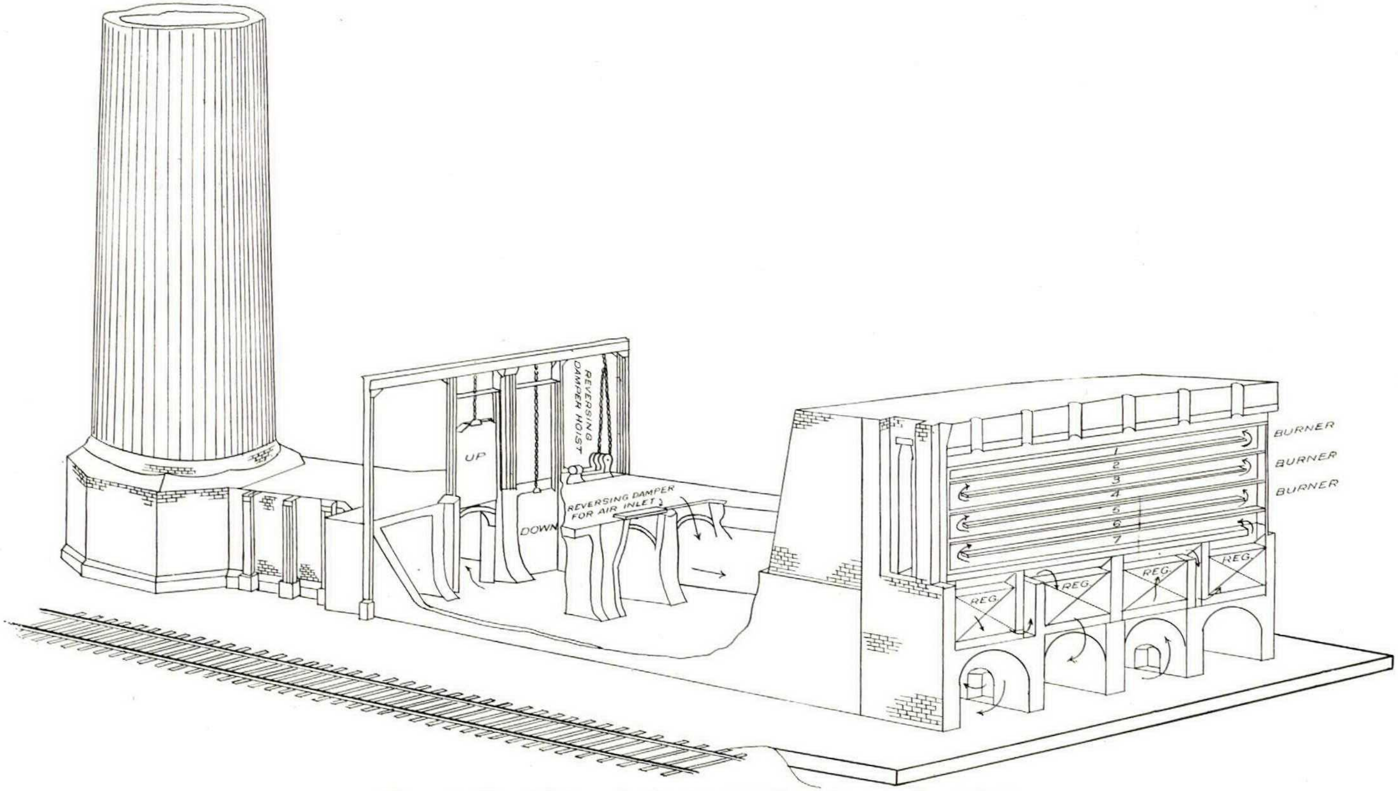
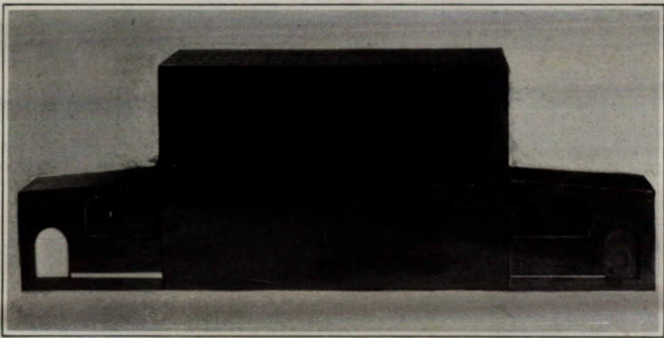
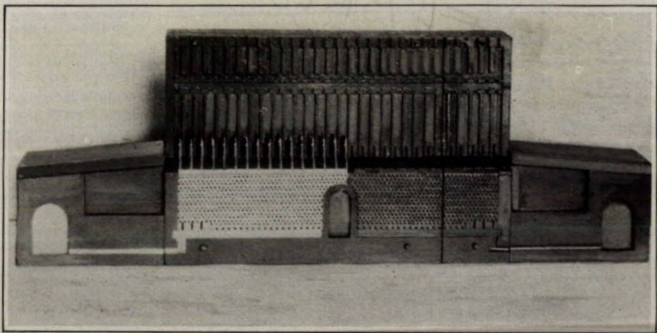


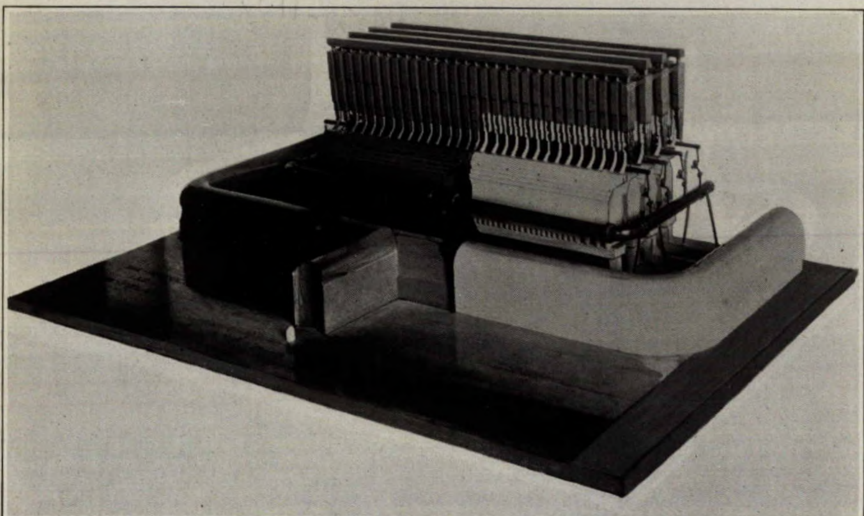
Figure 6. Semet-Solvay standard regenerator coke oven; flue system.



A. Model, Koppers original patent; end of battery.

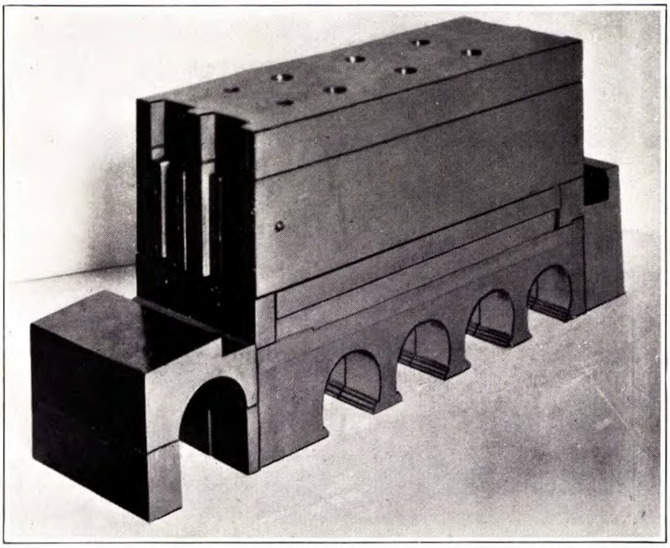


B. Model, Koppers original patent.

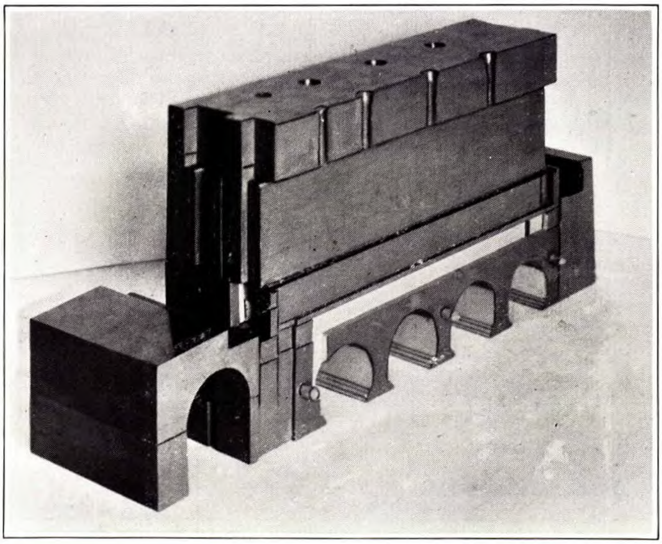


C. Model, Koppers original patent; showing all flues, air and gas inlets with brickwork removed.

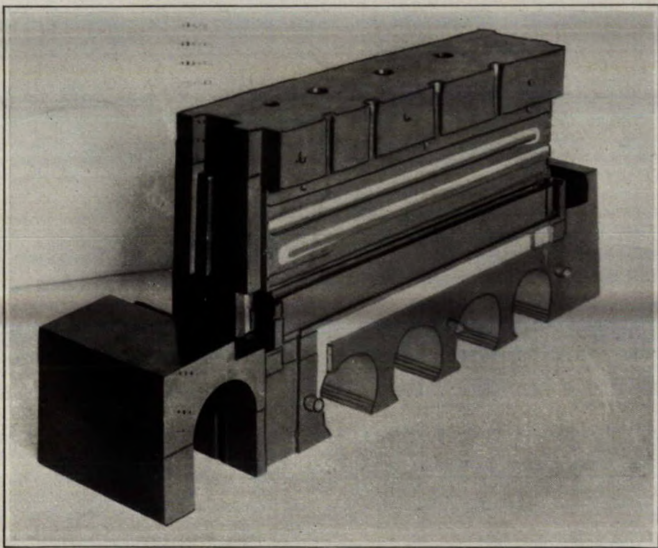
PLATE XXVII



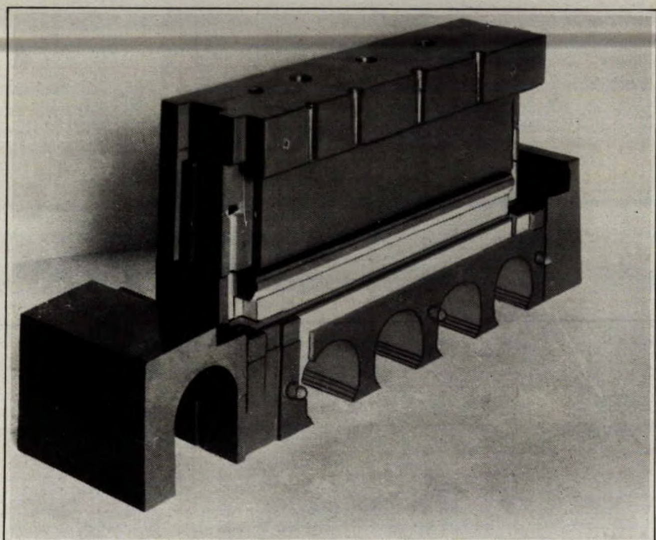
A. Model, original Semet-Solvay Company's sole flue recuperator oven showing division wall separating ovens.



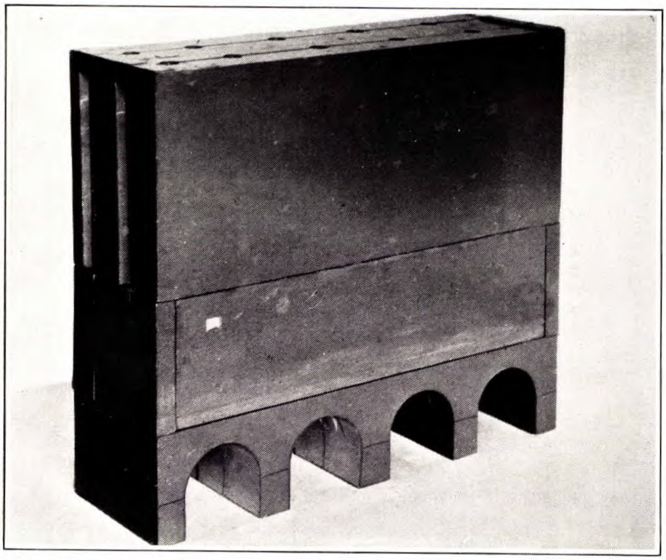
B. Model, vertical section through coking chamber and air inlet flues. Original Semet-Solvay oven.



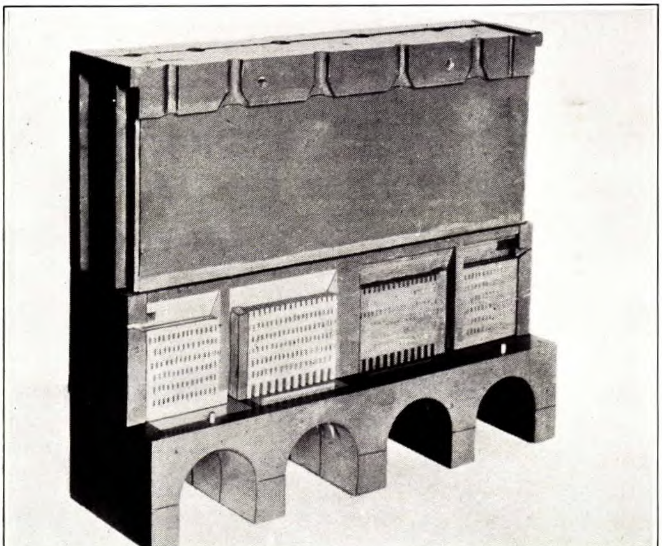
A. Model, vertical section through heating flues and sole flue. Original Semet-Solvay oven.



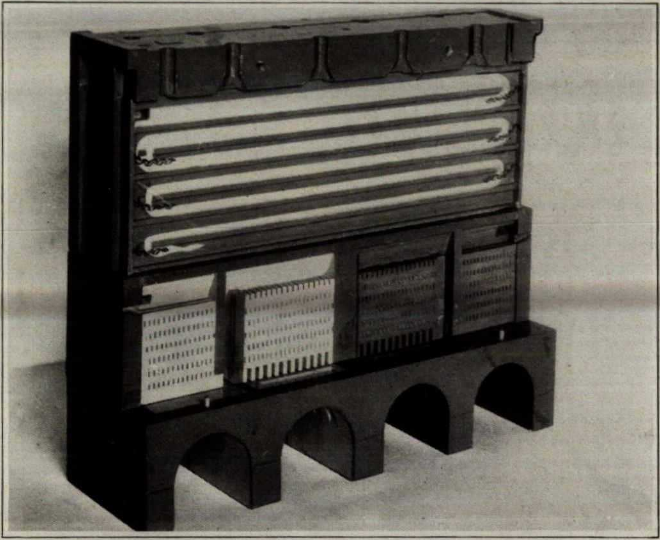
B. Model, vertical section through coking chamber, sole flue, air inlet, and air risers. Original Semet-Solvay oven.



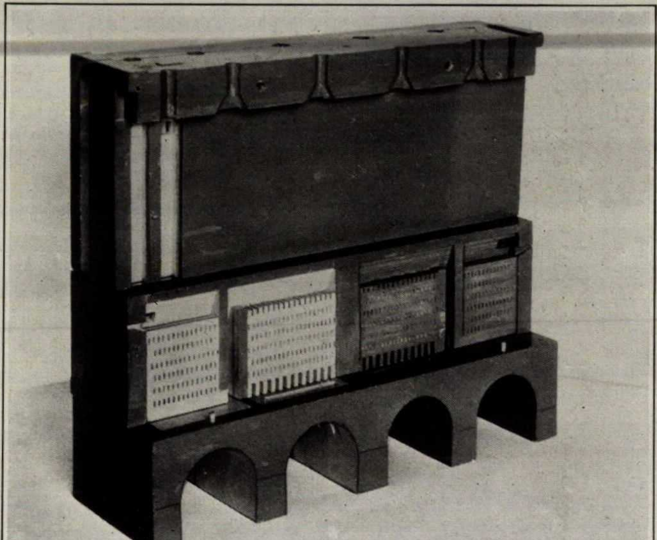
A. Model, double-pass regenerator coke oven showing division wall separating ovens. Semet-Solvay Company.



B. Model, vertical section through coking chamber and regenerators.

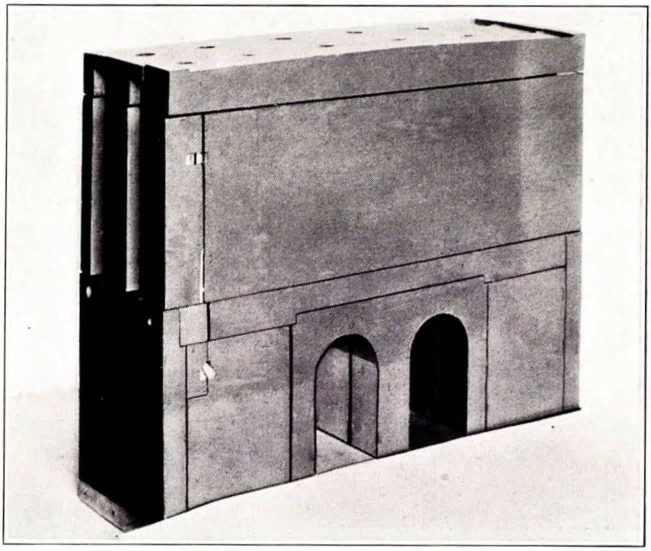


A. Model, vertical section through oven heating flues and regenerators.

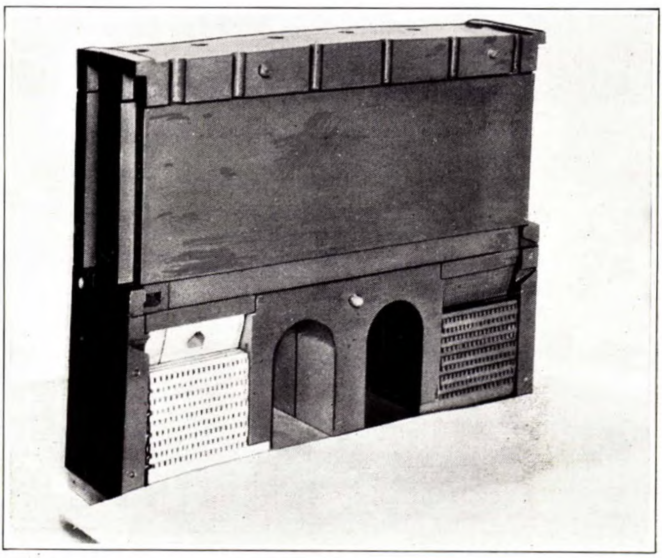


B. Model, vertical section through risers in division wall and regenerator.

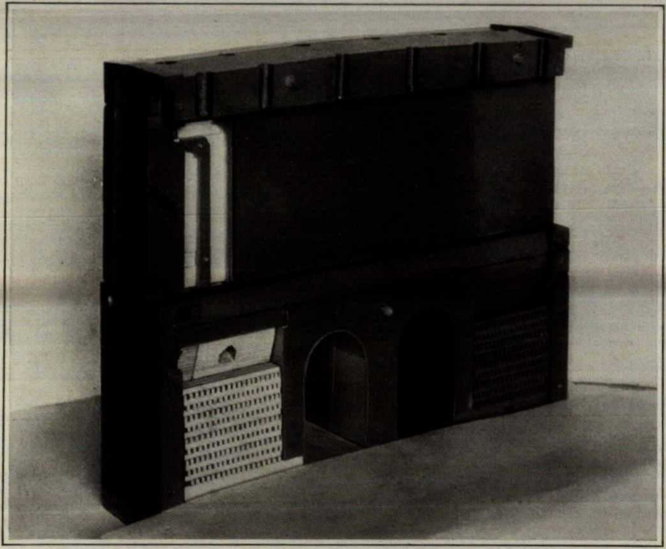
PLATE XXXI



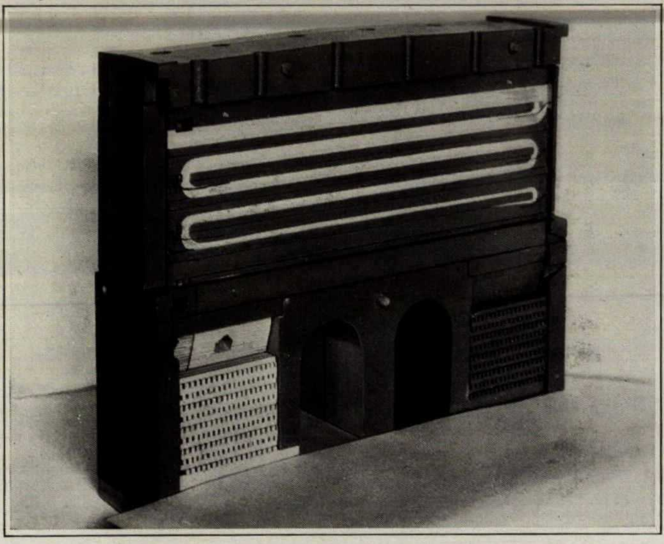
A. Model, single-pass regenerator coke oven showing division wall separating ovens. Semet-Solvay Company.



B. Model, vertical section through coking chamber and regenerators.



A. Model, vertical section through oven heating flues and regenerators.



B. Model, vertical section through risers in division wall and regenerator.

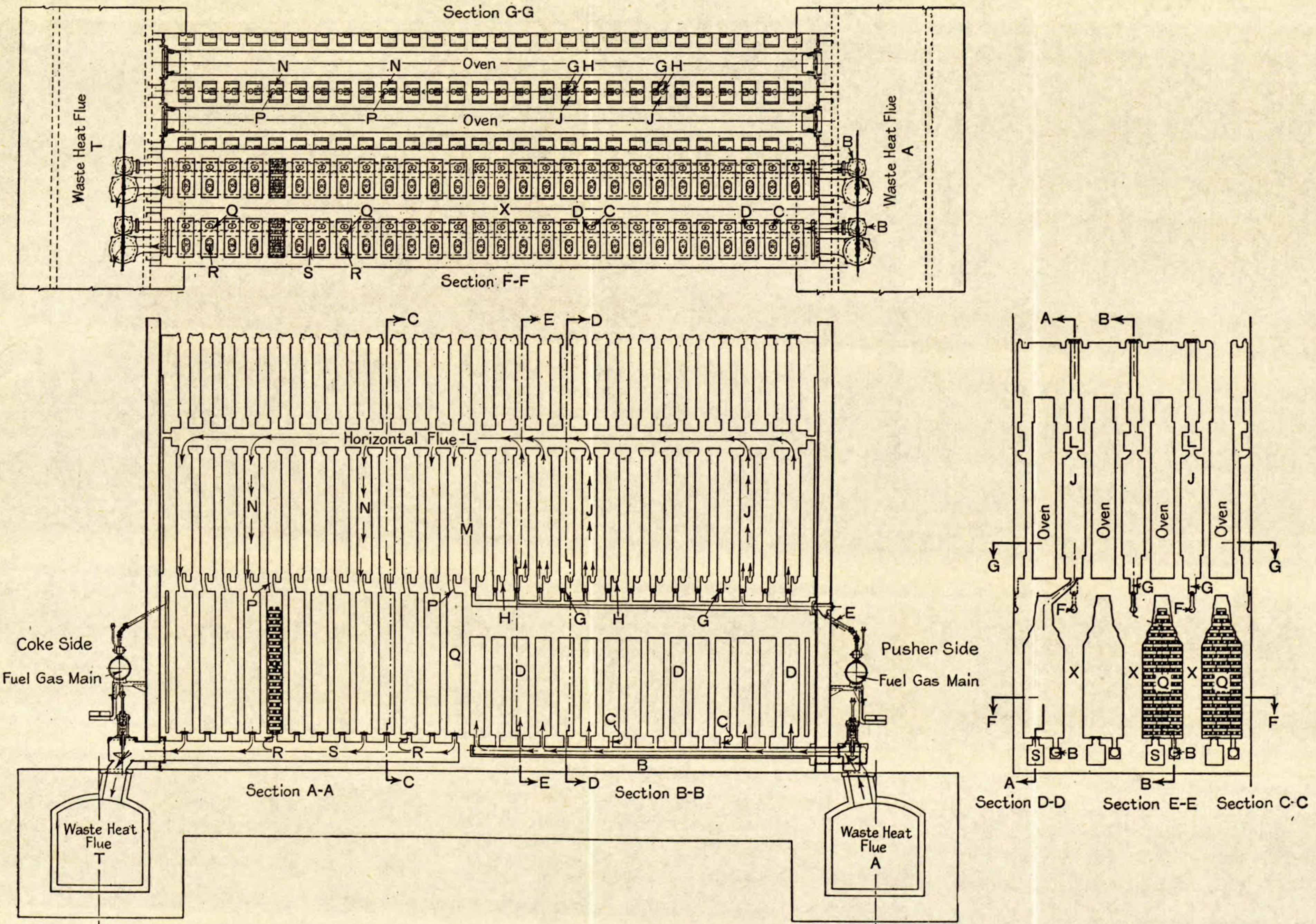


Figure 7. Wilputte regenerative coke oven; flue system.

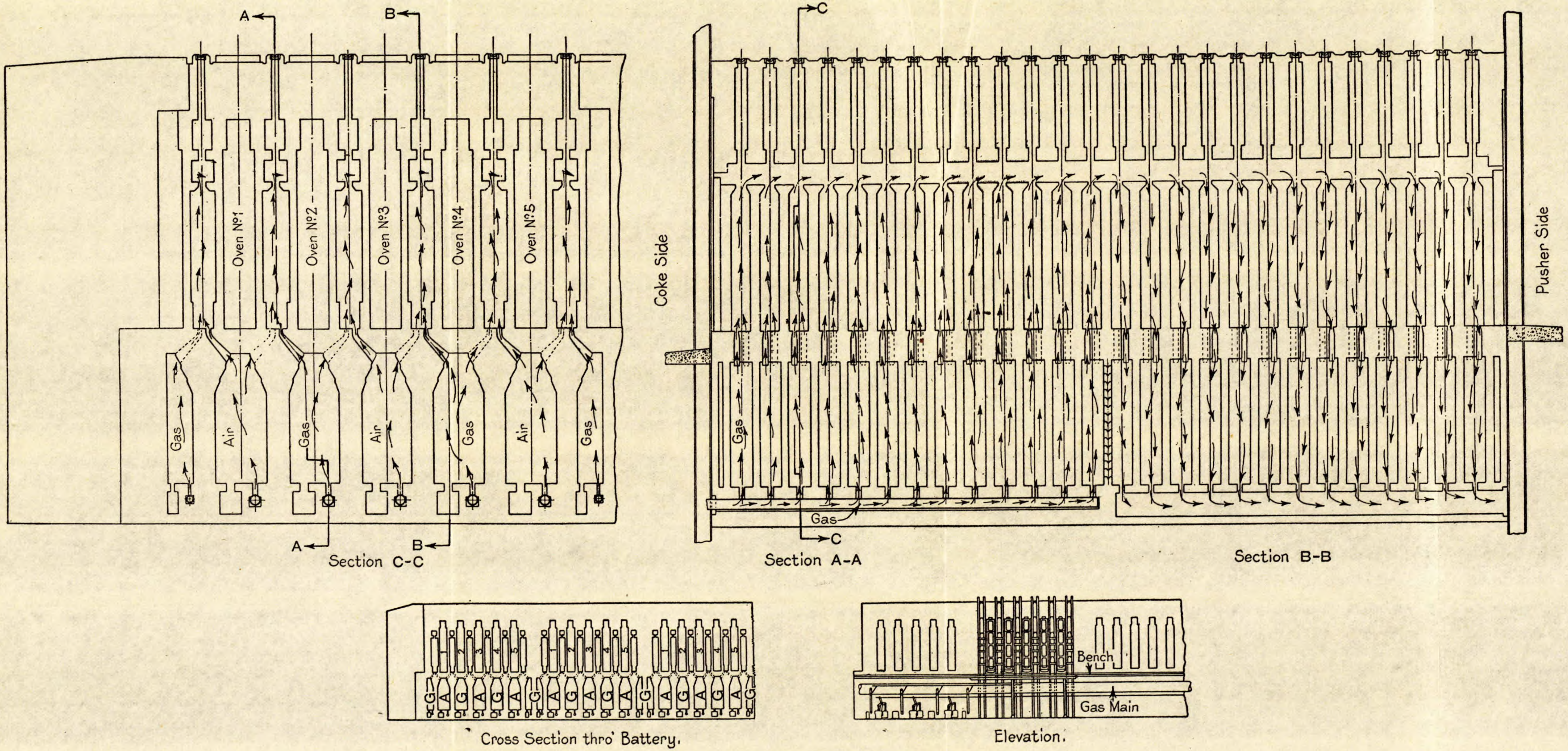
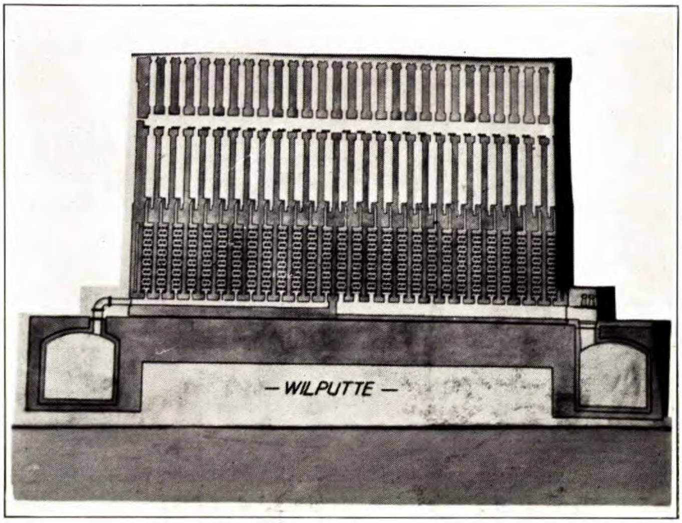


Figure 8. Wilputte gas oven.

WILPUTTE OVEN

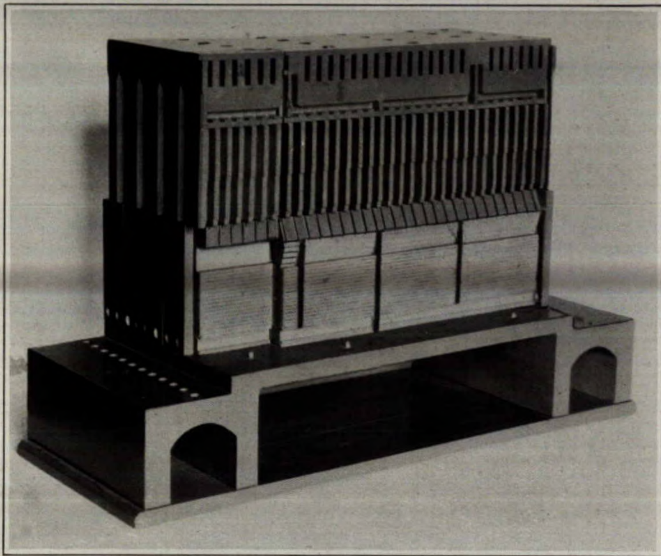
This oven, unlike others of its type, has a separate regenerator for each set of vertical heating flues (*See* Figures 7 and 8). Each regenerator has a separate air inlet and waste gas outlet which measure the air admitted and control the combustion products that escape. This arrangement ensures perfect regulation of air and gas supply and the correct distribution of combustion products. On both sides of the battery beneath the regenerators, air supply and waste gas conduits are connected separately to the respective waste heat flues. With such perfect control great economies result, there being little excess air to carry heat to the stack. Control of air and gas also gives control over flame length, preventing localizing of heat.

PLATE XXXIII

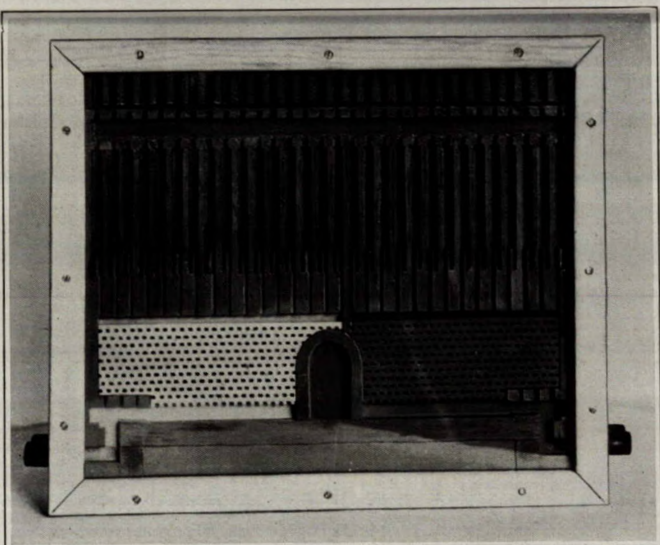


Picture drawing, Wilputte coke oven, vertical section through vertical heating flues and regenerators.

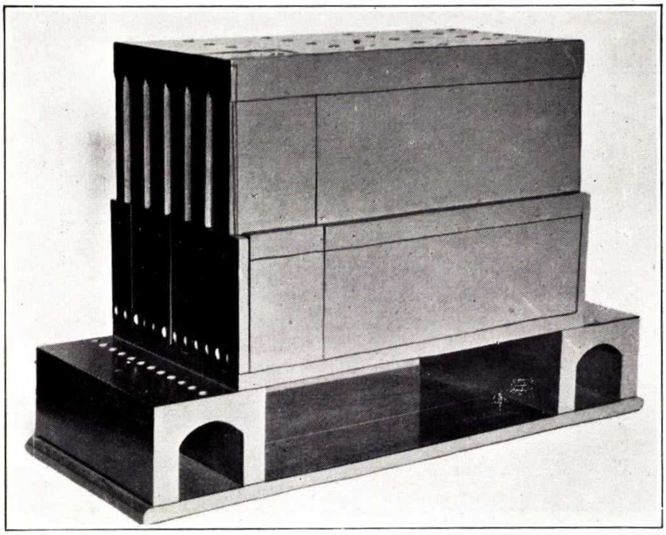
The Wilputte gas oven differs from the coke oven only in that provision is made for preheating producer fuel gas as well as air. Like all other vertical flue ovens it uses producer gas efficiently as auxiliary fuel. The regenerators are for gas and air alternately and each flue is connected to two regenerators, receiving air from one, gas from the other. Figure 8 shows the ovens divided into sections, each with five coking chambers, six heating walls, and seven rows of regenerators of which the two end rows are half the capacity of the others. Each regenerator, except those at the end, is connected to two flues, and all have steel supply pipes and separate waste heat channels to secure the same perfect control as in the coke oven.



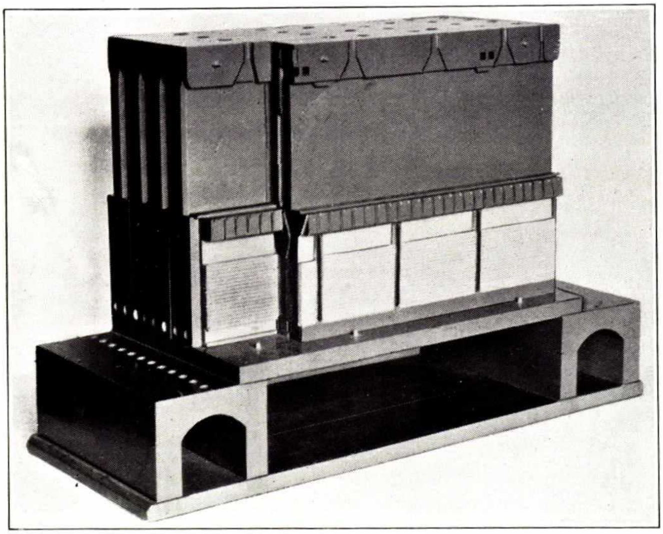
A. Model, Koppers oven, vertical section through vertical heating flues and regenerators.



B. Vacuum model, Koppers original oven, vertical heating flues and regenerators.



A. Model, Koppers oven, Becker type, end of battery.



B. Model, Koppers oven, vertical section through coking chamber and regenerators.

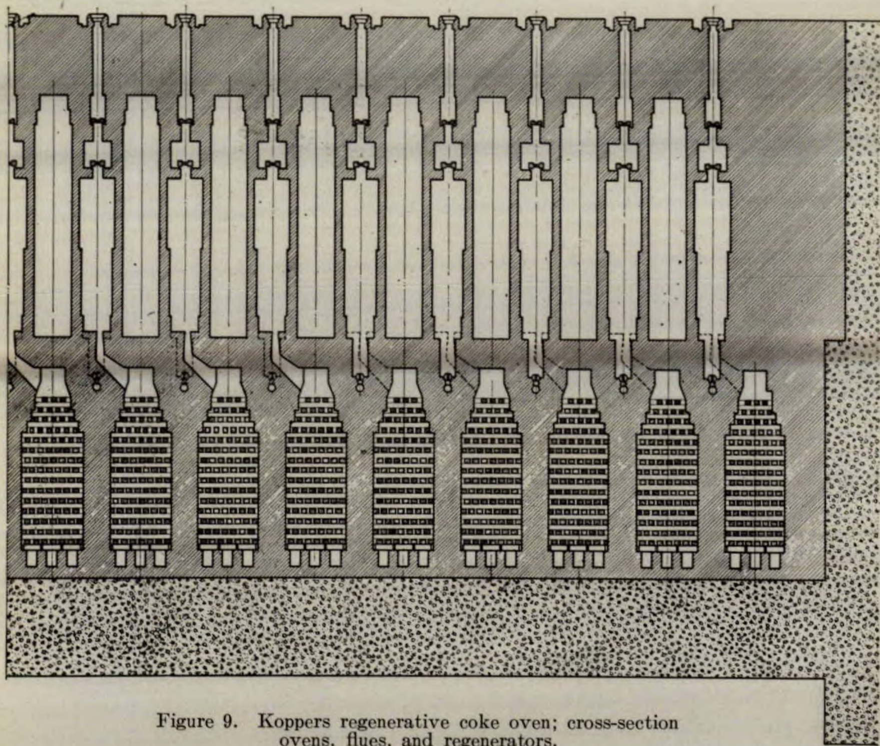


Figure 9. Koppers regenerative coke oven; cross-section ovens, flues, and regenerators.

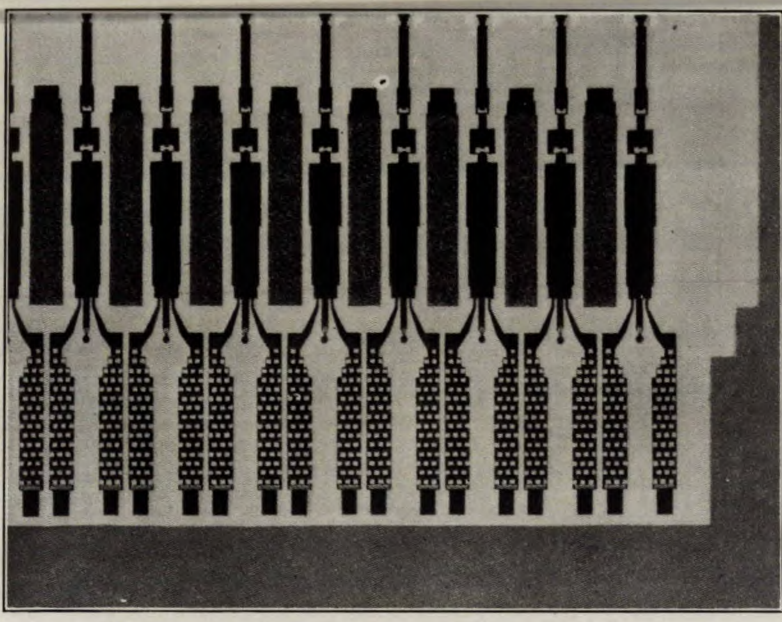
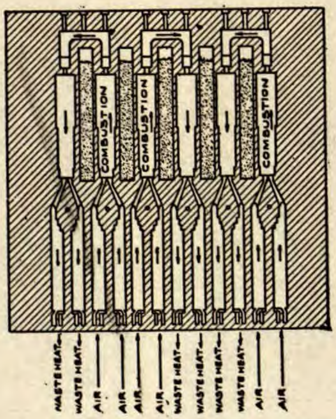
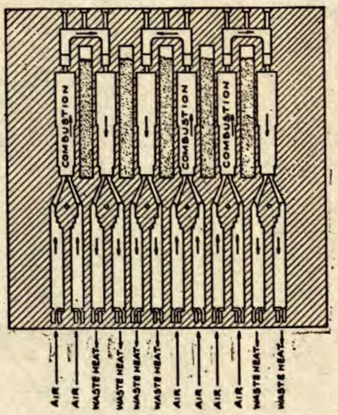


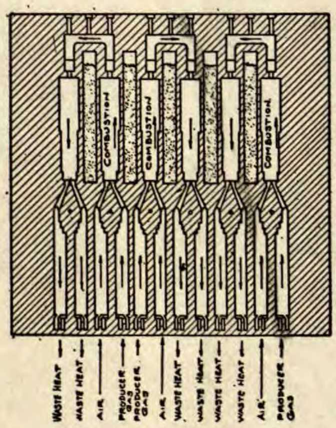
Figure 10. Koppers regenerative coke and gas oven; cross-section.



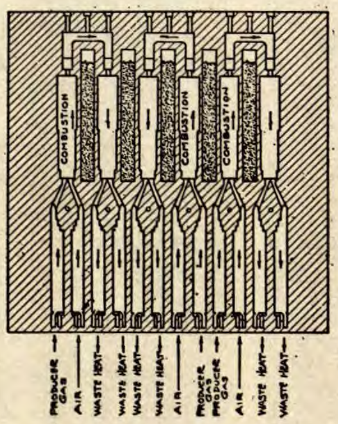
Coke oven gas heating.



Coke oven gas heating reversed.



Producer gas heating.



Producer gas heating reversed.

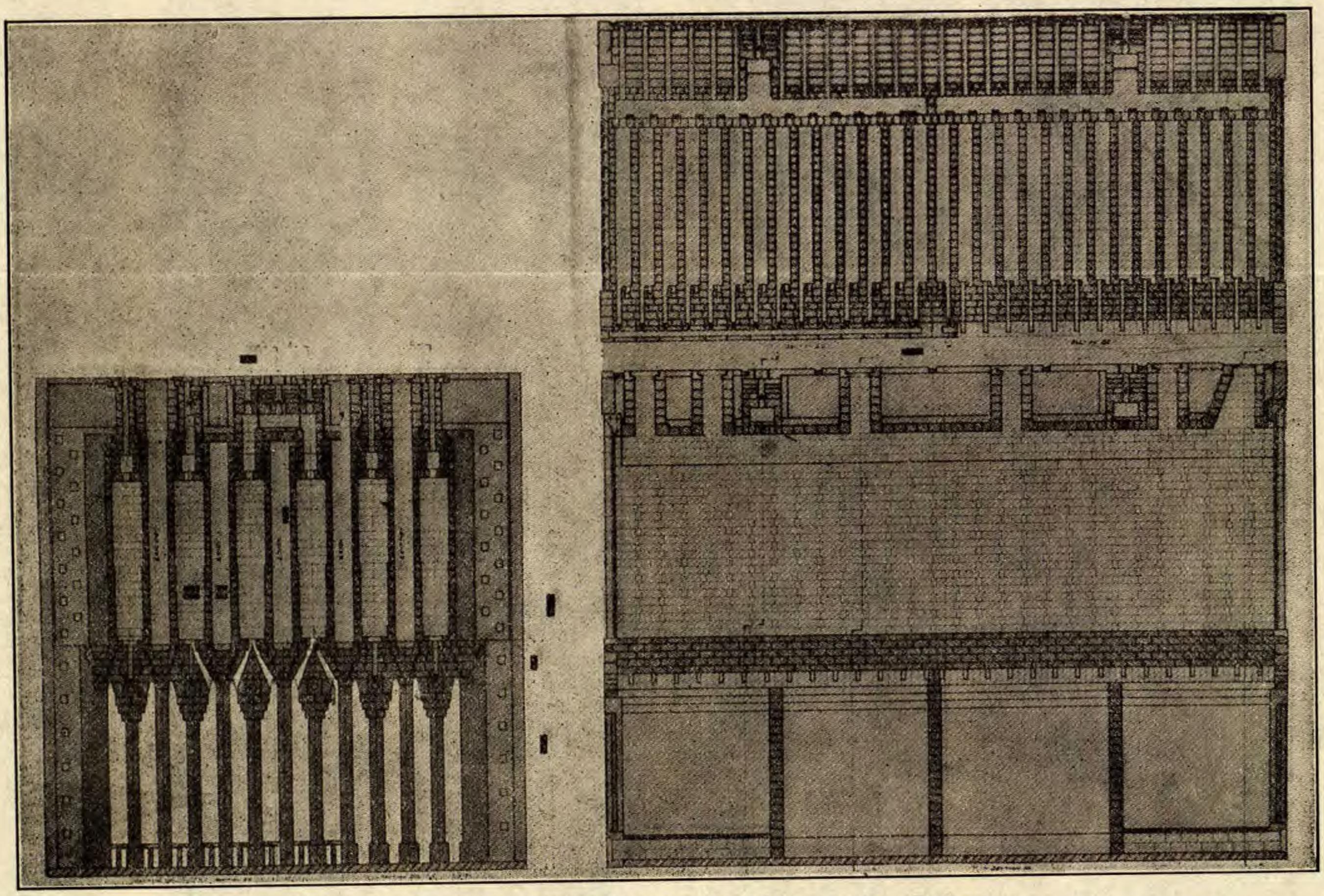


Figure 11. Koppers new combination oven; plan and cross-section. Becker oven.

Claims made for this oven are, uniformity of heat distribution, lowest gas consumption, and ruggedness. Actual results have shown that these ovens have very low gas consumption.

KOPPERS OVEN

The Koppers coke oven is of the vertical type, with individual regenerators for each oven. The flues are strong enough to carry the weight of the top of the battery, thus saving space, for the distance from centre of ovens is reduced to a minimum (*See* Figure 9). The fuel gas enters the gas duct lying beneath the flues and each flue is served with a removable nozzle through which gas passes into the flues. Pre-heated air from the regenerators passes into the base of the vertical flue through an air port, meets incoming gas, the burning gases passing upward in the flue, combustion taking place along half the oven length at one time. The reversal of the flow of gases is automatically controlled and reversals occur at intervals of 15 to 20 minutes. The quantity of gas admitted to a flue is controlled by changing the size of nozzle, or the pressure on the fuel gas main. Each flue is accessible for inspection and regulation. Sliding bricks regulate the flow of combustion products into the horizontal flue, thus regulating draft. The horizontal flues also are provided with peep-holes for inspection. Dampers regulate draft in each regenerator outlet and inlet and in the flues leading to the stack. Once regulation is established it is not necessary to interfere with the regulation as a whole, unless coking time or coal is to be radically changed.

The cross regenerative combination coke and gas oven differs from the coke oven in that there is a division wall built in the regenerator, and from the regenerator two lines of ports are provided to the flue system (*See* Figure 10). When operated as gas ovens, gas from a central producer plant is provided, the gas being cleaned and cooled before delivery to the ovens. Both gas and air are regenerated, and combustion is regulated as in the coke oven. One regenerator is given over to preheating of air, air from one side of the regenerator division wall going to one set of flues and that from the other side to the next set. The adjacent regenerator preheats the producer gas and distributes it in similar manner. When operating as a coke oven, the regenerators preheat air only and the operation is the same as in the coke oven. The upper structure of the oven is similar to that of the coke oven. Great economy is claimed for this type of oven operating on producer gas.

The third type of oven, designed and built by the Koppers Company, is known as the Becker, or Improved Type Koppers Company Combination Coke and Gas Oven (*See* Figure 11). The great efficiency claimed for this oven is attributed to the cross-over flue principle. The heating walls are divided into two or more groups, each group having its own horizontal flue and a cross-over flue centrally located with respect to the vertical flues it serves. The products of combustion collect in the horizontal flues, pass over the top of the oven, and are distributed downward through the flues of that oven; thus reversal of flow of the gases takes place over the top of the oven and down the opposite wall instead of longitudinally in same wall as in earlier types. It is claimed that a reduction of area in horizontal flues makes the lengthening of vertical flues possible, thus shortening the coking time. This increases the output per oven and, it is claimed, improves the quality of coke. The advantages claimed for this type of oven are due to the cross-over flue design which has changed pressure conditions and made possible new standards of heat distribution throughout the oven. Figure 11 shows system of regenerator control when producer or coke oven gas is used for fuel gas.

FOUNDATION OVEN

The Foundation Oven Corporation builds a by-product oven called the American coke oven, but it is popularly known as the Foundation oven.

It has vertical flues and the design involves the burning of the fuel gas in each alternate flue and the return of these gases in every intermediate flue along every heating wall of the battery, thus doing away with the horizontal flue found in all other vertical flue ovens. It is claimed that this feature not only gives stronger construction and permits increase in height of oven—thus obtaining higher charging capacity with a narrow oven—but that a continuous heat supply is obtained throughout the oven and the coal is not subject to variation in the coking rate as is the case with ovens in which the flow of gas is reversed from front to back and from side to side. The return of gas in adjacent flues prevents cold tops and hot bottoms and ensures a progressive heat supply in a tapered oven. The oven has the usual horizontal regenerator and two sole flues which affect balanced draft and uniform distribution of air and waste gases without the use of slide brick, etc.

These features make for long oven life, simplicity of operation, good coke structure (especially when using high volatile coals), and good conditions for production and preservation of by-products. Low initial costs are claimed by the manufacturer.

ROBERTS OVEN

The Roberts oven is designed in three types—recuperative, regenerative, and combination—whereby it can be heated with coke oven gas, producer or blast furnace gas, regenerating gas, as well as air when neces-

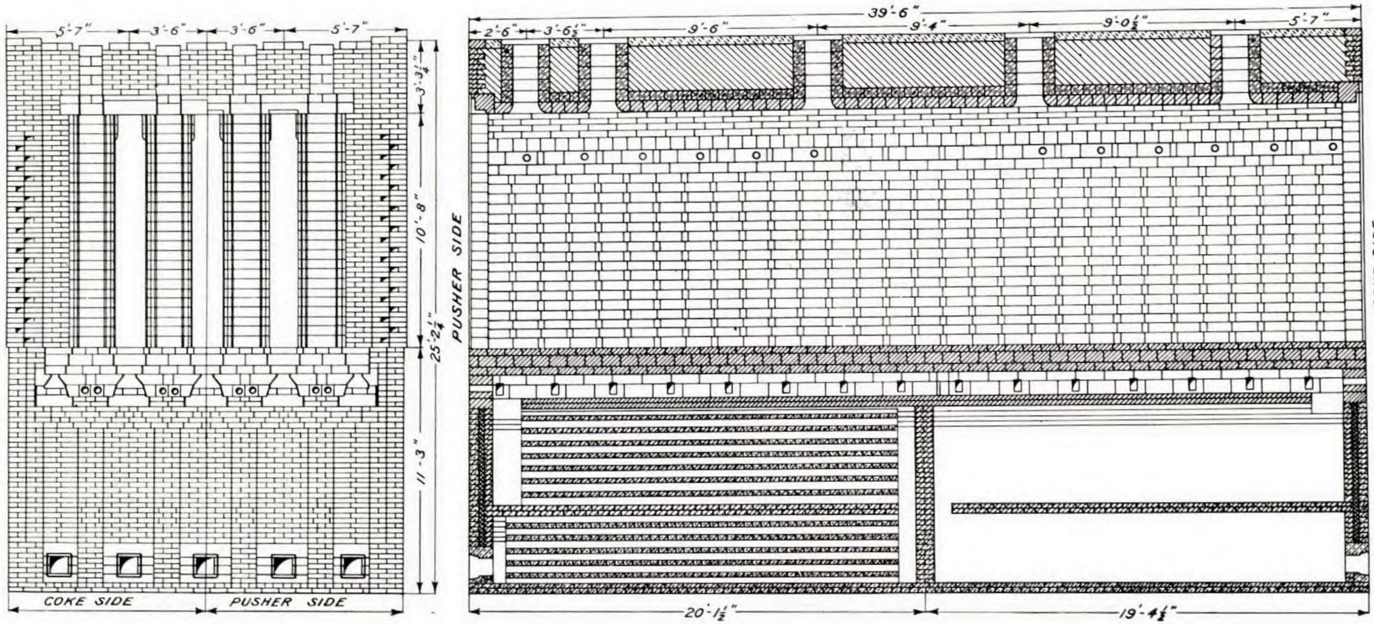
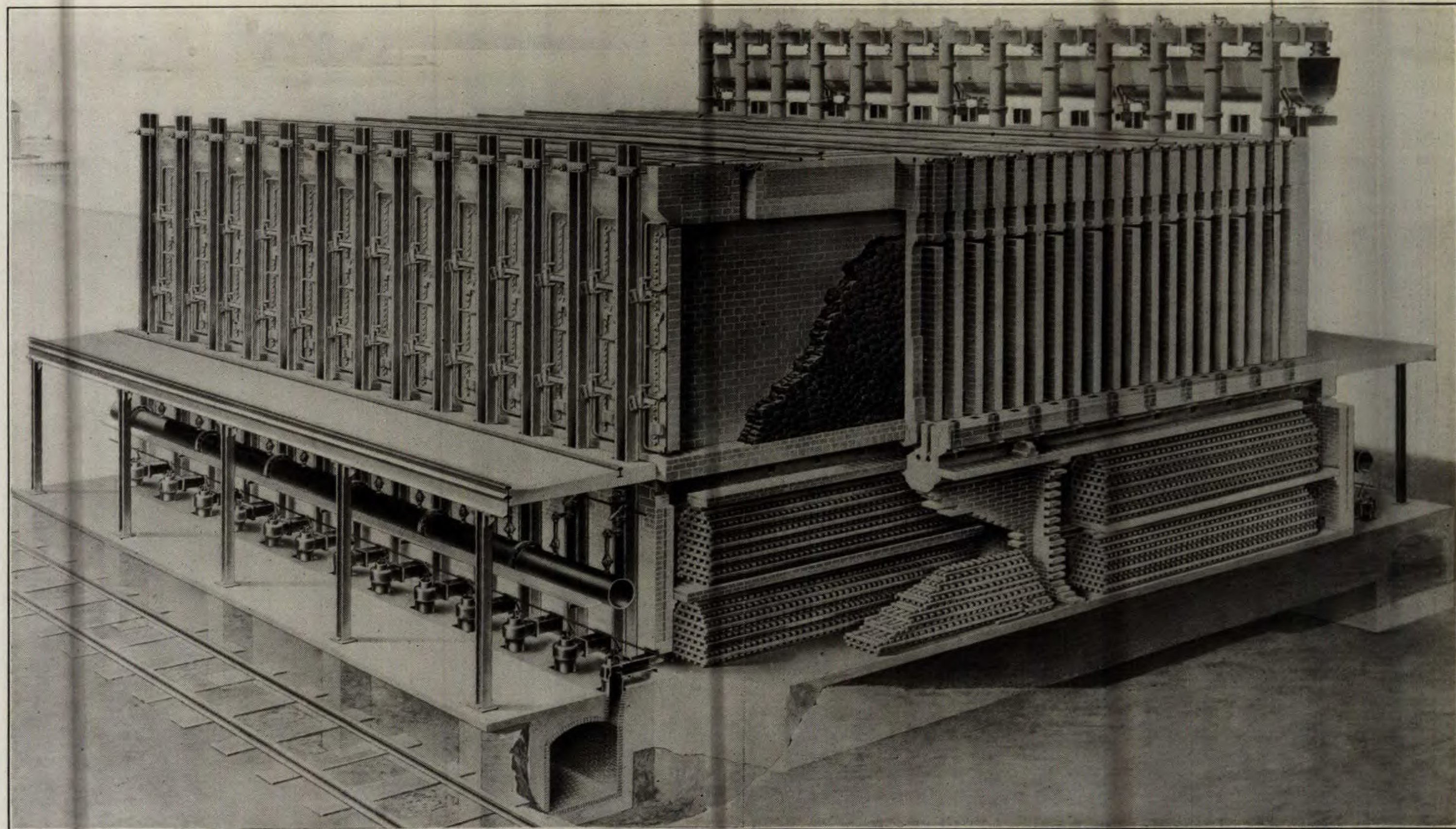


Figure 12. Flue system—Foundation oven.



American coke oven, Foundation Oven Corporation.

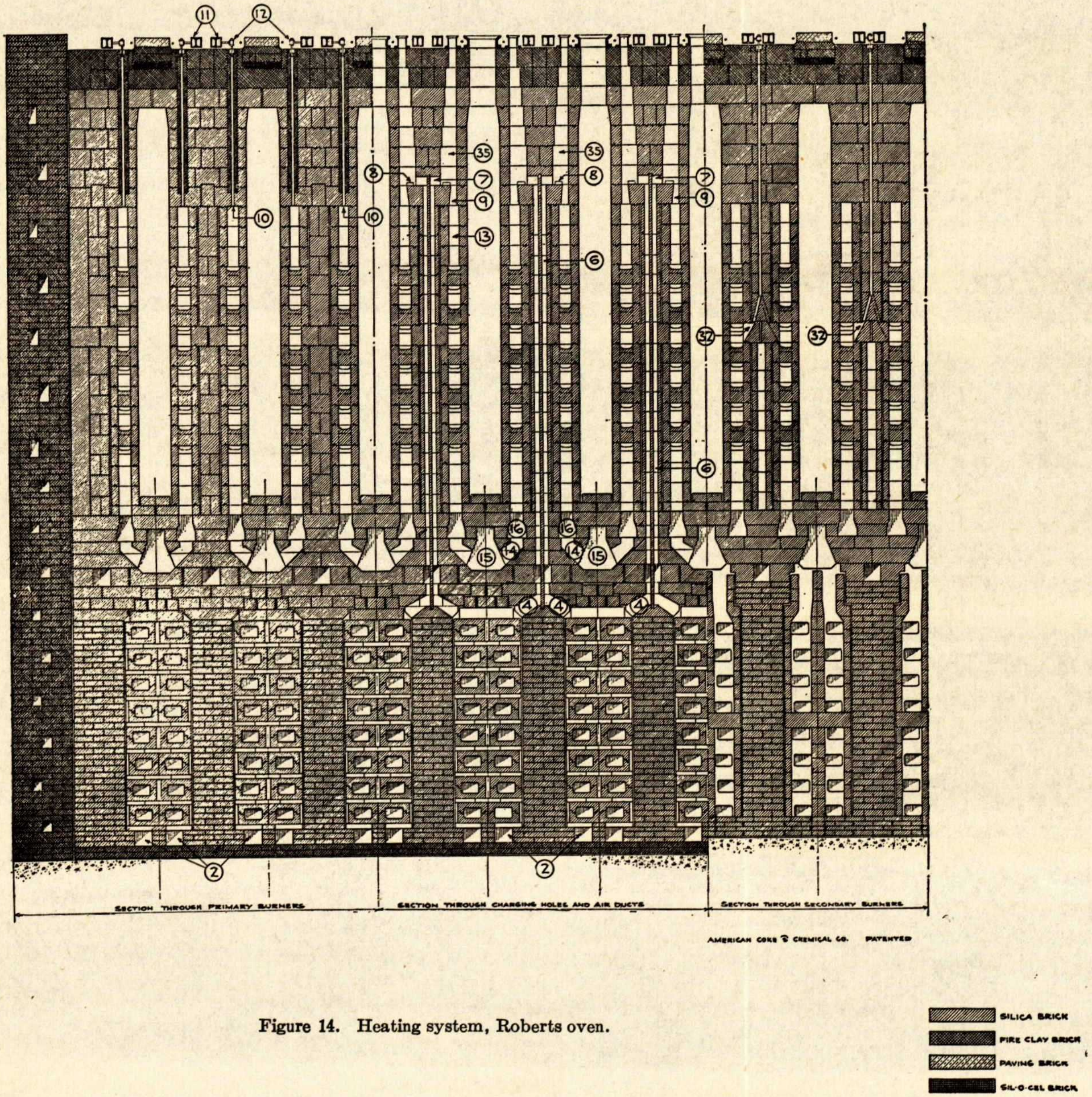


Figure 14. Heating system, Roberts oven.

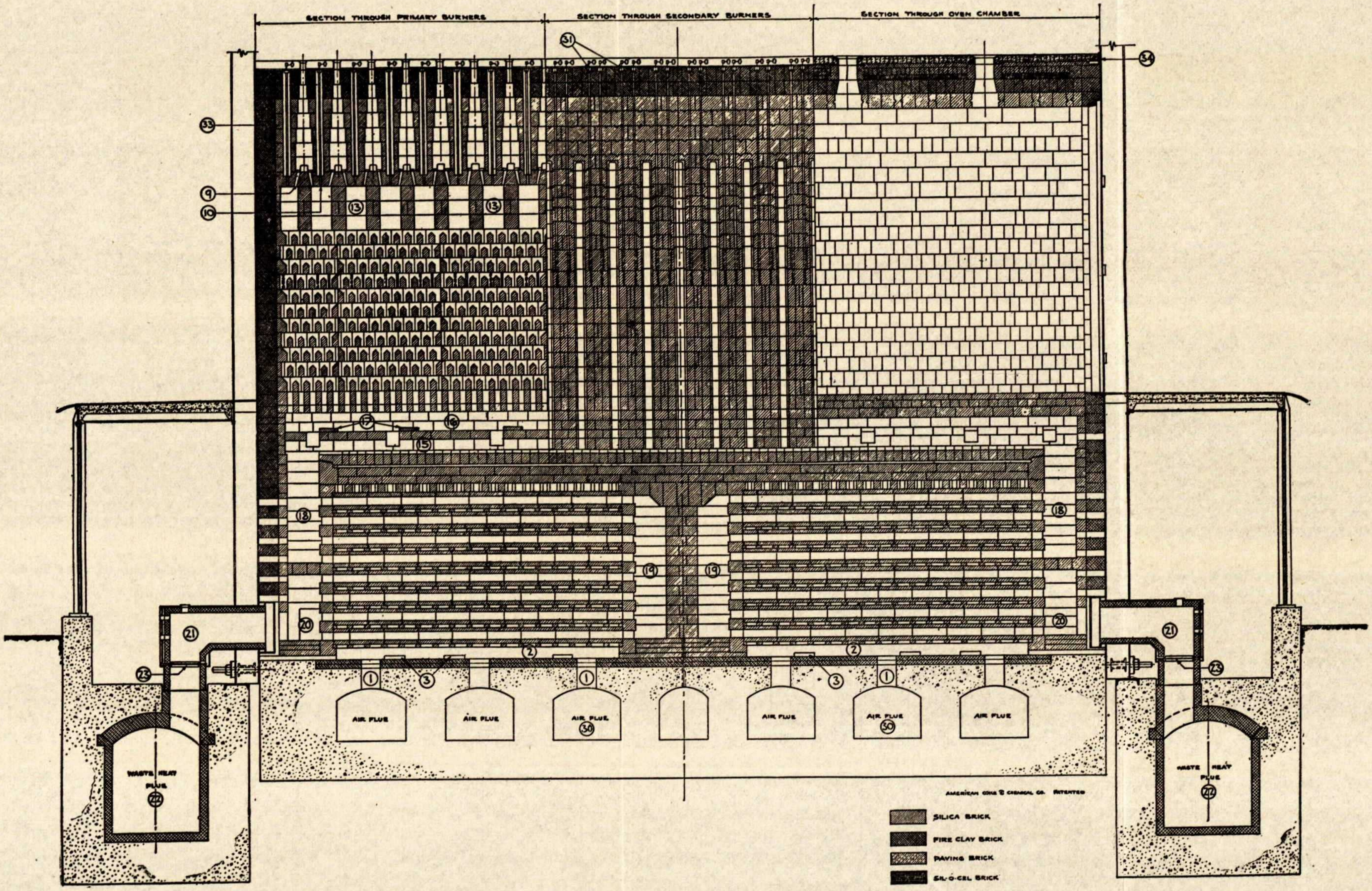


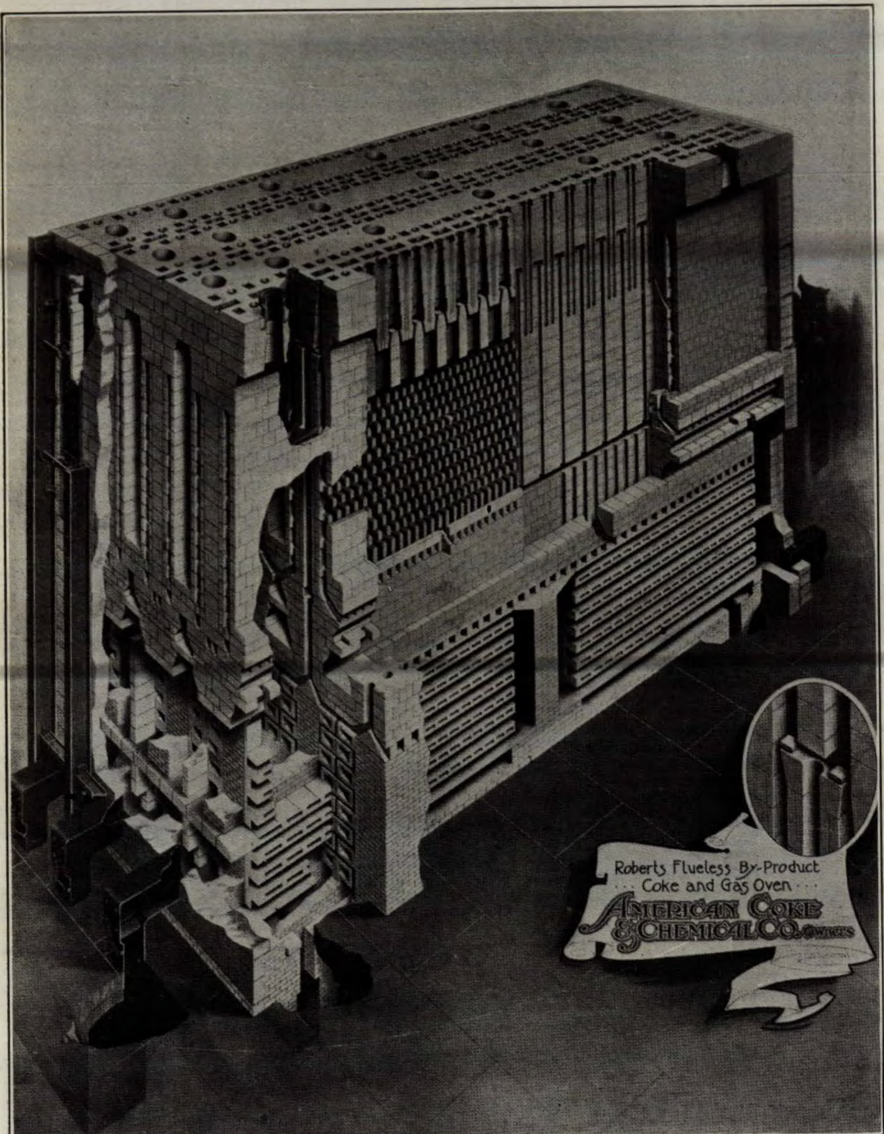
Figure 13. Heating System, Roberts oven.

sary. This oven having no distinct flues is in some cases called the "flue-less" oven. The brickwork of the heating chamber on either side of the coal chamber is so constructed that gases impinge on staggered connecting brick which are integral with the heating walls, thus distributing the gases throughout the chamber. Each oven has its individual heating walls and the two adjacent heating walls between ovens are divided by large, flat blocks through which pass the ducts for air and secondary gas. The oven shown in Figures 13 and 14 is of the recuperative type. Air, after passing through the recuperator where it is preheated, ascends the central duct between the heating walls and enters the top of the oven heating chamber around the primary gas nozzles. Control of air is obtained by slide brick where it enters the heating chamber and in a similar manner at the entrance to the recuperator. The gas entering the oven is divided into two equal parts, one for primary fuel, the other for secondary fuel, and the amount of gas is controlled by means of orifices in the manifolds or body of the individual burner cocks. By varying the size of these orifices, the amount of primary or secondary gas can be regulated to suit a given condition. In order to compensate for oven taper, the orifices gradually increase in size towards the rear of the oven. Better distribution of heat is claimed by this method of introducing small, accurately measured quantities. Secondary gas is admitted about halfway down the heating chamber and is controlled by the same method as the primary gas, this being done to prevent localization of heat in the oven. The gas at the bottom of the mixing chamber strikes the checkered wall and is broken up into three parts, and as there are twenty-four primary burners in each heating wall, there will be seventy-two streams of burning gas flowing downward. It is claimed that so efficient is heat distribution that it is necessary to admit secondary gas, otherwise coking could not be successfully carried out in the bottom of the oven. It is also claimed that, by these methods of control of gases, heat application to the coal charge is such that inferior grades of coal can be used and that more coal can be treated per dollar invested. The Roberts oven can coke, it is claimed, 30 tons of coal per day on 12-hour coking time.

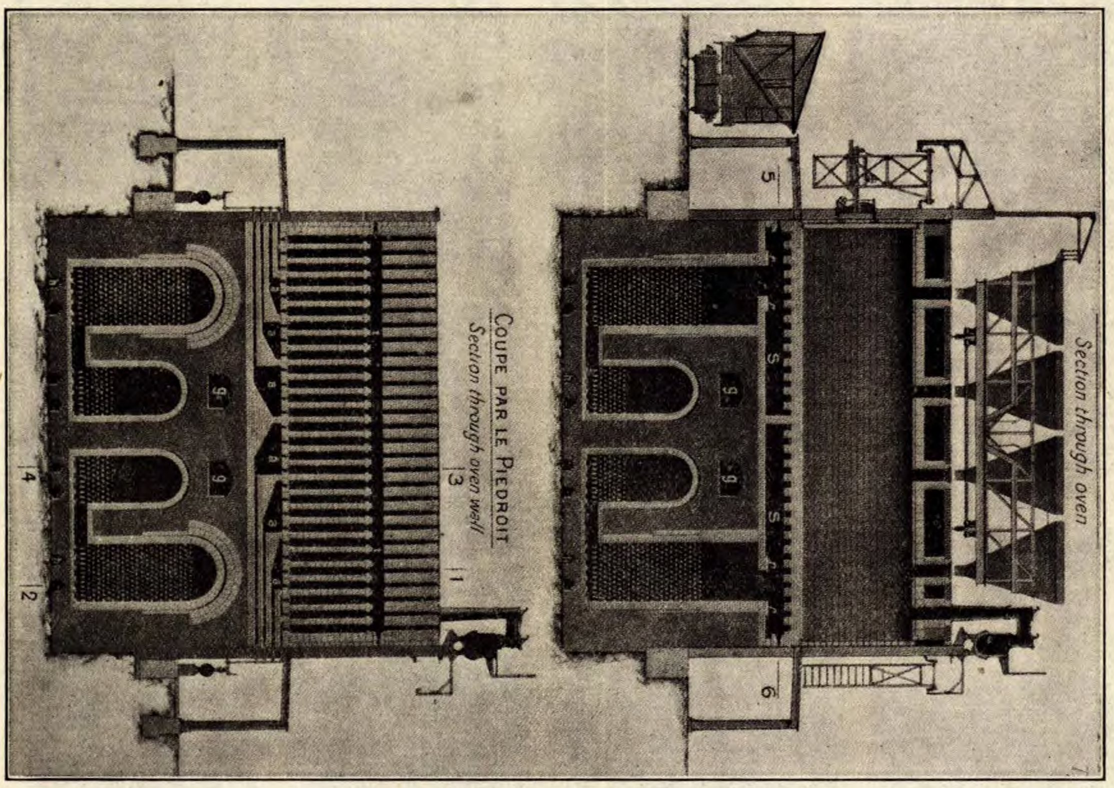
PIETTE OVEN

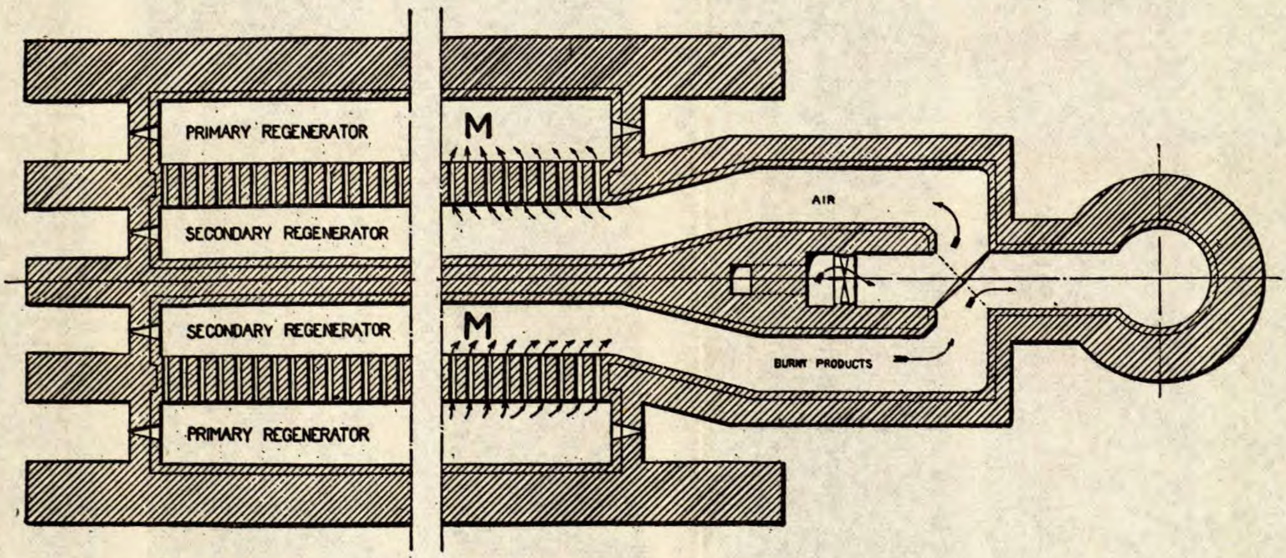
The Piette oven is designed and built by the Franco-Belgian Coke Oven Corporation and is made in the several conventional types such as waste heat, regenerator, etc. The ovens so far constructed in North America are the regenerative type and this oven will alone be described. It is heated with vertical flues and has longitudinal heat regenerators working

PLATE XXXVII



Roberts oven, American Coke and Chemical Company.





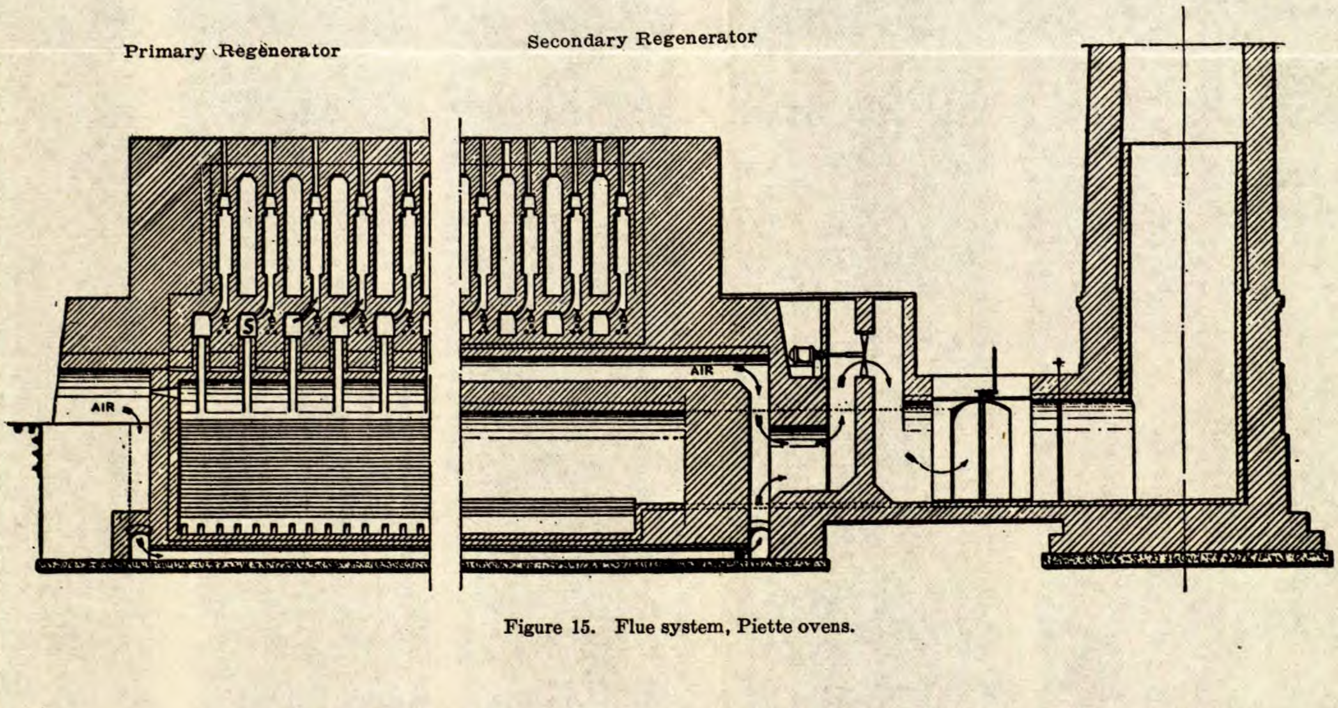


Figure 15. Flue system, Piette ovens.

transversely. Figure 15 shows the position of the reversing mechanism, and how products of combustion and air circulate in the regenerators. The oven walls are divided into two unequal parts with reference to their transversal axis, the reversing of gases of combustion being made from one part of the oven wall to the other part of the same oven wall. The sole flue of each half oven wall is divided into four parts, each division being fed by a special piping provided with its regulating cock and distributing the gas to a series of four vertical flues. A general regulating cock, independent of the reversing cock, is also provided. Air is controlled for each half oven wall by a damper located at the entrance to the sole channel, and for each flue or nozzle by dimensions of the opening. The double regenerator promotes maximum heat absorption and the air passing through the secondary regenerator is heated to about 250° F. before entering the primary regenerator. Peepholes are provided where needed. The principal advantages claimed for this system are: that flues with upward flow of gases are far from the flues with downward flow, thus reducing leakage; that distribution of gas in each oven wall by several compartments which are individually fed, and the supply of gas to only three or four nozzles is most satisfactory; that remoteness of flues under gas from flues heated by products of combustion allows more complete cooling, with the result that work of the regenerators is facilitated; that the constant supply of air under the sole flues, and the outlet of waste products at the higher parts of the flues, render damper regulation unnecessary; that longitudinal regenerators working transversely allow equalization of heat in the whole battery, without preventing isolation of any oven; that the design of ovens is remarkable for stability and simplicity of operation; and that the expansion of linings and arches of the regenerators is completely independent of the general sustaining mass of the battery.

Table XX.—By-Product Coke Ovens, North American Continent

Semet-Solvay Ovens

—	—	Number of ovens in plant
The Solvay Process Co	Syracuse, N.Y	40
American Manganese Co. and S. S. Co	Dunbar, Pa	110
Semet-Solvay Co	Ensley, Ala	240
National Tube Co	Benwood, W.Va	120
Semet-Solvay Co	Detroit, Mich	216
Philadelphia and Suburban Gas Co	Chester, Pa	40
Bethlehem Steel Co	Lebanon, Pa	90
Empire Coke Co	Geneva, N.Y	46
By-Product Coke Corporation	Chicago, Ill	280
Central Iron and Coal Co	Holt, Ala	60
Bethlehem Steel Co	Steelton, Pa	120
Otis Steel Co	Cleveland, Ohio	100
North Shore Gas Co	Waukegan, Ill	13

Table XX.—By-Product Coke Ovens, North American Continent—Continued

Semet-Solvay Ovens—Continued

—	—	Number of ovens in plant
Citizens Gas Co	Indianapolis, Ind	41
Kentucky Solvay Coke Co	Ashland, Ky	108
Semet-Solvay Co	Buffalo, N.Y	60
Portsmouth Coke Co	Portsmouth, Ohio	108
Chattanooga Coke and Gas Co	Chattanooga, Tenn	24
Ironton Solvay Coke Co	Ironton, Ohio	60
Ford Motor Co	Detroit, Mich	120
The Steel and Tube Co. of America	Indiana Harbor, Ind	120
Sloss-Sheffield Steel and Iron Co	Birmingham, Ala	120
Bethlehem Steel Co	Buffalo, N.Y	60
Bethlehem Steel Co	Johnstown, Pa	88
Hamilton By-Product Coke Co	Hamilton, Ont	25
Milwaukee Coke and Gas Co	Milwaukee, Wis	50

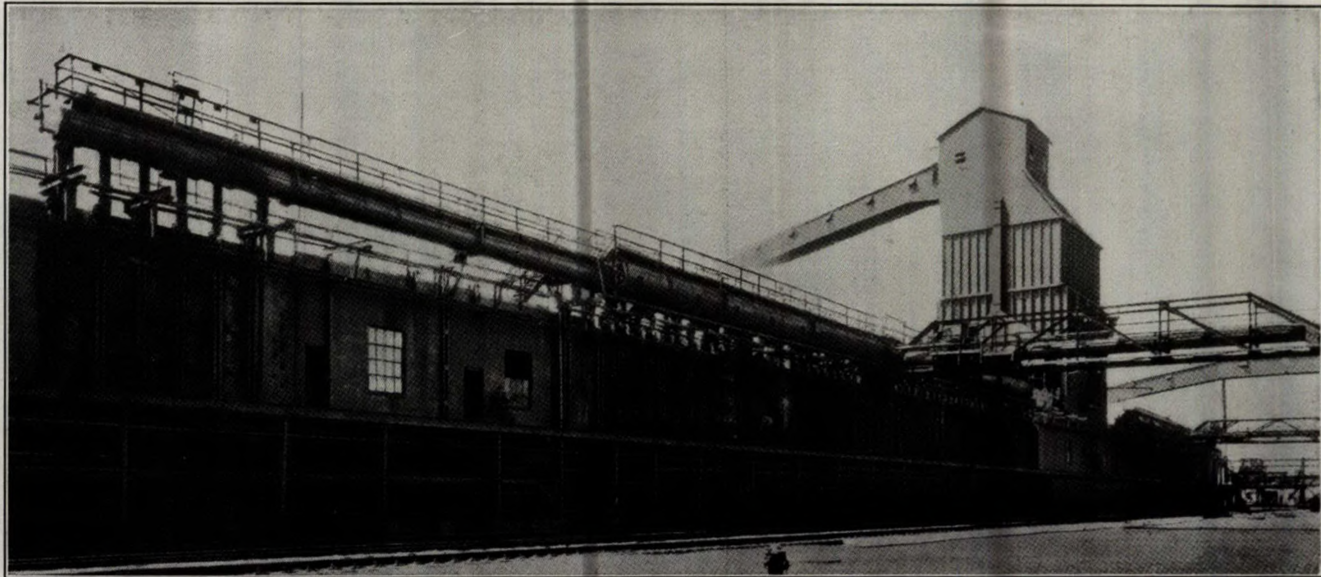
Koppers Ovens

Illinois Steel Co	Joliet, Ill	280
Illinois Steel Co	Gary, Ind	700
Tennessee Coal, Iron, and R. R. Co	Fairfield, Ala	434
Minnesota Steel Co	Duluth, Minn	90
Carnegie Steel Co	Clairton, Pa	1,134
American Steel and Wire Co	Cleveland, Ohio	180
National Tube Co	Lorain, Ohio	208
Woodward Iron Co	Woodward, Ala	170
Coal Product Mfg. Co	Joliet, Ill	35
Algoma Steel Corp	Sault Ste. Marie, Ont	110
Inland Steel Co	Indiana Harbor, Ind	130
Republic Iron and Steel Co	Youngstown, Ohio	204
Bethlehem Steel Co	Sparrows Point, Md	360
Bethlehem Steel Co	South Bethlehem, Pa	424
Bethlehem Steel Co	Steelton, Pa	60
Laclede Gas Light Co	St. Louis, Mo	56
Bethlehem Steel Co	Johnstown, Pa	92
Toledo Furnace Co	Toledo, Ohio	94
Youngstown Sheet and Tube Co	Youngstown, Ohio	306
LaBelle Iron Works	Follansbee, W.Va	94
United Furnace Co	Canton, Ohio	47
McKinney Steel Co	Cleveland, Ohio	204
Brier Hill Steel Co	Youngstown, Ohio	84
Gulf States Steel Co	Gadsden, Ala	37
Seaboard By-Products Coke Co	Jersey City, N.J	165
Minnesota By-Product Coke Co	St. Paul, Minn	65
Colorado Fuel and Iron Co	Pueblo, Colo	120
Indiana Coke and Gas Co	Terre Haute, Ind	30
Dominion Iron and Steel Co	Sydney, N.S	180
Providence Gas Co	Providence, R.I	40
Jones and Laughlin Steel Co	Pittsburgh, Pa	300
Rainey Wood Coke Co	Swedeland, Pa	110
Alabama By-Products Corp	Birmingham, Ala	75
Donner Union Coke Corp	Buffalo, N.Y	150
Domestic Coke Corporation	Fairmount, W.Va	60
Pittsburgh Crucible Steel Co	Midland, Pa	100
Chicago By-Product Coke Co	Chicago, Ill	105
Milwaukee Coke and Gas Co	Milwaukee, Wis	100
Camden Coke Co	Camden, N.J	37
Columbia Steel Co	Salt Lake City, Utah	33
Weirton Steel Co	Weirton, W.Va	37
Battle Creek Gas Co	Battle Creek, Mich	11
Bethlehem Steel Co	Buffalo, N.Y	114
The Consumers Power Co	Milwaukee, Mich	19
Trumbill Cliffs Furnace Co	Warren, Ohio	47
Diamond Alkali Co	Painesville, Ohio	37
Winnipeg Electric Co	Winnipeg, Man	17

Table XX.—By-Product Coke Ovens, North American Continent—Continued

—	—	Number of ovens in plant
Otto Ovens		
New England Fuel and Trans. Co	Everett, Mass	400
Camden Coke Co	Camden, N.J	100
Hamilton Otto Coke Co	Hamilton, Ohio	100
Allegheny By-Product Coke Co	Glassport, Pa	120
Bethlehem Steel Co	Johnstown, Pa	210
Citizens Gas Co	Indianapolis, Ind	100
Michigan Alkali Co	Wyandotte, Mich	54
Zenith Furnace Co	Duluth, Minn	65
Bethlehem Steel Co	Buffalo, N.Y	94
Carnegie Steel Co	Farrell, Pa.	212
Dominion Iron and Steel Co	Sydney, N.S	120
The Steel and Tube Co. of America	Mayville, Wis	108
Wilputte Ovens		
Citizens Gas Co	Indianapolis, Ind	40
Wisconsin Steel Co	S. Chicago, Ill	88
Coal Products Mfg. Co	Joliet, Ill	18
Woodward Iron Co	Woodward, Ala	60
Steel Co. of Canada	Hamilton, Ont	80
Algoma Steel Corp	Sault Ste. Marie, Ont	25
Roberts Ovens		
Penn. Iron and Coal Co	Dover, Ohio	24
St. Louis Coke and Chemical Co	Granite City, Ill	80
Gas Machinery Ovens		
Indiana Coke and Gas Co	Terre Haute, Ind	30
Linton Gas Co	Linton, Ind	3
Cambria Ovens		
Cambria Steel Co. (Franklin Plant)	Johnstown, Pa	190
Cambria Steel Co. (Rosedale Plant)	Johnstown, Pa	120
Klonne Ovens		
Seattle Lighting Co	Seattle, Wash	20
Central Indiana Gas Co	Muncie, Ind	22
Rothberg Ovens		
Bethlehem Steel Co	Buffalo, N.Y	282
Bauer Ovens		
Nova Scotia Steel and Iron Co	Sydney Mines, N.S	30
Bernard Ovens		
Nova Scotia Steel and Iron Co	Sydney Mines, N.S	160
Piette Ovens		
Laclede Gas Light Co	St. Louis, Mo	8
Foundation Ovens		
Granby Consolidated Copper Co	Anyox, B.C	30

Plate XXXVIII



Pusher side of ovens at Chicago By-Products Coke Company, with Becker new style combination oven in the foreground.

CHAPTER X

BLUE GAS AND PRODUCER GAS

Ever since the by-product recovery "coke" or "gas" oven has been coming into more general use for the manufacture of "town" gas, great attention has been paid by builders and operators of coke ovens to flexibility. But, although flexibility in gas output is important, coke output is also important to a plant producing domestic coke. In Canada, the success of a coke plant depends on the domestic demand for gas, and a plant must be large enough to provide gas sufficient not only for present, but for anticipated demands. As regards the coke there will be a greater demand than can possibly be met for many years.

The type of plant to be installed depends upon whether a straight coke-oven plant is required or a plant having its coke ovens provided with auxiliary equipment for the production of oven fuel. With a straight coke-oven plant, between 60 and 65 per cent of the gas from the coal is available for sale, whereas with a combination plant, from 60 to 100 per cent of the coke-oven gas can be immediately withdrawn for sale. Thus a plant of the first type of any given gas capacity offers a maximum amount of coke and by-products; a plant of the second type permits a minimum production of these products per unit of gas required. The second type also permits of maximum flexibility. The straight coke-oven plant can, when all the coke is sold at fair prices, produce gas cheaper than any other process. When flexibility in output is desirable, the second type can manufacture gas cheaper because flexibility can be obtained in the straight coke-oven plant only by changing the rate of operation—that is, high gas peaks mean fast operation which causes a large production of coke. Holders, of course, will smooth out the peaks, but this involves additional investment. The second type alleviates this condition as the oven gas released from fuel services varies in accordance with demand for town gas. In the one case, the tonnage of coal carbonized is determined by the demand for gas; in the other it can be kept at a minimum amount throughout varying demands for gas. The selection of the type of plant should be based on exact knowledge of the factors involved. Should these factors change modifications can be easily made to meet the new conditions, that is, a straight coke-oven plant can at any time be made a combination plant, should gas demands increase faster than the coke market; or, vice versa, a combination plant can operate as a straight

86227—8

coke-oven plant placing less and less dependence upon the auxiliary fuel equipment. Extra ovens can at any time be added without serious interference to operation.

Although, in exceptional instances, coke-oven plants have reported that less than 2,000,000 B.T.U.'s were required to coke one ton of coal, general practice indicates that about 2,200,000 B.T.U.'s are required.

The auxiliary fuels proposed for heating coke ovens are blue gas and producer gas. Careful investigation has led to the conclusion that vertical flued ovens with large gas combustion areas use producer gas with its long flame much more effectively than blue gas; and that the horizontal flued oven with relatively small gas combustion areas uses blue gas with its short flame more effectively than producer gas.

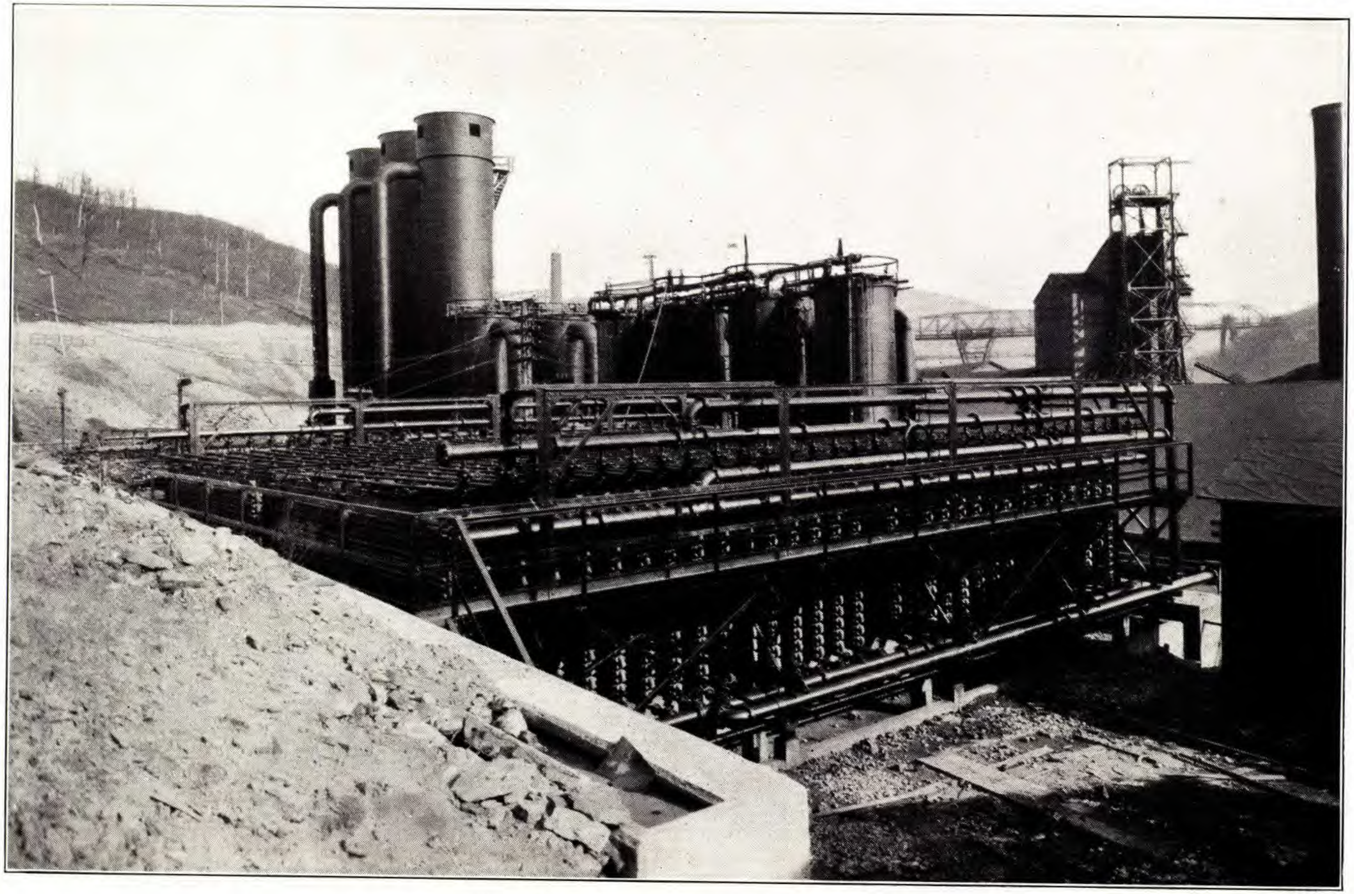
In regenerative by-product ovens burning coke-oven gas 0·87 cubic feet of air must be preheated for each cubic foot of products of combustion; about 0·81 cubic feet when burning blue gas; and about 1·13 cubic feet when burning producer gas. This indicates a more nearly relative interchangeability for coke-oven and blue gas. Producer gas, to be used effectively, requires double regeneration, as the percentage of inerts in this gas is very large, and without such regeneration cannot be burned with the flame temperatures attainable with coke-oven or blue gas, the latter two using single regeneration of air only. With double regeneration, the expense of the distribution system also has an important bearing on the work.

Advocates of blue gas for oven firing point out that a plant carbonizing 200 tons of coal per day can produce from 1,400 to 2,200 M cubic feet of town gas as desired by simply varying the amount of blue gas and coke-oven gas used as oven fuel, the speed of operation remaining constant.

On the other hand, for most efficient operation, a 200-ton plant using producer gas will produce either 1,400 M or 2,200 M cubic feet and can obtain intermediate amounts only by varying the speed of operation. This objection can be overcome either by a carburetted water-gas set to take care of the variations, or a sufficient holder capacity so that the plant can run steadily. To secure maximum efficiency for producer gas firing the ovens must be run close to capacity. A complete plant using producer gas should, therefore, include the ovens, producers, and carburetted water-gas set. The use of blue gas eliminates one of these processes, simplifying operation and reducing capital charges.

For producer gas is claimed the advantage of cheap oven fuel, because coke breeze and fines can be used, and there is no doubt that this claim is well founded when the ovens run at full capacity. Where steam coal is expensive it may be better to use the breeze and fines for steam generation. The modern stoker efficiently utilizes breeze. The question of

86227—8½



Typical installation cooling coils and scrubbers.

fuel is one that must be carefully considered, although it is not so much the cost of oven fuel that counts, but the cost of the finished product.

Although blue gas is more expensive than producer gas, the efficiency of a plant using either would be about the same when total cost is figured up.

The following data regarding producer and blue gas sets are of interest in connexion with the auxiliary firing of ovens:

Feet		M. cu. ft.	
1–10	blue gas set will produce	2,000	Gas per day
1–11	" "	3,000	" "
1–12	" "	4,000	" "

A blue gas set (including blowers, igniter, exhausters, seal pots, etc.), costs about $50,000, according to its capacity. The building, including fuel handling, costs $40,000 to $60,000, and the waste heat boiler $15,000 to $18,000, the relief holder (100,000 cubic foot capacity) $25,000 to $30,000, and automatic control $3,000 to $6,000.

Producers are made in sizes running from 10 to 40 tons per day capacity, producing 1,500 M to 6,000 M cubic feet of gas per day. The producer with necessary equipment will cost from $30,000 to $90,000. Waste heat boilers cost about $15,000 each, building and fuel handling about $60,000 to $80,000, and the relief holder about $10,000.

A producer gas plant will cost from $20,000 to $70,000 more than a blue gas plant of the same capacity.

Producer Gas, Cost of Manufacture

Capital charges per ton coke gasified	$ 1 25
Operating cost " "	1 50
Fuel cost " "	6 00
	$ 8 75
B.T.U's per ton coke gasified	17,000,000
Cost per million B.T.U's in gas	51·4 cents
Cost per thousand cu. ft. gas	6·43 "

Blue Gas, Cost of Manufacture

Capital charges per ton of coke gasified	$ 0 75
Operating cost " "	1 00
Fuel cost " "	6 00
	$ 7 75
B.T.U's per ton coke gasified	13,000,000
Cost per million B.T.U.'s in gas	59·5 cents
Cost per thousand cubic feet gas	17·9 "

The modern producer will efficiently handle up to 50 per cent breeze in the coke without appreciable loss in capacity, and the fuel charge of $6 per ton is thereby materially reduced, lowering the cost of the gas.

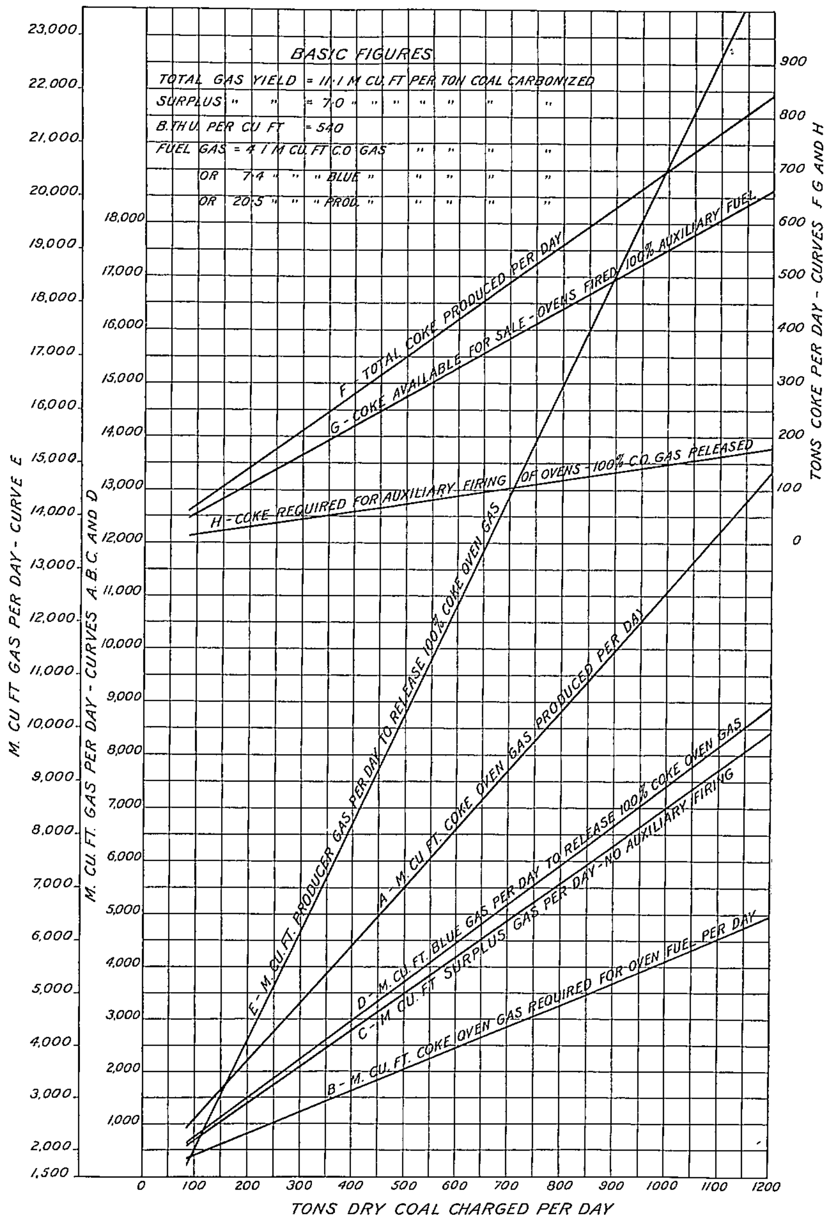
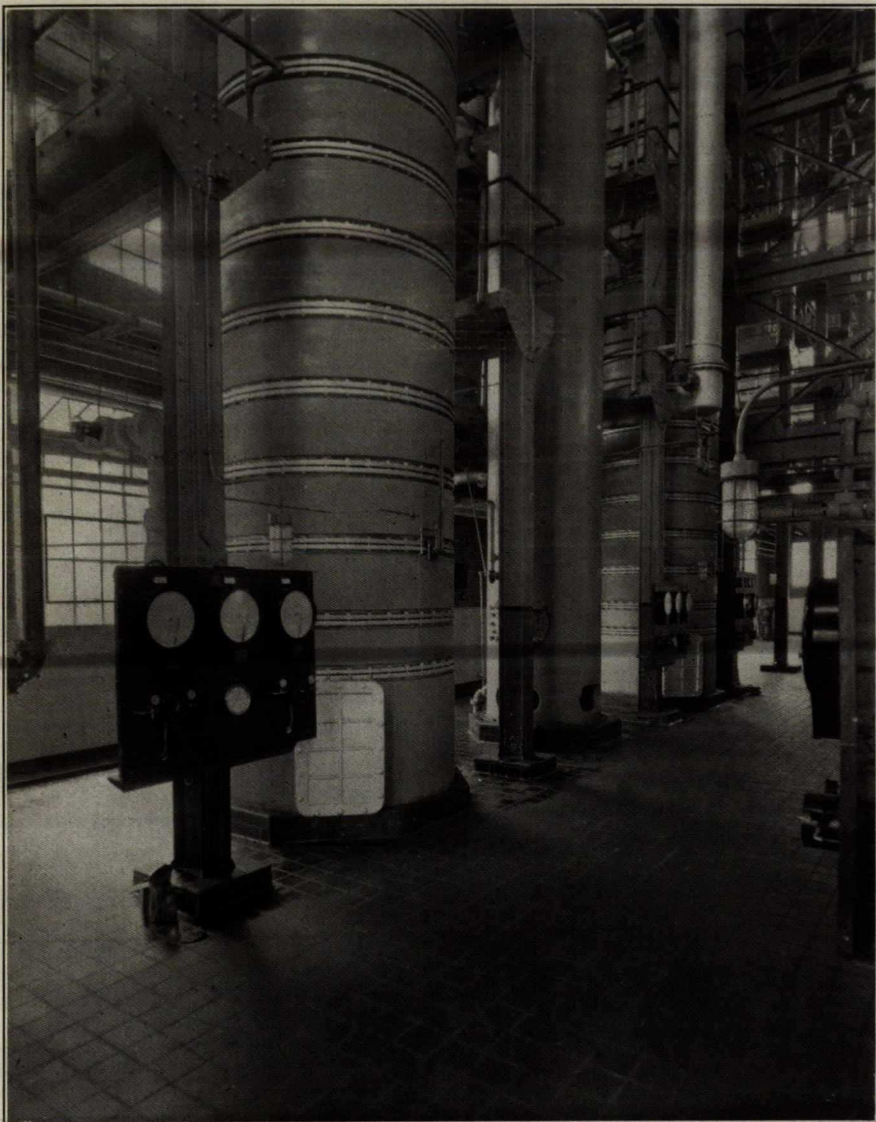


Figure 16. Curves showing capacities, productions, gas requirements, etc., for by-product recovery coke-oven plants.



Distillation columns.

CHAPTER XI

RECOVERY SYSTEMS

There are today on this continent two distinct systems of recovering by-products, exemplified by the Koppers and Solvay types, and as all other systems are similar or modifications, a description of these two processes will suffice.

The object of a by-product recovery plant is not only to recover by-products, but to clean the gas and render it fit for domestic and industrial purposes.

Ammonia may be recovered as ammonium sulphate or as aqua ammonia, crude or refined. In the past a few plants installed methods known as indirect recovery systems, for the recovery of ammonia as sulphate. These methods scrubbed or washed the gas with cold water, distilling the weak liquor to release the ammonia vapours, which are then passed through an acid bath for conversion into sulphate. This method, although suitable for the recovery of ammonia as liquor, is uneconomical and has been discarded in favour of the direct recovery system. In this system the coke-oven gas, after tar has been extracted, is passed through a bath of sulphuric acid of such low temperature and acidity that hydrocarbons are not appreciably affected. The bath contains 5 per cent or 6 per cent free sulphuric acid and is kept up to strength by continually adding acid. Mechanical separaters ensure that no appreciable amount of acid is carried from the saturaters by the gas, hence there is no danger of corrosion. Maximum combination of ammonia gas and sulphuric acid occurs at about 120 to 130 degrees F., and a neutral, white, well-crystallized salt is produced. In the saturater, the gas bubbles through the acid and the intimate contact of ammonia with the acid forms ammonium sulphate which precipitates as a solid salt from the "mother" liquor.

By means of an air or steam ejector, the salt is lifted from the saturater to a drain table, from which, after sufficient quantities of salt have been collected, it is dumped into a centrifugal drier. After a "spin" is made, the dry salt is ready for sale and may be kept indefinitely without deteriorating. Liquors and tars from the primary coolers and tar extractors, mains, etc., are separated by decantation—the tar going to storage or dehydrator as necessary, when it is ready for use or sale. The liquor is pumped to storage tanks, from which it is taken to the stills—the released vapours from the still being piped into the stream of coke-oven gas just before the saturaters—and is converted into sulphate with the ammonia in the gas.

Typical installation, ammonium sulphate plant. Note centrifuges, saturaters, piping, etc.

For the production of liquor, the saturater is, of course, unnecessary and the coke-oven gas, after passing the tar extractors, is passed through tower grid scrubbers, where the gas is sprayed with clean, cold water which forms weak ammonia liquor. This liquor is pumped to storage tanks with weak liquor collected from the primary coolers, mains, etc., and is then sent to the stills. In this case, however, the stills are equipped with the necessary concentrating and purifying apparatus.

Concentrated ammonia is usually produced at small plants where freight rates are unfavourable, or at other plants where marketing conditions for sulphate are unfavourable, or where markets exist for concentrated liquor for refrigeration, explosives, chemicals, fertilizers, drugs, and soaps.

The weak liquor, which varies in colour from yellow to orange, contains both free and fixed ammonia, with traces of the volatile constituents of tar such as piridin, phenol, etc. The free ammonia, composed chiefly of ammonium sulphide, carbonate, and cyanides, will dissociate in the presence of steam. The fixed ammonia exists chiefly as ammonium chloride and will liberate ammonia in the presence of steam when sufficient lime, usually as milk of lime, is added to the solution.

The impurities in weak ammonia liquor are chiefly hydrogen sulphide, carbon dioxide, cyanide compounds, and organic matter. The still has several parts known as the free and fixed stills, condensors, or dephlegmators, washers, vaporizers, heat exchangers, economizers, absorbers, etc. From the still the waste liquors carrying calcium chloride, carbonate, and sulphate, etc., are led to the sewer or disposal plant. The gas from the still passes through the dephlegmator, where reflux action occurs—cooling and condensing some vapours which return to the still. Then the gas passes through various washers which perform direct and indirect cooling and washing of the ammonia gas—the small amount of liquor being returned by vaporizers serves for the more efficient removal of hydrogen sulphide, carbon dioxide, and organic matter. Liquor with a concentration as high as 30 per cent is not an uncommon practice without plugging or stoppages in the apparatus or use of chemicals to produce highest grades. After washing, the gas enters the absorber where it is absorbed in clean, cold water or goes to a compressor where it is liquified. It is then ready for sale.

In recovering light oils, which are so important in the manufacture of explosives, motor spirit, etc., the same system of scrubbing the gas is used. Light oils, owing to their vapour tension and the relatively large volume of coke-oven gas (approximately $1\frac{1}{2}$ per cent by volume), pass through the by-product apparatus as vapours into a tower grid scrubber where the gas is washed with "wash oil" which is selected according to carefully drawn specifications and which has solvent or absorbent pro-

Interior of by-product building, Cambria plant, Bethlehem Steel Company. Note exhauster, saturaters, etc.

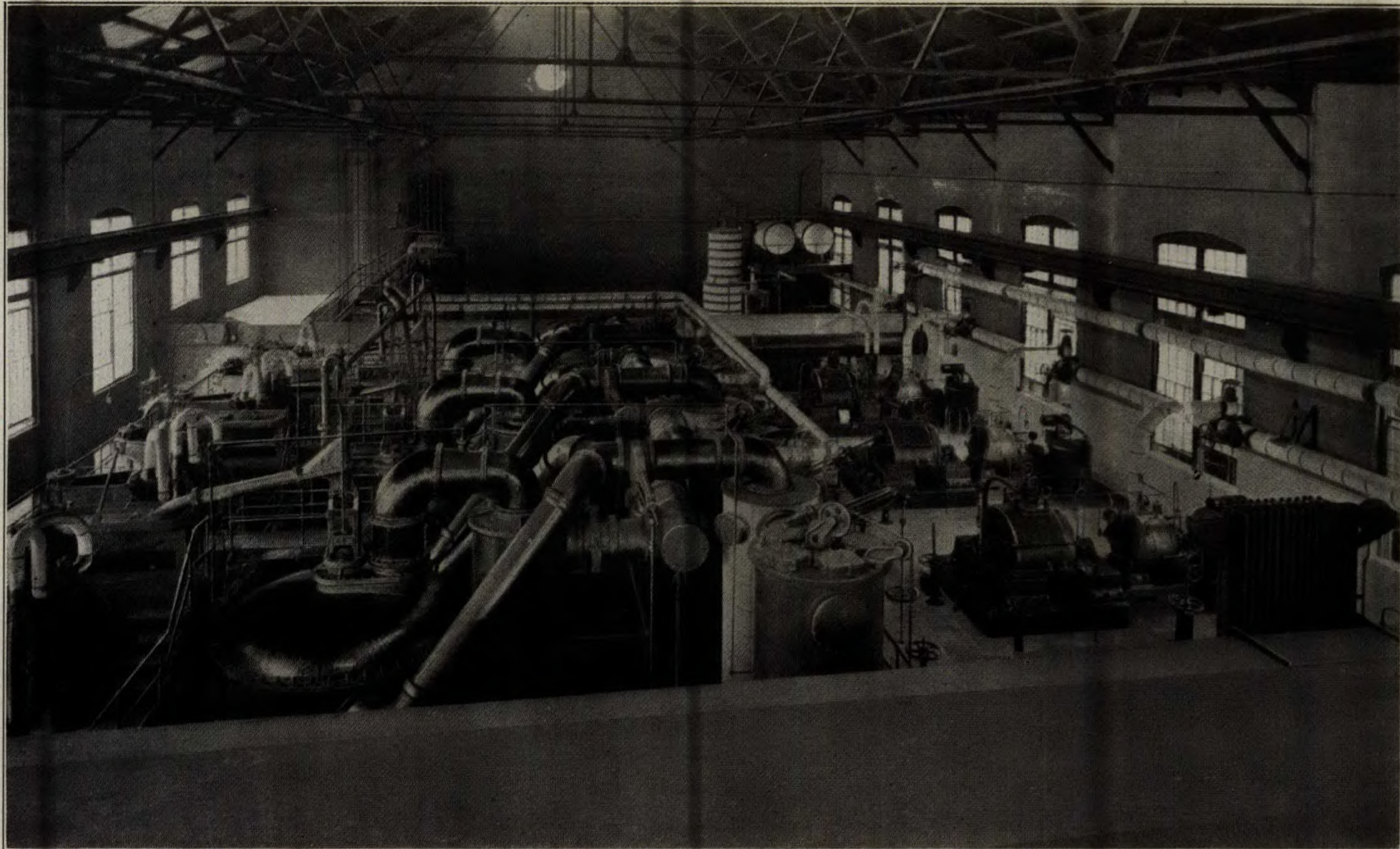
perties for light oils. Although the yield varies according to the coal used, and the operation, light oils will have approximately the following composition:

	Light oil per cent	Gals. per ton of coal
Pure benzol	45 to 55	1·57 to 1·92
Pure toluol	14 to 18	0·49 to 0·63
Xylols	8 to 12	0·28 to 0·42
Solvents	8 to 12	0·28 to 0·42
Residue	12 to 16	0·42 to 0·56

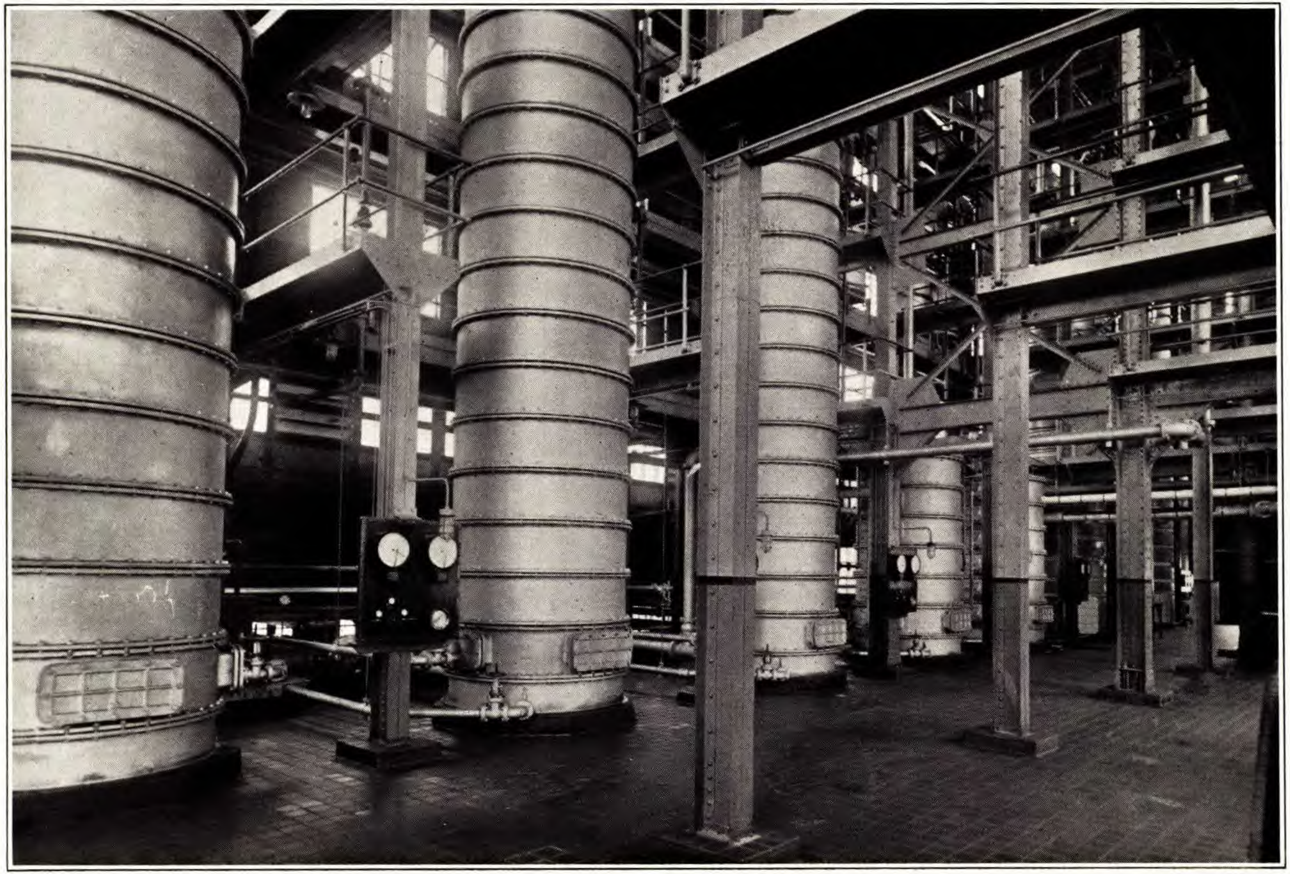
The wash oil, after passing through the scrubbers, is then sent to the benzol plant for distillation, for recovery of the light oils, and for rectification of the latter. Wash oil is introduced into contact with the gas on the counter flow principle, the fresh washing medium entering the system where gas contains the least benzol vapours. From the scrubbers the wash oil is passed through several heat exchangers, then through a preheater into the crude still. The preheated oil, flowing downward through the rings of the still, meets ascending steam and benzol vapours. Benzol vapours are conducted to a water-cooled condenser, and the condensate, light oil and water, are separated by decantation. The light oil is subsequently distilled in intermittent stills of large capacity (10,000 to 25,000 gallons), which fractionate the light oil into its several component parts. The operation is one chiefly of temperature control. Benzol and toluol are distilled off by indirect heating, the higher boiling constituents by direct steam. These stills are known in some cases as pure product stills when producing fractions testing to rigid specifications. In making motor benzol only one fractionation is usually necessary.

When it is desirable to produce pure products, pure-product stills must be installed. In making motor benzol, however, the purification is accomplished by washing crude benzol with sulphuric acid and caustic soda, which has the effect of removing olefiant and phenoloid substances, forming resinous matter of high boiling point, part of which is left behind as residue when distilled, and part settles out in the agitator washer. The caustic soda and water are sent to the sewer; the acid sludge from the agitaator is sent to a boiler or tank where it is treated with direct steam which separates acid and resins, allowing a recovery of sulphuric acid of about 35 to 40 degrees Baumé, which can be used in the saturaters for making sulphate.

In the United States certain plants have successfully recovered the cyanides in the gas, usually as sodium ferrous cyanide, by washing the gas with a ferrous carbonate solution, after ammonia, benzol, and tar have been extracted, the resulting cyanide liquors being cleaned and evaporated with the subsequent production of crystals. In England ethyl alcohol has been recovered by use of sulphuric acid, there being from 1½ to 2 gallons



Interior of by-product building, Sparrow Point plant, Bethlehem Steel Company.



Light oil stills.

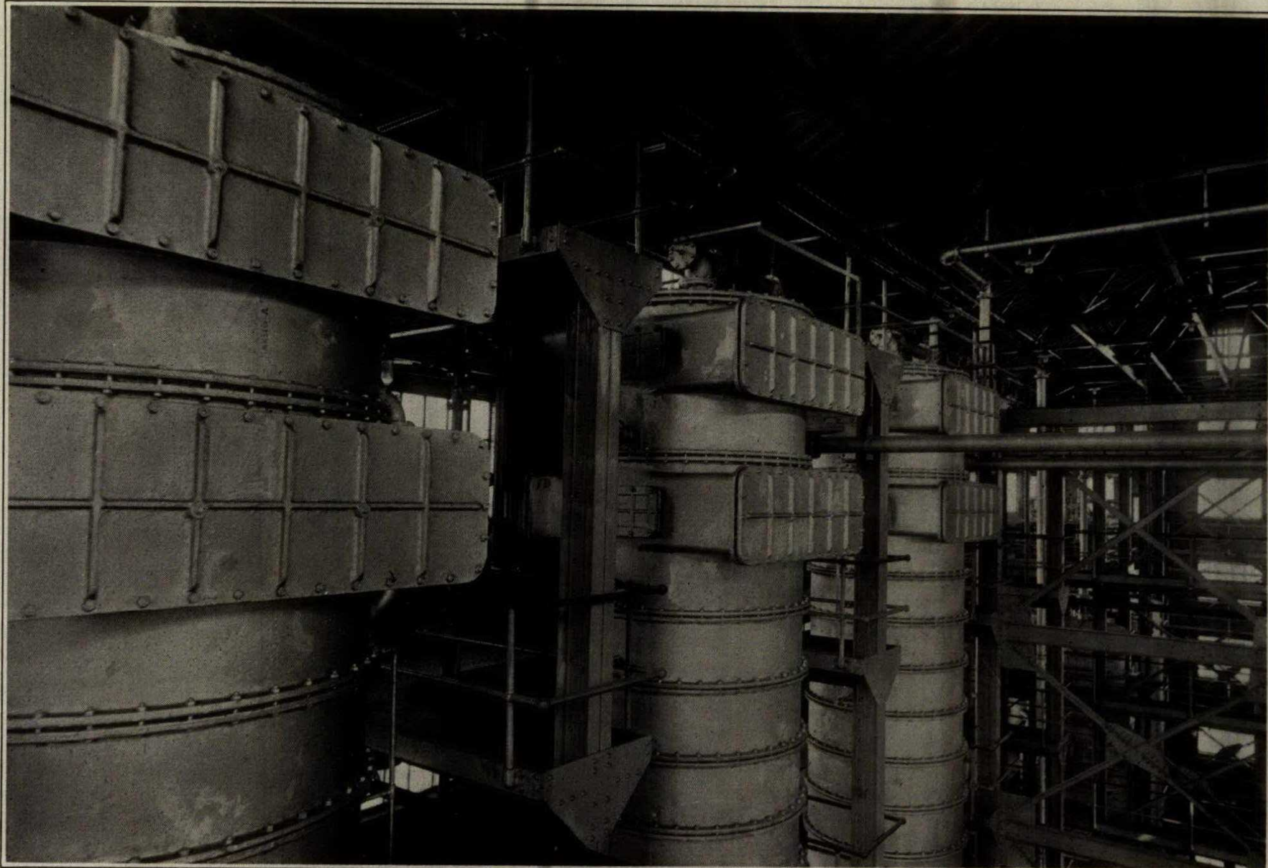
Boiler stills.

present in coke-oven gas. Neither of these attempts is today commercially successful, as cheaper methods of manufacture exist, but these products will probably be recovered when prices increase.

The above process of by-product recovery is followed generally at most plants; although the process may differ in detail. Certain manufacturers and builders of apparatus have stills, of larger capacity, producing more simply and easily than others, refined products or products other manufacturers cannot produce.

The Solvay system starts the recovery of by-products in the hydraulic main in the ovens. The gas is first cooled by a spray of liquor in the valve body which brings down certain tar oils, reducing the temperature from about 600 to 700°C., to 175 to 185°C. As the gas passes through the main towards the off-take pipe it passes through curtains of sprayed liquor—the sprays being located between each oven so that gas entering the off-take main is reduced to about 125°C. Tar, liquor, and gas all flow through the same main, the liquor usually containing only fixed ammonia on account of temperature. Just before the gas enters the primary cooler, which is of the tower grid type, the liquor and tar drop into a decanter in which the tar and liquor are separated—the tar going to storage, and the liquor returning to a collector tank, from which after cooling it is again pumped to the oven sprays. Fresh water is continuously added to the circulation and weak liquor drawn off to storage, from which it is sent to the still for rectification. This system of spraying the gas eliminates the labour of "tar" punching, collects products automatically, and is highly efficient.

The gas entering the primary cooler, about 80°C., is directly sprayed with liquor which brings down the lighter tars and most of the naphthalene at that point in the system where it should be taken out. Other systems recover naphthalene in the benzol plant, where it is a nuisance to handle and difficult to dispose of. The liquor and tar overflow from the primary cooler into the same decanter, and liquor used for spraying the primary cooler is pumped through cooling coils before being returned to the sprays. This enables the gas to be cooled to 25 to 30 degrees on leaving the primary cooler. The gas is then drawn through the exhauster, passed through a tar extractor, which removes the last traces of tar fog, and then into saturaters without being preheated. The Solvay ammonia still produces a very dry gas which enters the saturaters with the coke-oven gas and consequently there is no necessity for preheating the gas to take up water vapour from the still. Water vapour in ammonia gas from the still weakens the acid bath to a point where recovery is unsatisfactory. Not having to preheat the gas results in steam economy. The recovery of sulphate from this point does not differ from other systems.



View of still tops, showing cooling rings.

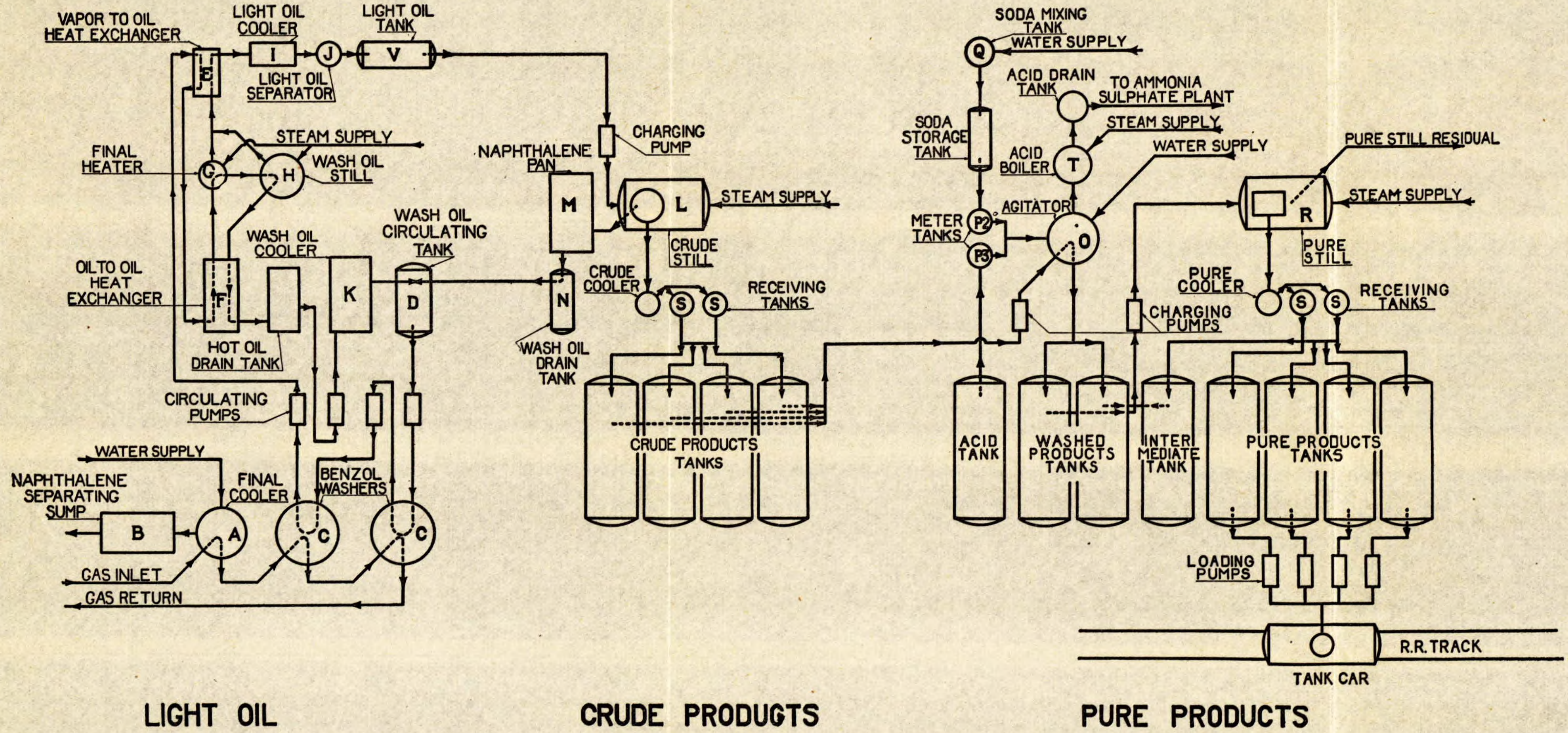


Figure 17. Flow diagram of Koppers benzol recovery plant.

The Solvay system of light oil recovery follows along the general lines of procedure heretofore discussed except that no difficulties are experienced with naphthalene. The claims for the stills are; large capacity, low steam consumption, simplicity of apparatus for production of motor benzol and pure products. The new 4-foot Solvay still will distill 2,500 to 3,000 gallons of 10 to 15 gramme liquor per hour and the 6-foot light oil still will handle 12,000 to 15,000 gallons of wash oil containing 2 per cent benzol. The steam consumption varies with various plants and kind of products produced; in manufacturing concentrated ammonia liquor, for instance, the steam consumption should not exceed 10 to 12 pounds per pound of ammonia figured as sulphate, and the distillation of wash oil should not require more than 40 pounds of steam per gallon of light oil produced with 5 to 6 pounds additional for the motor benzol still.

The Koppers system differs chiefly in using indirect cooling in the primary coolers and at times it is necessary to have men handling tar at the ovens. The gas entering the primary coolers comes into contact with a series of tubes through which the cooling water is circulated, thus cooling the gas and bringing down most of the tar and at the same time extracting most of the naphthalene. The counter current principle of flow is used. Approximately 15 to 20 per cent of the ammonia is collected here in water solution and is chiefly fixed ammonia. The tar and liquor are drained into a decanter where separation of liquor and tar takes place—tar going to storage, and liquor to storage tanks, from which it is pumped to the stills as required. The gas from the exhausters is passed through tar extractors to remove last traces of tar fog—then through the preheaters to the saturaters. The preheating is required to take care of water vapour to prevent dilution of the acid bath in the saturaters. This system also makes use of a final cooler, tower grid type, where the gas is again sprayed —this time with clear, cool water to remove the last traces of naphthalene, thus rendering the gas ready for commercial use. The light oil recovery is similar to the Solvay process, grid-type tower coolers being used, and the treatment and handling of the benzol products are similar—the main differences lying in the style and type, and capacities of stills, exchangers, coolers, condensers, etc.

Both systems are good and have been successfully used for years. The choice depends on results required, based on size, initial cost, and operating costs of the two systems.

As before explained, other manufacturers of stills and recovery apparatus produce equipment which operates on similar lines and principles, but it is usually better to install the equipment of the oven builder, otherwise difficulties may occur in securing the capacities, quality of products, etc., desired.

CHAPTER XII

TYPICAL PLANT

The operations in the by-product coke plant are divided as follows: coal washing; coal handling; coke-oven operation; coke screening; by-product apparatus operation; tar operation; ammonia liquor operation; sulphate operation; light oil operation; benzol operation; surplus gas operation; steam generation; electric current generation; water supply; store expense; mechanical shop; locomotives; locomotive cranes; railroad car service; plant transportation; laboratory; research and development; plant administration.

In the United States the washing of coking coals is not usual, but in some cases is practised. Coal-washing plants will as a rule remove more than 50 per cent of the sulphur and 20 per cent of the ash. For by-product coking purposes some of the Nova Scotian coals are washed.

The coal-handling operation continues from the time the coal enters the plant to the time it is sent to the bins over the ovens. It embraces the actual handling, the grinding and blending, and covers the operation of all machinery.

After the coal enters the bins, and until it is delivered as coke on the wharf, it is handled by the coke-oven department. The coal from the bins is delivered into a charging larry, weighed, and delivered to the individual oven. The coke ovens are the heart of the plant, for the control of the coke quality and coking time, and the quality and quantity of the by-products are regulated by this department. The coke is pushed from the oven by a machine—known as a pusher—into a quenching car, where it is quenched with water, and is finally delivered, cooled and ready for screening, on the coke wharf. This department, also, as a rule has charge of, or works in close conjunction with, the by-products department in handling the gas and by-products.

The coke-screening operation covers the handling of the coke from the time it is dropped on the wharf; screens, grades, crushes, if necessary, and loads the products into cars, wagons, trucks, or storage bins. This operation also covers all warehousing of coke.

Coke-oven gas evolved from the coal is collected in a large main on the ovens, known as the hydraulic main. From this main it is carried to the by-product apparatus. After leaving the ovens the gas first enters a primary cooler, where it is cooled and a large part of the tar and naphthalene is extracted, the finished tar being run into collector tanks. The gas passes to the exhausters and then through tar extractors into the ammonia recovery apparatus—either liquor or sulphate. It then passes into the light oil scrubbers, where light oils are absorbed, and then usually runs into a final cooler where the last traces of tar and naphthalene are removed. Some of the gas is returned to the ovens for fuel, the remainder going to the surplus gas plant.

In the tar operation the tar leaving the primary coolers is collected in tanks, dehydrated if necessary, and is pumped to storage, or loaded into cars ready for shipment.

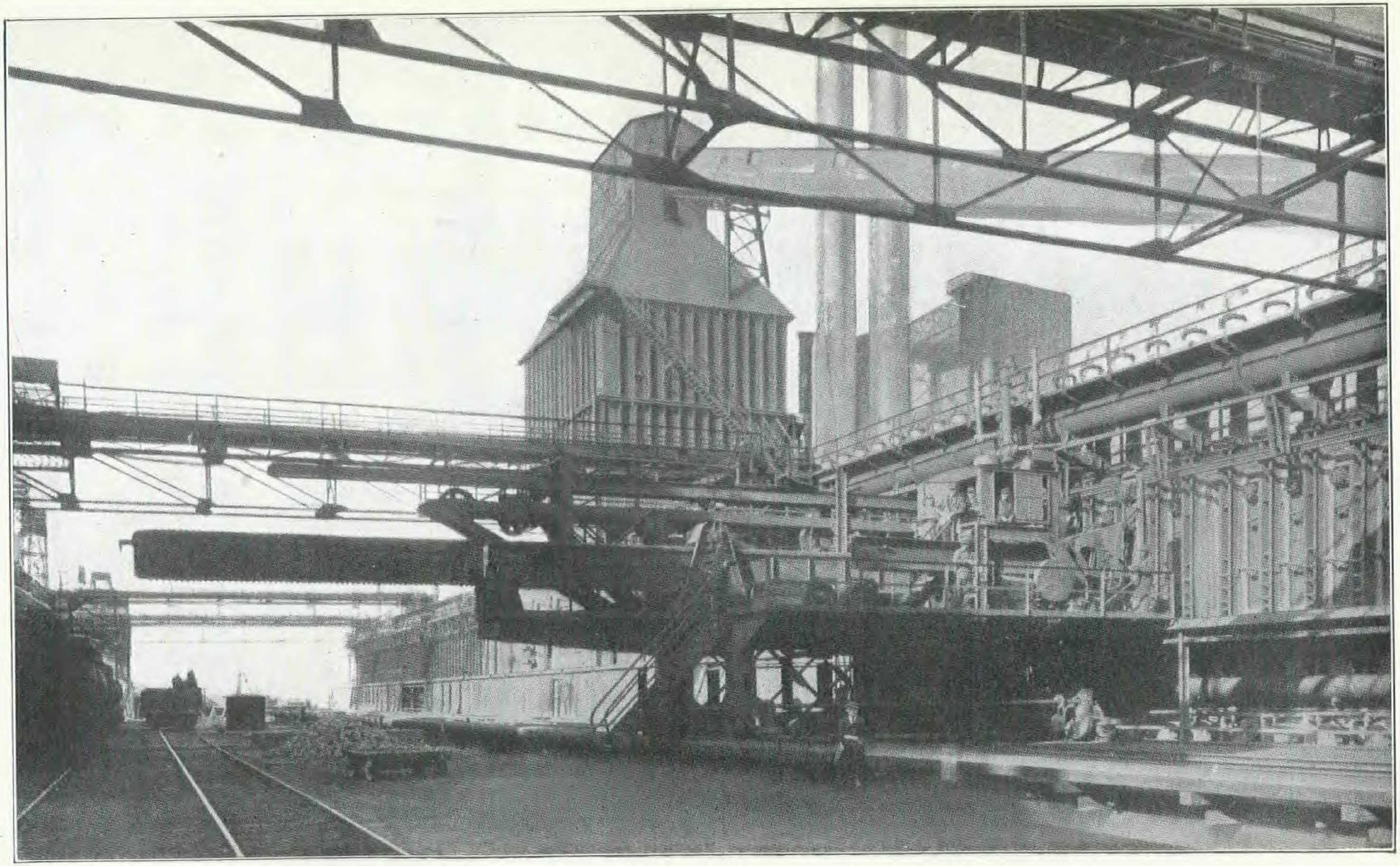
The ammonia liquor operation takes the weak liquor from the ammonia scrubbers, carries it to the distillation plant, where it is purified, concentrated, and made into various commercial grades. Either anhydrous or aqua ammonia can be produced and are ready for commercial use without further treatment. All equipment, such as pipe-lines, pumps, stills, etc., are maintained and operated by this department.

The sulphate operation covers the operation of the saturaters, preheaters, if any, stills, etc. The salt is ejected from the saturaters along with a small part of mother liquor; is drained on draining tables and dried in centrifugal dryers and then sent to storage or for further drying by use of heat to produce a grade known as Acadian salt. All equipment, acid storage, tanks, pumps, etc., are operated as a unit under this department.

The gas, after leaving the saturaters or ammonia scrubbers, passes into the light oil scrubbers, where the gas is sprayed with a petroleum oil known as wash oil, which absorbs the light oil in the gas. The wash oil is then sent to the light oil plant, where it is distilled, the crude light oil being sent to storage or the benzol plant, and the wash oil is washed, cooled, and returned to the scrubbers. This operation demands great skill, numbers of heat interchanges being made, automatic heat control, temperature control, etc., making up the operation. Pumps, lines, cooling coils, condensers, stills, etc., are operated as a unit.

The benzol plant takes crude light oil as received from the light oil plant and produces commercial benzol, 100 per cent or 90 per cent toluol, xylol, and solvent. It also handles the washing of light oils with sulphuric acid and caustic soda to produce motor benzol. All the stills, etc., for the rectification of light oils, and all the washing apparatus, pumps, machinery, etc., operate as a unit. Usually the benzol plant is linked under the operation of the light oil plant.

Surplus gas operation takes care of the gas after leaving the final coolers—a part being returned to the ovens for fuel; the remainder, or surplus gas, is sent to purifiers, which frees the gas from sulphur, H_2S, etc. Usually in selling gas to gas companies, a booster station is maintained from which the gas is pumped at the required pressures, to holders or for distribution. Where it is necessary to maintain a high B.T.U.



Koppers ovens, pusher side, Youngstown Sheet Plate and Tube Company, Youngstown, Ohio.

standard, an enrichment station is in some cases installed near the purification and booster station. Owing to the fact that delivery of gas involves most efficient and regular service, this station is usually equipped with instruments for recording B.T.U.'s, volumes, pressures, temperatures, etc.

Steam generation on the coke plant is important, as power is supplied for running exhausters, stills, electric generators, etc. In coke plants, where sulphate is made, the boiler requirements are somewhat lower than in plants making ammoniacal liquor. Whether electric power is generated at the plant or purchased is a factor in determining the size of the boiler plant. Modern practice in a coke-plant boiler house usually involves the installation of stokers suitable for burning coke breeze, other low-grade fuels, tar, or gas.

In Canada, it is not likely that the current will be generated at the coke plants, as cheap hydro power is as a rule available. In coke plants where the current is generated, the operation is commonly linked up with the boiler house and operated as a unit power house. Most modern coke plants are electrified—motors being used to drive the pumps, conveyer belts, pushing machines, charging larries, etc.

The question of water supply is very important. Requirements of a moderately sized plant are from 2 to 2·5 gallons of water per minute per ton of coal carbonized per day. It usually pays to install self-contained water supply for a coke plant, including necessary reserves for fire purposes. Drinking water only should be purchased. In a few cases a good supply of water is available, but great care should be taken to ensure a permanent flow, and in general it is more satisfactory to control the supply.

The supply store is an important item in a coke plant. This department usually functions under the direction of the mechanical shop.

The mechanical department is, as a rule, in charge of the operation of the power house; it attends to the general upkeep and repairs of all machinery and buildings.

Locomotives and locomotive cranes—usually under the direction of the coal and coke handling foreman—handle all incoming coal and outgoing coke, and arrange and place cars for the shipment of other products, such as light oil, tar, and ammonia.

Plant transportation includes the operation and direction of plant tractors, automobiles, teams, etc. The departments requiring such service are responsible for operation, but the mechanical department attends to the maintenance.

The laboratory is under the supervision of a chief chemist, who is, as a rule, responsible to one of the higher plant executives.

The plant administrative department is organized as is usual in other industries.

There are, of course, many other minor operations to be considered, operations such as are common to nearly all manufacturing plants. They include packing, distribution, the welfare of the staff, transportation, fire protection, etc., but are largely dependent upon the size of the plant.

An important question is the location of the plant, in regard to which, the main factors are as follows: character of soil; railway facilities; dock possibilities; wagon road connexions; water supply; power supply; plant waste disposal; accessibility (from standpoint of securing materials for construction and operation); foundation materials; labour and housing conditions; taxes, fees, restrictions, laws, etc.

Table XXI is a typical cost sheet summarizing operating and other data on a typical plant, capable of carbonizing 1,000 tons of coal per twenty-four hours. A plant of this size is chosen as an example because the tendency in modern coking practice is to build in such units as experience has shown to be the most economically operated; for a single unit (one battery of ovens) a 1,000-ton plant will best show typical results. Many economical plants are built in much smaller units, but there are other factors to be taken into consideration.

The plant in Table XXI would as a rule consist of a single battery of ovens, from forty-five to sixty ovens in the battery, the number of ovens being dependent on the size of oven, style or type, and the coking time. The coking time plays a very important part in the physical characteristics of the coke produced. Such a plant should produce about 7,300 M cubic feet of surplus gas per day and 700 tons of coke. The coke yield varies with the grade of coal used and the plant practice, a yield of 70 per cent commercial coke from dry coal being a fair average. Hours of operating and repair labour as shown have been consistently bettered in actual practice. The expense items in the table are the usual ones allowed and are conservative—the labour rates are based on Canadian conditions. Such a plant would cost about $2,500,000.

The cost of coal is assumed to be $7 per net ton f.o.b. plant which should be ample in the Toronto–Hamilton–Windsor area.

Good practice on a by-product plant commonly results in better yields than those shown, although, as pointed out in retort practice, gas coals usually yield larger amounts of tar and gas. Prices shown are based on prices for the by-products in December 1923, which have not since materially changed; the gas price depends on locality, cost of labour, materials, etc.

The table shows the items that affect the cost of manufacturing coke, and that a good domestic fuel can be placed in the hands of the consumer at lower prices than anthracite.

Table XXI.—Typical Plant: Estimate for Cost and Returns of Operation

Dry coal per day net tons	1,000
Commercial coke per day, 70% from dry coal	700
Operating labour, hours per ton dry coal	1·50
Repair labour, hours per ton dry coal	0·30

Expenses		Per ton dry coal
Operating labour (50 cents per hour)		$ 0·750
Repair labour (60 " ")		0·180
Repair material		0·200
Supplies and lubrication		0·050
Fuel		0·400
Tank car rental		0·030
Switching		0·020
Manufacturing materials		0·150
Power and water purchased		0·120
Miscellaneous other expense		0·050
Total operating expense		1·950
Insurance	0·5% on $2,500,000	0·034
Taxes	1·0% on 2,500,000	0·068
Depreciation	6·0% on 2,500,000	0·408
	7·5% Total fixed charge	0·510
Total Expense		2·460
Cost of coal, assuming coal at $7 per net dry ton		7·000
Total Cost		9·460
Returns from by-products—		
25 lbs. sulphate at 0·025 cents per lb		0·625
3·0 gals. light oil at 0·10 cents per gal		0·300
9·0 gals. tar at 0·08 cents per gal		0·720
4% boiler fuel at $4		0·160
7·3 M cu. ft. purified gas at 0·35 cents		2·555
Total by-product credits		4·360
Net cost per ton dry coal		5·100
Net cost commercial coke		7·28

Table XXII.—Manning of 1,000-ton Plant

—	Number of men shift work	Number of men day turn only
Office, supt., clerical, and eng.	....	10
Ovens	32	1
Coal handling	....	6
Coke handling	12	
By-products, including ammonia and benzol apparatus	14	1
Power, light, and water	12	
Mechanical	3	22
Yard cranes and locomotives	16	10
Patrolmen-janitors	3	1
Laboratory	....	4
Purification—holders, etc	....	4
Totals	92	59
	151	

The total labour cost for manning the plant as outlined above is about $930 per day or an average wage of $5 per day for a plant which operates on a three-shift basis.

A test recently conducted on a battery of coke ovens showed what may be accomplished in the way of heat balances, with modern plants. The test took place while the plant was in full commercial operation and conditions were normal.

Total Heat Balance: Coke Oven Plant
(Basis One Net Ton Dry Coal)

—	B.T.U.	Per cent
Input—		
Latent heat in coal	29,100,000	93·10
Sensible heat in coal	4,800	0·015
Latent heat in fuel gas	2,150,000	6·88
Sensible heat in fuel gas	4,000	0·012
	31,258,000	100·00
Output—		
Latent heat in coke	18,900,000	60·50
Sensible heat in coke	1,111,000	3·56
Latent heat in fuel gas	6,050,000	19·35
Latent heat in tar	1,500,000	4·80
Sensible heat in tar	49,000	0·15
Heat of vaporization of tar	14,000	0·04
Sensible heat of stack gases	326,000	1·04
Latent heat water in stack gases	177,000	0·56
Sensible heat in stack gases	98,100	0·31
Latent and sensible heat in condensate	309,000	1·00
Radiation and losses	357,000	1·14
Total heat output	29,682,000	95·00
Unaccounted for	1,576,000	5·00

Sensible Heat Balance

(Basis One Net Ton dry Coal)

—	B.T.U.	Per cent
Input—		
Sensible heat in coal	4,800	0·22
Sensible heat in fuel gas	4,000	0·18
Latent heat in fuel gas	2,150,000	99·60
Total sensible heat, input	2,159,000	100·00
Output—		
Sensible heat in coke	1,110,000	51·50
Sensible heat in fuel gas	361,000	16·70
Water in fuel gas	310,000	14·45
Sensible heat in tar	63,000	2·92
Sensible heat in stack gases	326,000	15·20
Water in stack gases	275,000	12·70
Radiation and convection	357,000	16·60
Sensible heat, output	2,803,000	129·87

Difference	644,000 B.T.U. per ton
Exothermicity of reaction	322 B.T.U. per lb. and 29·9% of input
Total gas produced per ton of coal	11,150 cu. ft.
Fuel gas consumed in oven flues	3,960 "
Per cent total gas used as fuel gas	35·5

Volumes at 60 degrees F. and 30 inches mercury

Analyses of Fuel Gas—

CO_2	1·5	CH_4	26·8
Ill	3·1	N_2	4·8
O_2	0·9	B.T.U	541 calculated
CO	5·3		545 observed
H_2	57·6		

Analyses of the waste gases entering waste heat flues were as follows:

CO_2	O_2	H_2
8·4	3·1	88·5

Excess air was 16·1 per cent and air infiltration raised this to 68 per cent at the stack, hence air leakage was found to be about 43 per cent of air used. Most of the leakage occurred at the bulkhead walls.

BY-PRODUCT COKE OVENS AT HAMILTON

The construction of the plant of the Hamilton By-Product Coke Ovens, Limited, was commenced in April, 1923, and completed in January, 1924.

The plant is designed to carbonize about 500 tons of coal per 24 hours, with the production of a maximum of about 5,500 M cu. ft. of gas accompanied by the recovery of tar oils and sulphate of ammonia. For reasons hereinafter explained, there is no recovery of light oil. The unique feature of the plant is its great flexibility in coke and gas output.

The ovens are twenty-five in number, 14-inches average width, 28 feet long between doors, and 9 feet 6 inches to the coal line, and are of the Semet-Solvay standard horizontal flued type; five flues high, with double pass regenerators (*See* Figure 6). The by-product recovery equipment is of standard Semet-Solvay design complete with final cooler for naphthalene extraction.

The plant, primarily, furnishes gas for city use to the United Gas and Fuel Company. A great deal of attention has been given to the selection of coals and the quality of coke produced. The coals used are the celebrated Elkhorn, a high volatile coal, mined by the Consolidation Coal Company at their Jenkins mine; and Pocahontas, a low volatile coal from West Virginia. Analyses of these coals are about as follows:

Proximate Analyses

—	Elkhorn	Pocahontas
	Per cent	Per cent
H_2O	2 to 3	1 to 2
Vol. matter	36 to 38	16 to 18
Fixed carbon	54 to 58	75 to 79
Ash	3 to 5	3 to 4
Sulphur	0·75 to 0·85	0·70 to 0·80

The resulting coke will analyse about as follows:

	Per cent
H_2O	1 to 2·5
Vol. matter	1 to 2·0
Ash	6 to 7
Sulphur	0·6 to 0·75
Fixed carbon	89 to 92

A mixture of 25 to 30 per cent Pocahontas and 70 to 75 per cent Elkhorn is used to produce this coke which, from a chemical standpoint, is second to none on this continent. The grades of coke produced are foundry, screened over 3·5 inches; egg coke 3·5 inches to $1\frac{5}{8}$ inches; nut coke $1\frac{5}{8}$ inches to 1 inch; and pea 1 inch to $\frac{1}{2}$ inch. All the coke passing through the $\frac{1}{2}$-inch screen is classified as breeze and is sent to the boiler house.

The plant is located on Burlington bay. Two creeks, which are to be made suitable for navigation, flank the plant on two sides so that coal can be brought in by water as well as by rail. Coal is handled to or from stock by locomotive cranes, the coal-stocking area being flanked by suitable tracks for the purpose. Incoming coal, for immediate use, is dropped from the car, into a track hopper, whence it is fed by an apron conveyer upon a 24-inch belt conveyer of Robbins type, which conveys the coal to the preparation plant. From this belt the coal is discharged into a rough

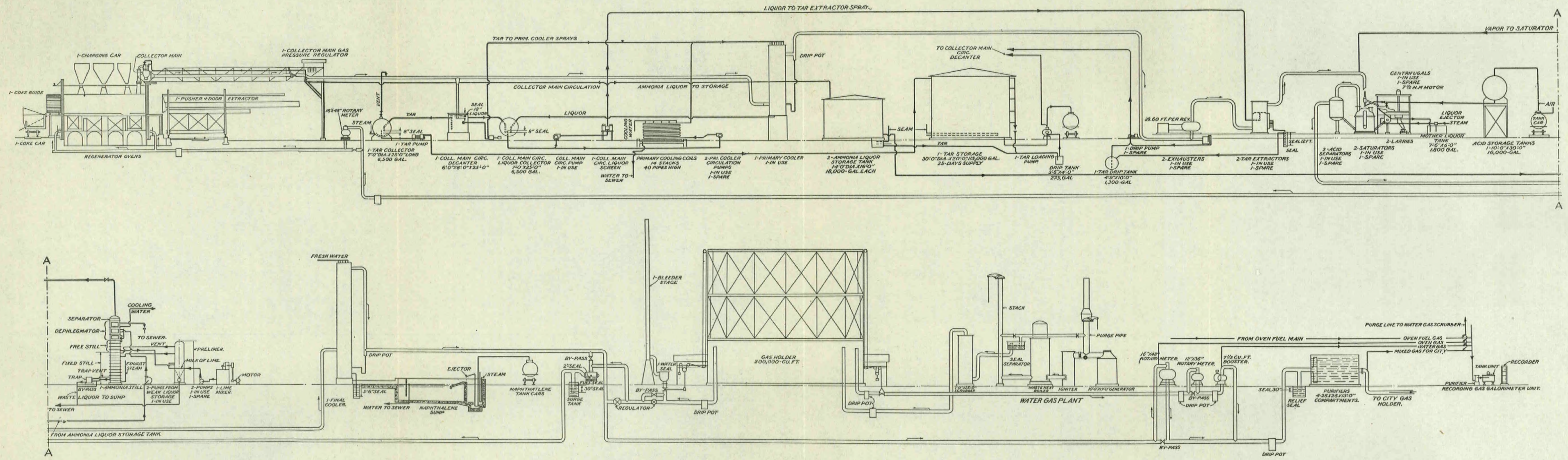
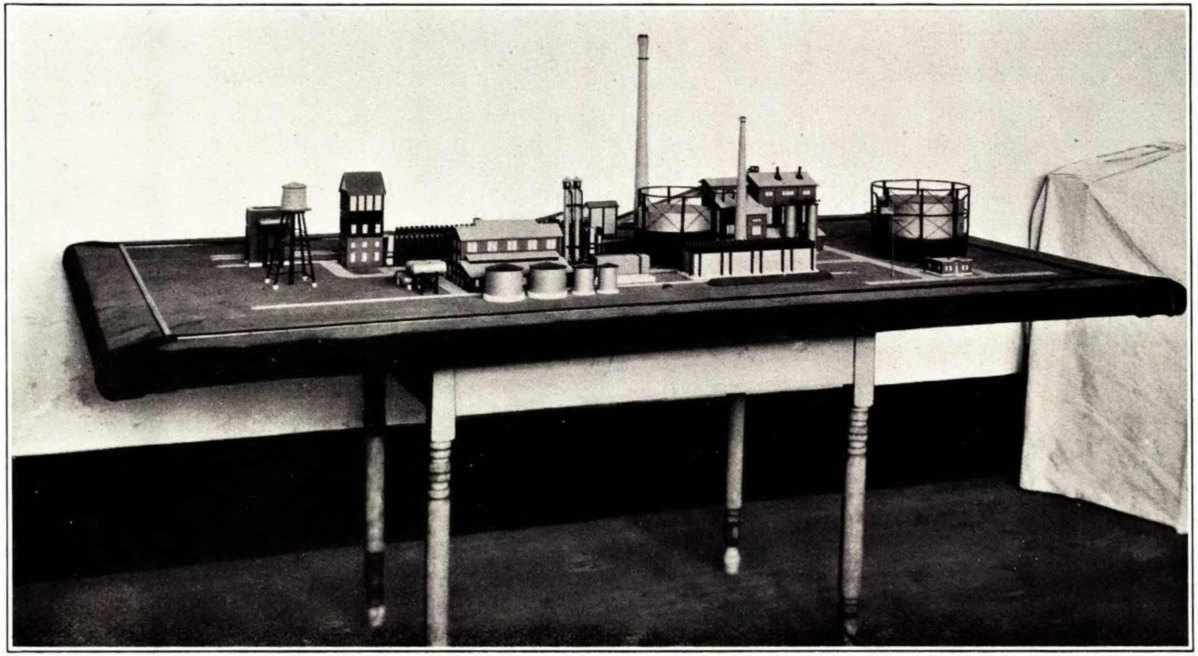


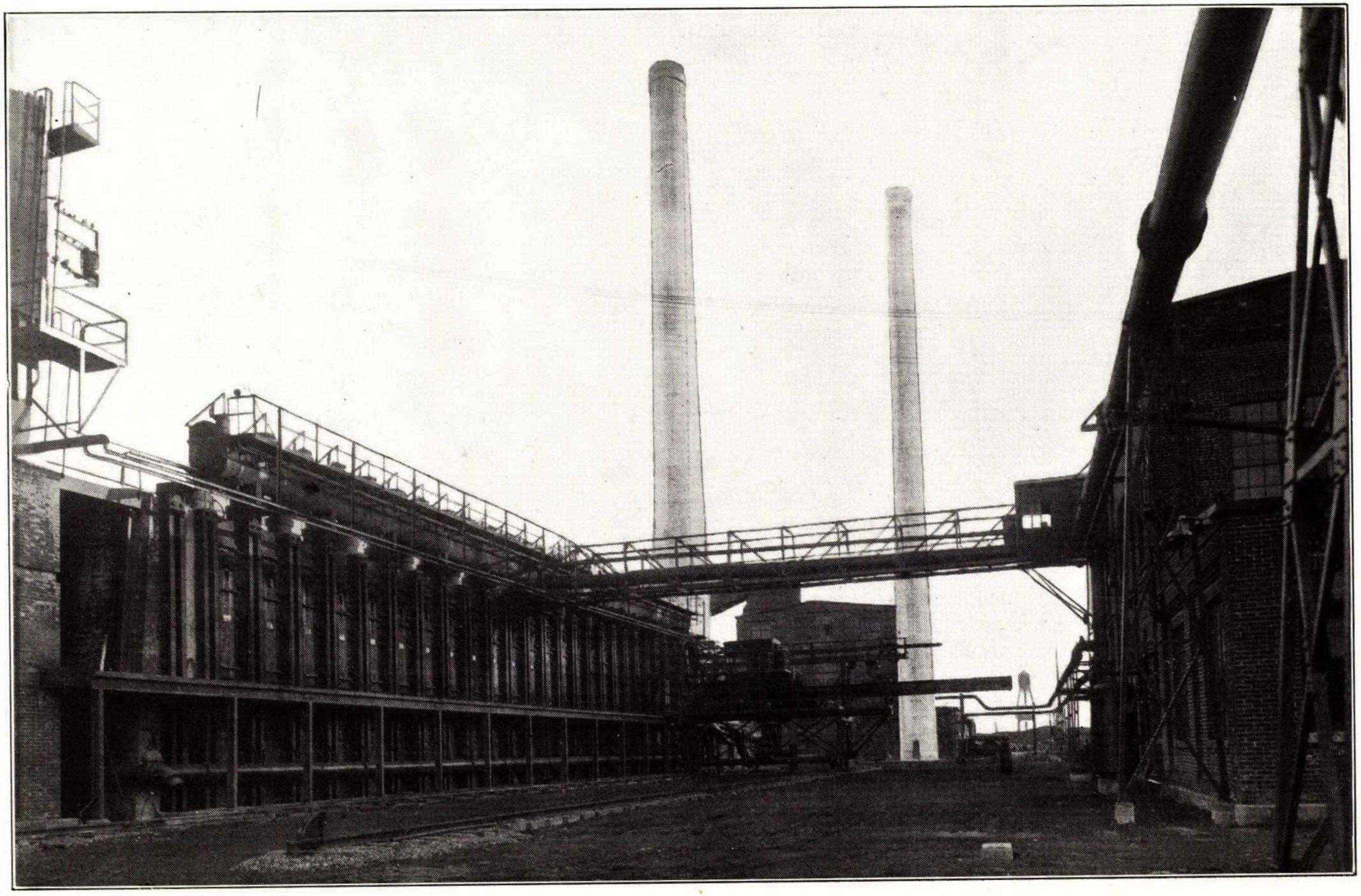
Figure 18. Flow sheet, coke and gas oven plant, Hamilton By-Product Coke Company, Limited, Hamilton, Ont.



Model, new Semet-Solvay coke plant at Hamilton.

crusher which crushes the coal down to $\frac{1}{2}$ or $\frac{3}{4}$-inch lumps, or smaller, as desired. A belt bucket elevator conveys this coal to either one of two 150-ton mixing bins. The coal from these bins discharges on a two-part mixing table which proportions the amount of mixture of the two coals. From this table the coal is fed into a hammermill pulverizer which grinds the coal and mixes it. After passing the pulverizer, the degree of fineness is such that 60 per cent to 85 per cent will pass through a $\frac{1}{8}$-inch mesh screen and 85 per cent to 95 per cent will pass through a $\frac{1}{4}$-inch mesh screen. The degree of fineness is, of course, controlled by the operator, and depends upon the kind of coke desired. From the pulverizer the coal is elevated by a belt bucket elevator to a belt which carries the coal to the oven bin which is of 450 tons capacity. The coal is now ready for carbonizing and no further preliminary treatment is necessary. From the bin the coal is discharged into the charging larry, taken to the particular oven ready for charging, is discharged through holes in the top of the oven, levelled, and the oven sealed. At the end of the carbonizing period the coke is discharged from the oven by the "pusher" into a quenching car. The doors on the ovens are "lifted" or removed by an automatic door lifter located on the "pusher" and "coke guide" car respectively. The hot coke is taken to the quenching station, where it is completely quenched in 45 seconds, the resulting steam ascending through the quenching tower to considerable heights in the air. This is a most picturesque sight and is not in any way objectionable to the surrounding community. After being quenched the coke is dropped on an inclined coke wharf from which it is fed onto a belt conveyer 24 inches wide which carries it first to the foundry screening station. Here all the coke over the 3·5-inch rotary grizzly screen is loaded into cars as foundry coke. The rejects from this screen pass on a belt conveyer to the domestic screening station where it is sized into egg, nut, and pea coke, bins being provided for storing a total of 250 tons of the various grades made. The breeze passes over a belt conveyer to the breeze bins over the stokers for use in the adjacent boilers. The domestic storage bins are so arranged that coke can be loaded into railway cars, trucks, or wagons for distribution, or can be bagged if necessary.

The total gas evolved from the coal is taken through the apparatus where the by-products are extracted, cooled, and a part may be returned to the oven flues for heating, the remainder going through three oxide purifier boxes where the last traces of sulphur are removed, and thence into the "town" gas holder ready for distribution. The gas used for heating is known as fuel gas and is admitted into the oven flues at proper points, being carefully measured as to the quantity by being passed through orifices under constant pressure. The air is admitted to the main arches at the end of the battery (*See* Figure 6), and enters the individual regen-



Pusher side of oven battery, showing pusher and levelling machine; also delivery gas lines at the Hamilton By-Product Coke Ovens, Limited, Hamilton, Ont.

erators of the ovens, where it is preheated to about 1,000° C., by contact with hot checker brick. The air then passes into the flues, either upward or downward, giving rise to the terms "updraft" or "downdraft". This preheated air oxidizes the gas, admitted at various points, which then passes into the other regenerator, the waste heat produced is utilized for heating up the checker brick, to provide heat for the cold incoming air on the next reversal. Reversals occur every 15 minutes, but only the air and waste products flow are reversed, the design of the oven being such that the gas burns continuously. Gas is admitted to the flues on the face of the ovens and is easy to regulate. Peepholes provide for inspection of flues. Meters measure the total gas used and the usual temperature and pressure instruments are located where necessary. Another new feature is the automatic regulator for stack draft. Irrespective of wind conditions the "pull" on the battery by this means is kept constant as desired—the limit of fluctuation being about 0·1 inch water. The pushing and levelling machines, door extractors, charging larry, and coke guide are all electrically driven, but the quenching car is hauled by a steam locomotive which is also used for the necessary yard shifting.

The by-products are recovered in the usual manner with standard Semet-Solvay equipment. The raw gas coming from the coal in the ovens is carried up from the oven through the standpipe into a large main. As the gas passes the valve box which is used to "cut" the oven in or out of the system, it receives an initial cooling by being sprayed with ammonia liquor. This spraying reduces the temperature of the gas from about 700° C., to 125 to 150° C., and also serves to bring down some tar. The ammonia liquor used for spraying contains "fixed" ammonia, no free ammonia being absorbed on account of the temperature of the liquor. Gas, liquor, and tar then flow together from this main through a pipe-line towards the primary cooler. Between each two oven uptake pipes there are additional sprays which further cool the gas so that the temperature of the gas at the entrance to the primary cooler is 80 to 100° C. The tar and ammonia liquor are separated from the gas just before entering the primary cooler. By decantation the tar and liquor are separated, the tar passing to a collector tank in which there are steam coils for further dehydration of the tar if necessary. Usually tar containing not more than 2 per cent water is considered "commercial". The liquor, after being separated from the tar, goes to a collector tank from which it is pumped back to the sprays on the hydraulic main in the ovens and thus recirculates. When this liquor absorbs enough ammonia to reach the desired strength, a part is sent to the weak liquor tanks where it is held until ready for distillation. The gas enters the primary cooler, which is of the circular grid type, the ascending gas meeting a spray of cool liquor where it is further cooled to about 25° to 30° C. The function of the primary cooler is to cool the gas. On cooling, the larger part of the tar is extracted from the gas. The tar and liquor then go into the decanter, where tar is separated as before, the liquor passing to the liquor tank. From this tank the liquor used for spraying the primary cooler is passed through cooling coils and recirculated over and over as before. A part of this liquor is continually being drawn off and enough fresh water is continuously added to make up the required volume. The weak liquor is chiefly "fixed" ammonia liquor containing soluble salts like ammonium chloride, etc.

From the primary cooler the gas, practically tar free, passes through the exhauster which draws the gas from the ovens, and forces it through the by-product apparatus and thence through the purifying boxes into the large holder ready for "city" use. After passing the exhauster the gas passes through a tar extractor where the last traces of tar are removed, and thence into a saturater where the gas bubbles through a bath of sulphuric acid, forming ammonium sulphate. This plant has two extractors of the usual bell type, two exhausters, two saturaters, and two centrifuges, so that any single piece of apparatus can be used with any other piece as desired. A steam ejector raises the sulphate and "mother" liquor into a settling box, the liquor returning to the saturater for further use. Fresh acid is continuously added to keep the bath up to required strength. When enough sulphate has accumulated in the settling box, for a "spin," it is run into the centrifuge, where it is spun for 15 to 20 minutes to remove all the liquor. After the spin the grey-white salt, ammonium sulphate, is dropped into a buggy and taken to storage. A portable belt conveyer handles the sulphate to and from storage, to the bagging machine where it is bagged and made ready for shipment. The sulphate runs about 25·5 per cent ammonia, contains less than 0·5 per cent free acid, and is a fine salt, uniform in size and colour. Located in the same building, which is known as the by-product building, is the ammonia still, The weak liquor from storage enters the top of the still where heat exchange takes place, the hot gases leaving the still warming the incoming cold liquor. After passing through this apparatus, known as a dephlegmator, the liquor runs into a compartment known as the "lime leg" where it is treated with lime to free the fixed salts. From here the liquor, now containing "free" ammonia, enters the still proper, where steam drives off the ammonia gas. The liquor leaving the bottom of the still contains little, if any, ammonia and goes to the sewer. The ammonia gas leaving the top of the still is comparatively dry and is carried to the saturater and is admitted along with the coke-oven gas. Although this still is only 4 feet in diameter it is capable of taking a feed of 3,000 gallons per hour of 18 to 20 gramme liquor. Almost all other systems except the Solvay have to preheat the coke-oven gas before it enters the saturater, because the ammonia gases coming wet from the stills weaken the acid bath. By preheating the coke-oven gas, it absorbs additional moisture and retains it at the higher temperature. Hamilton is producing about 10 imperial gallons of tar and about 30 pounds of sulphate of ammonia per ton of coal carbonized.

After leaving the saturaters the gas passes through a final cooler of the tower grid type where it is sprayed with clean, cool water to remove any naphthalene which may be present, and which is liable to cause stoppages in lines, meters, etc. The gas leaving the final coolers passes through the station meter into the purifying boxes where the sulphur is removed, and thence into the city holder. The meters are of a new displacement type made by the Connersville Blower Company. Iron filings mixed with sawdust or shavings are used for purifying the gas. Raw gas from the ovens usually runs from 400 to 600 grains of sulphur per 100 cubic feet, in which condition it is not suitable for domestic purposes. For domestic use the sulphur content should not be over 20 grains per 100 cubic feet.

The laboratory is equipped for making all the necessary analyses. A Thomas recording calorimeter continuously measures the calorific values of the various gases.

The boiler-house and blue water gas sets are located in one building. Steam is supplied by two 200-horsepower horizontal drum water tube boilers fired by "Coxe" stokers. The Coxe stoker is a development of the Combustion Engineering Corporation during the past few years, and most successfully burns fine slack coals, or coke breeze, or any inferior fuel difficult to burn, and has been known to burn successfully fuels containing as high as 40 to 50 per cent ash. These stokers are capable of forcing the boilers from 250 per cent to 300 per cent of normal rating. Under ordinary conditions one boiler is capable of carrying the plant load. Fuel is automatically fed to stokers. Ashes drop into hoppers beneath the boilers and are removed to the dump by auto truck. Forced draft is supplied by steam-driven "Sirocco" fans and the boilers are fully equipped with measuring meters, draft gauges, etc. Water for the boilers is supplied from the city mains and is purified by a feed-water conditioning system known as the "Permutit" system, using "zeolite" as the purifying agent. A very small labour force is required to operate the plant.

Power is supplied by the Dominion Power Company on two separate lines, thus protecting the plant in the event of failure of one line. All circulating pumps are electrically driven, steam-pumps being used only on tar handling. Two motor generator sets are installed for converting alternating current to direct current for operating the pusher, charging larry, and coke guide cars. One motor generator set is a spare.

Mill water is supplied by electrically driven pumps located near the inlet or creek and a 50,000-gallon storage tank 50 feet high gives the required head. These pumps furnish all the cooling and quenching water required. Additional protection is provided by a connexion with city water and fire mains.

A blue water gas set supplies an auxiliary fuel for oven firing; by this means the gas output can be varied almost instantaneously. This set, installed by the Gas Machinery Equipment Company, consists of a generator, igniter chamber, waste heat boiler, and automatic control. Egg coke is dropped into the generator and when combustion has reached the desired point, air is turned off and steam admitted, which results in the formation of blue water gas. The steam is passed both in an upward and downward direction through the hot fuel, the steam reacting with the hot carbon, giving rise to the formation of the gas. This gas runs about 50 per cent to 60 per cent hydrogen, 30 per cent to 35 per cent carbon monoxide, with relatively small proportions of CO_2, N_2, O_2, etc. Owing to the excellent quality of coke used, three hundred and forty runs have been made without clinkering the generator, making a gas of calorific value of 300 to 320 B.T.U.'s per cubic foot. Air is blown through the fire for about 1·5 minutes, then is shut off, and steam is blown for about 2·5 minutes. The generator is 11 feet in diameter and can produce 2,500 to 3,000 M cubic feet of 300 B.T.U. gas per 24 hours. When the generator is being blown with air, the waste gas produced passes into an igniter chamber where it is ignited and burned before passing into a Wickes waste heat boiler. This gives maximum efficiency, as this boiler generates all the steam required for blowing the generator and in addition generates a surplus of steam which is piped into the general system and used where needed at the plant. Automatic control shifts all valves, starts and stops the turbines, and controls all the operations except charging coke into, and removing ashes from, the generator. The gas is sent through a washer, sprayed with water to remove any tarry matter or dirt, and is then piped to the blue gas relief holder. The generating equipment is complete, adequate by-pass valves, etc., being provided so that the machine can be used whether generating steam or not. The automatic control reduces labour, the operation being easily performed by one man.

As already stated, no attempt has been made to recover light oil, benzols, etc. The reason for this is the small amount of oils available for recovery and the desire for maximum flexibility of output. The coke-oven gas runs about 575 to 590 B.T.U.'s per cubic foot. The calorific value of the gas manufactured in the by-product oven is controlled by the pressure exerted on the ovens, and can be changed within reasonable limits by slight changes in control. Pressure on the ovens is automatically controlled by a butterfly valve in the gas main on the ovens and is further regulated. In other words, if the total gas evolved from one ton of coal be 10,500 cubic feet of 575 B.T.U. gas, about 12,000 cubic feet of 500 B.T.U. can, by changes in the operation, be produced without appreciably increasing the percentages of inerts in the gas.

About 2,000,000 B.T.U.'s are required to coke one ton of coal and the Hamilton ovens have shown such efficiency when operating on coke-oven gas that less than 35 per cent of the total gas will be required for coking the coal. The efficiency when using blue gas as oven fuel is about the same. By leaving the light oils in the gas, the coke-oven gas can be diluted with blue gas down to the standard required by law, but it is understood that the Hamilton plant will always give their customers advantages by producing "city" or "town" gas of not less than 500 to 525 B.T.U.'s.

The ovens can, therefore, be operated as straight coke ovens using part of the gas for firing ovens, and hence 60 per cent to 65 per cent of total gas evolved is surplus for city consumption. Having a blue gas holder of 250,000 cubic feet capacity, almost on instant notice, 100 per cent of the total gas evolved from the coal can be put into city service. The water gas generator is kept banked and can be started in less than an hour and a half. The coke-oven gas is of such high calorific value that it can be diluted with blue gas, thus again increasing the gas output to take care of peak demands. The plant has the widest possible variations in gas output of any plant of its kind in North America. The domestic coke produced at Hamilton satisfies a long-felt want. Compare its ash contents of 6 per cent to 7 per cent with the 20 per cent to 30 per cent in anthracite, which sells for $3 to $4 per ton more. Unfortunately the plant is relatively small, and can supply only the nearby demands. It may, however, be confidently anticipated that more of these plants will be installed at strategic points or the production of "town gas" and domestic coke.

CHAPTER XIII

GENERAL CONCLUSIONS: OVENS

An attempt has been made in the previous chapters to describe the types of ovens and the methods of by-product recovery in vogue on this continent. The claims advanced are, primarily, the claims of the builders; the final selection of oven and by-product apparatus must be made by the engineers and owners after studying local conditions.

The question of horizontal-flued, versus vertical-flued, ovens has been closely associated with the question of blue gas versus producer gas. The horizontal-flued oven lends itself to the adaption of blue gas much better than the vertical-flued type, but the vertical-flue oven is better suited for the use of producer gas. Flexibility, ease of operation in varying gas output, and the value of the finer sizes of coke must be considered, for producer gas can be made cheaply where "fines" have little value as a steam fuel, but in Canada, where fuel costs are high, this advantage may be somewhat offset. Although producer gas is cheaper, blue water gas gives maximum flexibility and for a complete plant is somewhat lower in initial first cost.

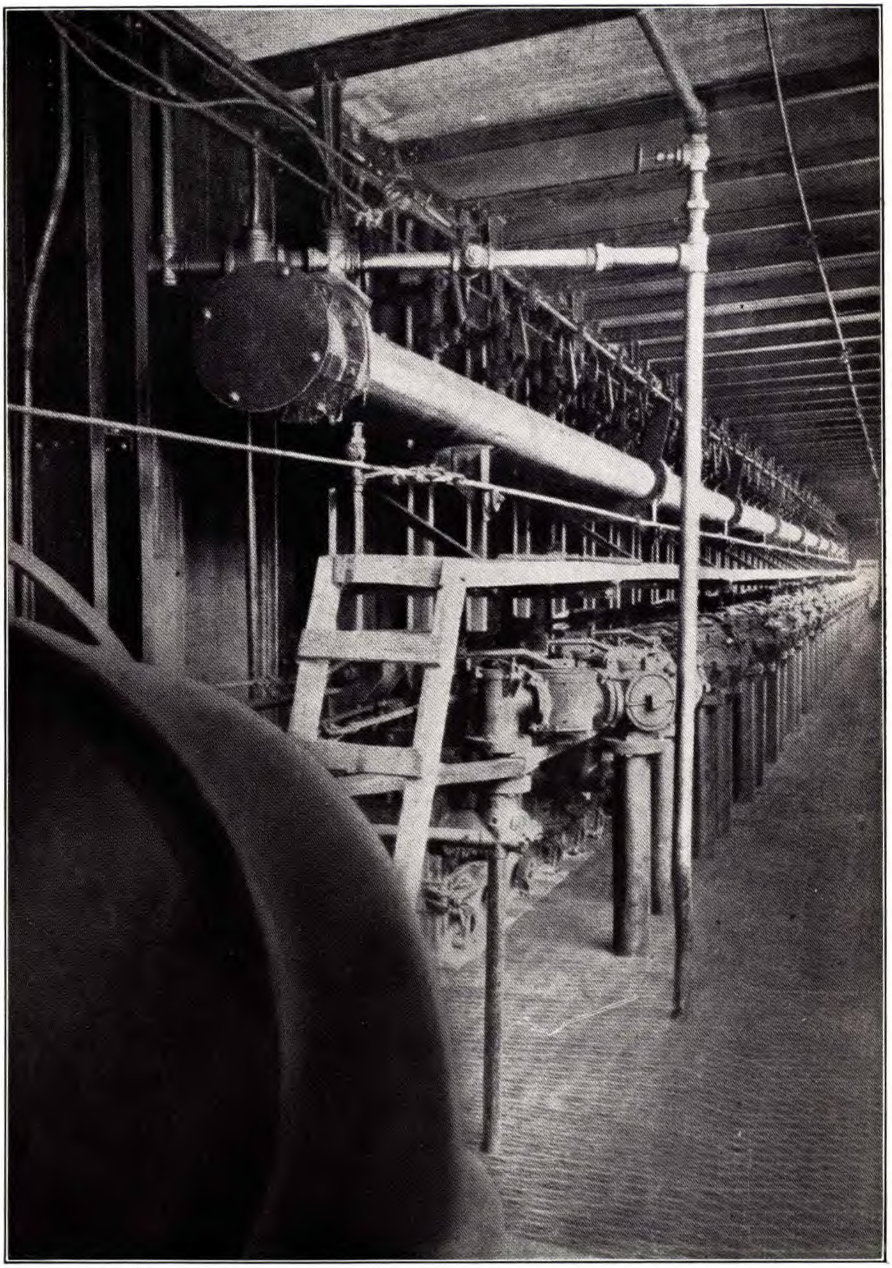
Some builders of ovens have based their claims as to the merit of their respective systems upon the rapid application of heat to the coal, but as all modern ovens now built in North America have a very refractory lining, almost any type of modern oven can be run at high temperature. The *width of the oven* is the real controlling factor. Until quite recently, the tendency was to build large, high, *wide* ovens; today narrow ovens are the vogue. In many cases this change has resulted in increased capacity in spite of the old rule of thumb that "coal is coked at the rate of an inch an hour."

Many ovens 16 inches to 18 inches in width are today operated on 13 to 16 hour coking time, and modern ovens, 14 inches wide, carbonize coal in 11 hours or less. In other words, the improvement in heating the ovens has accomplished less than the diminution in width. In Canada, however, the width may be an important feature, for where coke plants are built primarily for the production of domestic fuel, and the coke can be produced and moved during the slack season (*See* Chapter VI), the narrow oven will prove satisfactory. If, however, to avoid stocking coke during that period, it is desirable to produce industrial cokes, it may be better to have wider ovens.

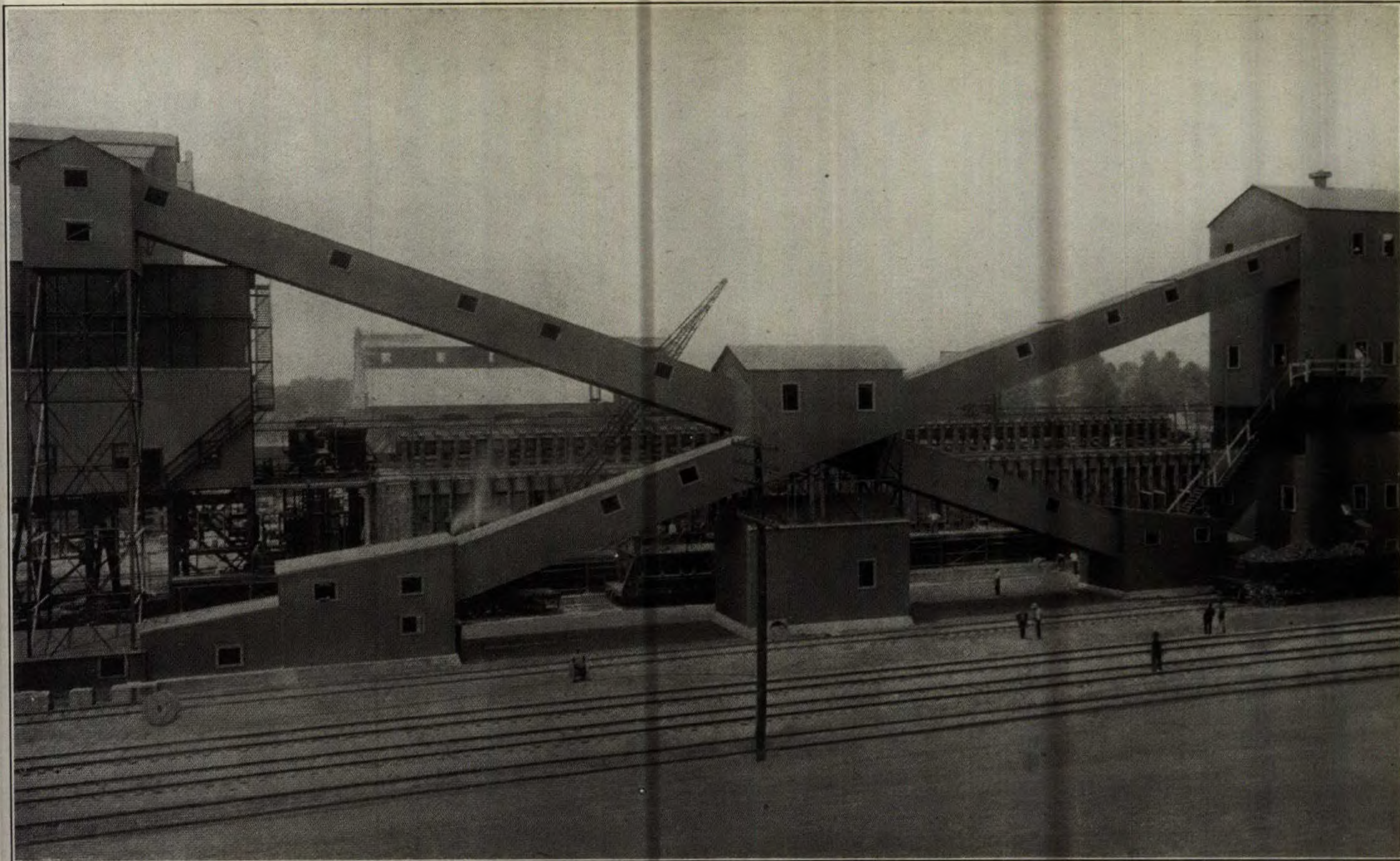
86227—10½

Factors governing the kind of plant to be erected are as follows: demand and rate of gas output; kind and quality of coke; kind and quality of by-products; initial cost; operating cost; nature of financing.

Nearly all the prominent builders of coke ovens do exceptionally good work, differing only in detail. Competition has reduced profits to a minimum. Operating costs are fairly constant, depending upon locality and quality and kind of products produced. Financing has not always been on a high plane and the failure of more than one plant has been due to over-capitalization. Excessive fixed charges and unwillingness to spend money to keep the plant in a good physical condition have also been responsible for failures. Sound financing is an essential factor in the success of a by-product coke plant.



Koppers arrangement for firing ovens with either producer or coke-oven gas.



Coal handling and preparing equipment, Laclede Gas Light Company, St. Louis, Mo.

CHAPTER XIV

DUTY ON COAL

Bituminous coal entering Canada for the manufacture of domestic coke is subject to a duty of 53 cents a ton on run-of-mine coal, and 14 cents on slack, which is equivalent to from 70 to 80 cents per ton of coke produced. Anthracite and coke from the United States enter duty free. Bituminous coal for the manufacture of metallurgical coke, receiving a 99 per cent drawback, is admitted almost free.

The Nova Scotia fields are now producing in excess of 6,000,000 tons annually. With the growing demands for fuel for industrial purposes in Ontario and Quebec, the ultimate limit of development of these coal fields will not be adequate to take care of the demand.

Practically all the coke manufactured in Canada for domestic purposes has been produced by the gas companies in their retorts, where the principal product is gas, and coke of secondary consideration. Recently, some of the by-product coke plants producing metallurgical coke have sold small amounts at reasonable prices to their employees and a few others, with whom the coke met with a most favourable reception.

To illustrate the effect of the duty, a coal containing 30 per cent volatile matter will usually yield about 70 per cent of the coal as coke. The coal used by the gas companies is much higher in volatile matter and the yield of coke is somewhat lower. If the duty is divided by the yield of coke ($\frac{53}{70}$) the additional cost is found to be 75 to 80 cents per ton of coke produced. In other words, either the consumer has to pay this additional cost or it is absorbed by the Canadian producer.

CHAPTER XV

TRANSPORTATION

The chief problem to be faced lies in the fact that central Canada is so far from the coal fields in the Dominion; this enables American fuels located so much nearer this central market to have the advantage when competing with coals from Nova Scotia and Alberta. Attempts are being made to have Canadian coal freight rates reduced, but the success of these efforts remains to be seen.

RATES

The following rates based on short tons are now in existence:

FREIGHT RATES—ALL RAIL

Anthracite: Scranton, Lehigh, and Wyoming Valley to Ontario and Quebec

—	Prepared sizes	Pea	Buckwheat No. 1	Smaller
	$ cts.	$ cts.	$ cts.	$ cts.
To Windsor	4 53	4 08	4 08	4 08
London	4 40	3 94	3 94	3 94
Hamilton	3 86	3 41	3 41	3 41
Ottawa	4 67	4 33	3 90	3 23
Montreal	4 42	4 06	3 73	3 05
Quebec	4 93	4 67	4 55	3 76

Bituminous: Pennsylvania and Ohio to Ontario and Quebec

From	Clearfield	Vintondale	Pittsburgh	Connellsville	St. Clairsville
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
To Windsor	3 69	3 69	3 84	3 99	2 88
London	3 49	3 49	3 64	3 79	3 28
Hamilton	2 99	2 99	3 14	3 29	3 14
Ottawa	3 92	3 92	4 14	4 14	4 94
Montreal	4 00	4 00	4 23	4 23	4 94
Quebec	4 99	4 99	5 21	5 21	6 04
Toronto	3 32	3 32	3 24	3 34	3 24

Bituminous: West Virginia and Kentucky

From	Fairmount, W.V.	Pocahontas district
	$ cts.	$ cts.
To Hamilton	3 98	4 18
Montreal	5 48	5 68

Bituminous: Maritime Provinces

Nova Scotia to Ontario and Quebec

To / From	Quebec	Montreal	Ottawa	Toronto
	$ cts.	$ cts.	$ cts.	$ cts.
Maccan	3 00	3 60	4 70	5 50
Springhill Jct	3 00	3 60	4 90	
Westville	3 50	3 90	5 10	
Stellarton	3 50	3 90	5 10	
Thorburn	3 55	3 95	5 10	
Point Tupper	3 90	4 20	5 50	
Smith Bras d'Or, Sidney, Sidney Mines	4 20	4 50	5 60	

Rail Rates on Great Lakes: Cargo Coal

High volatile		Low volatile	
West Virginia—Kentucky to lake	$1.91 by rail	West Virginia to lake	$2.06
Dock charge	0.08	Dock charge	0.08
	$1.99		$2.14

Vessel rate from Ashtabula, Sandusky, and Toledo will vary from 40 cents to 50 cents per ton to Port Colborne, from 75 cents to $1 to Hamilton and Toronto. Unloading charges and harbour charges are about 35 cents per ton. Freight rates from Great Britain to Quebec and Montreal are approximately $2 per ton and from Nova Scotia to Lake Ontario points approximately $1.75 per ton, to which must be added wharfage and discharging fees amounting to about 50 cents per ton.

Coal brought to St. Lawrence River points from Hampton Roads carries a rail rate of $2.62 from West Virginia and Kentucky points to the docks, where a 5 cents charge is added for dumping, and the vessel rates approximate $1.50 to $2.00 per ton.

It will, therefore, be easily understood that Nova Scotian coals, 1,000 miles away from Montreal, find it necessary to compete with coals from the American fields scarcely half that distance away, and can do so only by taking advantage of water transportation.

The vessels bringing coal from Great Britain and Nova Scotia to Montreal carry from 4,000 to 12,000 tons, but vessels of that size cannot pass through Lachine canal. If, however, the canal were enlarged so as to admit of the passage of these freighters, coal could be landed in Lake Ontario ports at a greatly reduced rate.

Alberta coals cannot compete much farther east than Winnipeg so long as the rate to points in Ontario is nearly $13. Even if this rate were $5 or $6 per ton, competition with low volatile American coals would have to be met, the latter coming into Ontario at less than $5 a ton.

There is probably no single factor of more importance to the coal and coke industries than that of transportation. On the other hand, there is no subject which is more dangerous to discuss unless *all the facts* are known. It is proposed to point out the conditions existing and just how these affect the by-product coke oven and gas industry.

The rates in effect on coke on a mileage basis in Canada are as follows:

Distance			*Rate per net ton*
Not over 5 miles			$1 00
6 and not over		10 miles	1 00
11	"	20 "	1 10
21	"	30 "	1 20
31	"	40 "	1 30
41	"	50 "	1 50
51	"	60 "	1 70
61	"	70	1 70
71	"	80 "	1 80
81	"	90 "	1 80
91	"	100 "	1 90
101	"	120 "	2 00
126	"	150 "	2 10
151	"	175 "	2 20
176	"	200 "	2 40
201	"	225 "	2 50
226	"	250 "	2 80
251	"	275 "	2 90
276	"	300 "	3 00
301	"	325 "	3 10
326	"	350 "	3 20
351	"	375 "	3 30
376	"	400 "	3 40
401	"	425 "	3 50
426	"	450 "	3 60
451	"	475 "	3 70
476	"	500 "	3 90
501	"	525 "	4 00
526	"	550 "	4 10
551	"	575 "	4 20
576	"	600 "	4 30
601	"	625 "	4 40
626	"	650 "	4 50
651	"	675 "	4 60
676	"	700 "	4 70
701	"	725 "	4 80
726	"	750 "	5 00

The leading railways are most sympathetic to the establishment of the coke industry in Canada and will at least give to the Canadian producer rates which are equivalent to or less than those in effect to foreign producers. It is only reasonable to assume that after coke plants are established and tonnages in quantity are assured, the railways will grant commodity rates, which will bring not only freight markets to the railways but cheaper coke to the public.

One of the larger ports of entry for coke is Windsor, through which coke from Detroit and other points in Michigan and Ohio is shipped into Canada. Naturally with such a large tonnage of coke, rates are much lower. However, for the purpose of comparison the following table has been drawn up.

Comparison Rail Rates on Coke

—	Rate per net ton	Approx. distance	Rate per mile	Rate per same basis as Detroit
	$		cts.	$
Detroit-Montreal	4·00	560	0·715	
Hamilton-Montreal	3·00	377	0·786	2 70
Montreal-Ottawa	2·50	115	2·17	0 82
Montreal-Quebec	2·40	172	1·40	1 23
Montreal-Sherbrooke	2·40	106	2·26	0 75
Boston-Sherbrooke	3·60	272	1·32	1 96

Another disadvantage is that switching charges are high. In many localities these now amount to 80 to 90 cents per ton. In the Connellsville coal and coke region, and other points in the United States where any considerable tonnage is moved, the switching charge is 19 cents per ton, but there have recently been indications that this rate will be raised to about 40 cents per ton.

In reviewing the whole transportation question, it has been found that it is not feasible to disturb in any way the rates on coal, except perhaps in individual cases, because these rates have been carefully built up over a period of years, and are surrounded with complexities, and reasons for their existence.

Many schemes have been proposed to adjust freight rates on coal, and some, such as the "Milling in Transit" scheme, have been tested. This scheme, which at present applies to the movement of grain, has been found unworkable, being unfair, and wrong in principle. A "zoning" scheme is already in use in certain areas on this continent, whereby a manufacturer is enabled to protect his market, the scheme prohibiting the invasion of competitors not normally interested in that market.

The favourable side of the transportation question lies in the receptive attitude of the railways. Although, perhaps, the complexities of rate-making render a complete answer to this preplexing question most difficult, it may be possible to go a long way towards a satisfactory solution by merely laying the facts before the proper authorities.

CHAPTER XVI

SUMMARY

Excluding the cost of land, the erection of the plants suggested in this report would cost nearly $11,000,000. Owing to climatic conditions, which may necessitate the storing of large quantities of raw materials, an additional amount of $2,000,000 to $4,000,000 would be required.

Based on present gas loads in the various cities about 5,000 tons of coal would be carbonized per day, with a resultant coke production of about 3,500 tons of coke per day. Amounts of other by-products to be produced, such as tar, light oil, and ammonia are shown in a table appended herewith.

During construction about 2,500 men would find employment, and about 1,000 men would have permanent employment in the plants, excluding salesmen and those handling the products outside the plant limits.

During construction about $5,000,000 would be spent for supplies, materials, wages, etc., and when the plants were in operation about $2,700,000 would be spent annually for the same purpose.

It appears probable that Ontario and Quebec can produce 800,000 to 1,000,000 tons of domestic coke annually, which would displace 25 per cent to 30 per cent of the anthracite now used in those provinces. With increasing demand for gas and coke, more and more anthracite would be displaced.

Gas manufactured by the coke-oven process can be sold at prices which will attract both the domestic and industrial consumer. Furthermore, the tendency will be towards increasing consumption, for the larger the plant, the cheaper the product.

With only a normal increase in gas consumption, it is quite possible that domestic coke will replace at least 50 per cent of the anthracite now used.

Table XXIII.—Output of Proposed New By-Product Coke Plants[1]—Other Data

City	Output of gas		Coal carbonized		Coke produced		Coke produced as domestic		Coke produced as industrial		Per capita consumption based on all coke produced	Per capita consumption of gas	Per capita consumption based on assumed domestic coke production
	Per day	Per year	Per day	Per year	Per day	Per year	Per day	Per year	Per day	Per year			
	M	M									Tons	Cu. ft.	Tons
Quebec........	600	220,000	90	32,900	63	23,000	30	11,000	33	12,000	0·24	2,300	0·115
Montreal......	11,000	4,000,000	1,570	574,000	1,100	401,500	900	328,500	200	73,000	0·54	5,400	0·44
Ottawa........	1,500	550,000	215	78,500	151	55,100	130	47,500	21	7,600	0·48	4,800	0·42
Toronto.......	13,500	5,000,000	1,930	705,000	1,353	494,000	1,000	365,000	353	129,000	0·76	7,700	0·56
Hamilton.....	3,000	1,100,000	430	157,000	301	110,000	100	36,500	201	73,500	0·92	9,200	0·31
Port Colborne	7,000	2,560,000	1,000	365,000	700	255,500	300	109,500	400	146,000	1·37	Industrial gas chiefly	0·59
London........	1,000	365,000	145	53,000	102	37,200	102	37,200	....	....	0·14	6,000	0·14
	37,600	13,795,000	5,380	1,964,400	3,770	1,376,300	2,562	935,200	1,208	441,100			

[1] Cities proper, only.

Table XXIV.—By-Product Coke Ovens, Canada: Approximate Figures for Establishment of the Industry

Locality	Approximate coal carbonizing capacity per day	Approximate tons coke produced per day	Lbs. NH_3 total per day	Imperial gallons light oils	Imperial gallons tar	Cost of plant exclusive of land	Approximate men employed to operate 3 8-hr. shifts	Approximate total money spent in locality per year	Approximate amount spent locally during construction	Number of men on construction	Estimated time to complete
						$		$	$		
Quebec.......	A 100	70	650	....	800	400,000	50	75,000	100,000	100	7 months
Montreal.....	B 1300	C 910	8,450	3,900	10,400	G 2,500,000	200	750,000	1,000,000	500	11 "
Ottawa.......	A 250	175	1,625	....	2,000	G 1,500,000	90	200,000	700,000	250	10 "
Toronto......	B 1,400	980	9,100	4,200	11,200	G 2,600,000	200	800,000	1,100,000	600	11 "
Hamilton.....	A 500	D 350	3,250	....	4,000	G 2,000,000	100	375,000	1,000,000	....	....
Port Colborne	B 1,000	E 700	6,500	3,000	8,000	2,000,000	160	500,000	1,000,000	500	10 "
	4,550	3,185	29,575	11,100	36,400	11,000,000	800	H 2,700,000	I 4,900,000	1,950	

A—Based on gas load.
B—Based on size of first unit, others to follow.
C—Approximately 200 tons per day will be produced as industrial coke.
D—Approximately 250 tons per day will be produced as industrial coke.
E—Approximately 400 tons per day will be produced as industrial coke.
G—Combination plants.
H—Wages, materials, supplies, insurance, etc.
I—Wages, materials, etc.

CHAPTER XVII

CONCLUSIONS

Ontario and Quebec are at present dependent on the anthracite fields of the United States for their supplies of domestic fuel. The possibility of an embargo on anthracite, the lack of control over supply and prices, the probability of a further rise in price, and the absence of coal fields in the "Acute Fuel Area"—all these facts point to the conclusion that independence, as regards domestic fuel, must be achieved as quickly as possible.

The by-product coke oven supplies a fuel which is at least as good as anthracite, and for which raw material (bituminous coking coal) exists in enormous quantities.

Reserves of oil in the world are being rapidly depleted. Canada, the second nation in the world in the automotive field, will require immense quantities of suitable fuel. The by-product oven supplies this fuel. It supplies, also, many other products essential to the life and development of a nation. The development of the by-product oven has had probably more to do with the progress of the United States during the last three decades than any other one thing, with the exception of electricity. Its products enter into agricultural pursuits, steel, textile, preservative, electrical, chemical, and other lines of industry, and it produces the basic constituents of modern explosives.

From a commercial standpoint, there is no question that by-product coking plants can be successfully introduced into Canada. Markets, with the exception of gas, exist in far greater extent than can possibly be supplied. With attractive returns to capital, coke and gas can be produced and sold at very fair prices. Anthracite producers will abandon the Canadian field only with great reluctance or under pressure, because it is their most dependable market. Therefore, it becomes evident that as both gas and coke are in steady demand for domestic purposes, the industry will be almost free, if not entirely so, from fluctuations in business due to industrial depressions.

The development of hydro-power in Ontario and Quebec has progressed by leaps and bounds in the past few years, but in Ontario the end of this development is, in certain sections, in sight. Even the completion of the St. Lawrence power and canal project will not afford Ontario sufficient waterpower. A further demand for power will necessitate the erection of steam plants. A possible solution of the fuel problem lies in this situation. A large coking plant, strategically located with respect to the steam-electric plant, could sell gas to such a plant to produce cheap power. If a coke-oven plant were built of sufficient capacity to satisfy the gas requirements of a 100,000 horsepower steam-electric plant, the amount of domestic coke made available would be ample to solve the domestic fuel problem of Ontario. Furthermore, the situation is such that an immediate solution would be probable—at most within the next five years. Co-operation in such a development would result in the elimination of the fuel problem.

Public interest in the manufacture of domestic coke is rapidly developing, and it is earnestly to be hoped that capitalists, assured of fair returns on their investment, and the excellent results to the country as a whole, will assist financially in the erection of coke ovens and support an industry that appears to be the best solution of the serious problem that now confronts the "Acute Fuel Area".