Use of Anthracite in Coke-Oven Mixes

A study was made of the effects on quality of coke produced from coke-oven mixes in which a part of the low-volatile bituminous coal, or, in a few instances, a part of the high-volatile bituminous coal was replaced by anthracite fines. Results of research study and of operating experiences at 21 byproduct plants producing blast furnace, foundry, and domestic cokes were published.75/ Several plants reported increased production of foundry coke by use of anthracite fines. Of the 21 plants, favorable results were reported in 10 plants, neutral or indeterminate results in 7, and unfavorable results in 4. At the time the report was prepared, 4 plants were using anthracite fines in regular production of blast-furnace coke, and 5 in regular production of foundry coke. Study of test data and of operating experiences indicated that the effects of additions of anthracite fines to coking mixtures vary considerably with the nature of the bituminous coals used and the operating conditions at the plant. In general, a larger, blockier coke was produced that showed a better shatter index (percent of coke retained on a 2-inch screen after the A.S.T.M. drop shatter test) and a poorer hardness index (cumulative percent of coke on a 1/4-inch screen after the A.S.T.M. tumbler test). A few plants successfully used 4 to 5 percent of anthracite fines in their mixes for making blast-furnace coke, and it is indicated that many plants can substitute 3 to 5 percent of anthracite fines for the same percentage of low-volatile Pocahontas coal without any serious effects on blast-furnace operation. Thus far, it appears that low-volatile anthracite is preferable to high-volatile; this observation needs further study. The effect of the addition of anthracite may vary with the rank, field, or bed of all the coals used in the coke-oven mix. Preliminary tests of various mixtures are of considerable value in determining the best combination of coals. Probably the best procedure is to start with the lowest practical percentage of anthracite fines and gradually increase this, making such changes in the percentages of high- and low-volatile bituminous coals as the test results indicate desirable.

Control of Bulk Densities of Coke-Oven Charges

Studies were made on the control of bulk density of the coke-oven charge and results of detailed studies of the coals used at three byproduct-coke plants were published.76/ This report summarizes operating difficulties traceable to fluctuations in moisture content of the coal and describes methods of measuring bulk density. The A.S.T.M. standard method of test usually employed for this measurement yielded lower results than those actually ecountered in coke ovens. A modified method, called the dropped-coal method, was developed which gave results that agreed with the average

75/ Seymour, Wm., and Schmidt, L. D., Utilization of Anthracite Fines in the Manufacture of Byproduct Coke: Bureau of Mines Rept. of Investigations 3808, 1945, 23 pp. See also footnote reference 66.

76/ Landers, W. S., Schmidt, L. D., and Seymour, Wm., Control of Bulk Densities in Coke Ovens: Studies on Coal Used at Three Byproduct-Coke Plants: Bureau of Mines Rept. of Investigations 3807, 1945, 22 pp.

density of the coal in the coke oven as calculated from the weight of charge and oven volume. Comparison of bulk-density measurements were made on the coal before and after treatment with 0.2 to 0.5 gallon of oil per ton of coal. The major effects of the addition of oil to the coal charge were: (1) Reduction of the fluctuations in bulk density with changes in the moisture content of the coal; (2) significant reduction in range of bulk density in a given coke oven; (3) increase in bulk density, except for coal of low moisture content; (4) reduction of the excessively high and dangerous bulk density for coal at low moisture content; and (5) lowering the angle of repose of the coal, except at very low moisture contents. The benefits of uniform bulk density of the coal charged to coke ovens are immediately evident through smoother plant operation and more uniform coke. Wartime needs for maximum production of uniform-quality coke and the inability of coke-oven operators to obtain regularly coal of desired purity have emphasized the immense value of careful bulk density control. Increased production of coke from existing coke ovens and avoidance of dangerous expanding pressures due to excessively high bulk densities have been the direct result of application of these Bureau of Mines studies.

Coke for Western Steel Production

The second most important, if not indeed the outstanding, raw material for making pig iron and steel is coal. Deficiencies in western coking coals for the production of high-quality blast-furnace coke and lack of markets for coke-oven byproducts have always been serious handicaps to technical progress in steel production in the West. A report discussing the problems incident to production of steel in western steel plants was issued.77/ During the period 1890-1940 the population of the 11 Western States (Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming) increased nearly 240 percent, whereas that of the other 37 States rose only 64 percent. Accompanying this rapid gain in population was an increase in steel production and consumption in the Western States. Because the war has added considerably both to population from increased migration of war workers to the West and to western steel-production capacity, the question as to the outlook for continued use of the expanded capacity in the postwar years becomes of urgent importance. Before the war the West had plants capable of producing 2,109,000 net tons of ingot steel per year and afforded a market for steel products equivalent to approximately 3,500,000 tons of ingots, a substantial part of which was supplied by plants in the Central and Eastern States. War expansion increased production capacity to 4,655,000 tons. Postwar operations of the new plants will depend upon the attainment of several objectives that involve serious problems in recapitalization, marketing, type of steel products, adjustments in freight-rate structure, and technical progress in supply and improvement of raw materials. Careful analysis of the various factors involved indicates that the problems, while serious, are not insurmountable barriers to postwar operation of the new western steel plants at a reasonably

77/ Bain, H. F., A Pattern for Western Steel Production: Bureau of Mines Inf. Circ. 7315, 1945, 35 pp.; Western Steel Problems. Present Installations Not Viewed as Postwar White Elephants: Min. and Met., vol. 26, 1945, pp. 329-330.

satisfactory rate. The technical aspects of western steel-plant operation are thoroughly considered. Progress in the improvement of coals from Colorado, Utah, and Washington for coke manufacture before and during the war, and suggestions for postwar consideration are discussed in detail.

Control of Combustion in Beehive-Coke Ovens

As a result of technical studies by Bureau engineers on the control of combustion in beehive-coke ovens, the "burning" of coal in these ovens has been changed from an art to a science. This new information enables operators with a moderate amount of technical training to determine by means of a few simple analytical tests and appropriate calculations whether a beehive oven is getting too little or too much air and whether the coal is being consumed by burning or is being properly coked. If rapid expansion of the beehive-coking industry should ever again become necessary, there now need be no fear that the art of "burning" beehive ovens would be lost. A recent paper covering this information and other salient findings was published.[78] Technical surveys and assistance and demonstrations of scientific control were continued at beehive plants during the year, although to a decreasing extent as the production of beehive coke declined. One plant, which has been in continuous operation for more than 50 years, has started a long-range improvement program based on the findings and recommendations of Bureau of Mines engineers.

Low-Temperature Carbonization of Alaskan Coals

Increasing demand in Alaska for liquid fuels and lubricants for both war and industrial purposes aroused concern regarding the supply of petroleum products. A general survey of the physical and chemical properties of 14 representative Alaskan coals was conducted to ascertain their potential use as a source of liquid fuel that might supplement present imports of petroleum products.[79] These 14 coals came from 5 mines and one prospect in 4 districts. The location, nature of floor and roof, and partings of the coal beds are given for each of the mines. The 14 samples included 1 high-volatile A bituminous coal and 1 high-volatile B bituminous coal from the Matanuska district; 1 subbituminous B coal from the Broad Pass district; 1 subbituminous C coal from the Fortymile district; and 6 subbituminous B coals and 4 subbituminous C coals from the Nenana district. Yields of carbonization products on the as-received basis, as obtained at 500° C. by the Bureau of Mines modified Fischer low-temperature assay, of the high-volatile A and B bituminous coals were (a) 68.8 and 72.7 percent of coke, (b) 40.9 and 28.8 gallons of tar and light oil per ton of coal, (c) 9 and 10 percent of water, and (d) 970 and 840 B.t.u. in gas per pound of coal, respectively. The 12 subbituminous coals tested yielded (a) 47.8 to 55.9 percent of char,

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78/ Kelley, J. A., Manufacture of Beehive Coke: Proc. Blast Furnace and Raw Materials Committee, Am. Inst. Min. and Met. Eng., vol. 4, 1944, pp. 26-42; discussion, pp. 42-45.

79/ Selvig, W. A., Ode, W. H., and Davis, J. D., Low-temperature Carbonization of Alaskan Coals: Bureau of Mines Tech. Paper 668, 1944, 16 pp.

(b) 9.7 to 37.3 gallons of tar and light oil per ton of coal, (c) 23.3 to 36.4 percent of water, and (d) 510 to 650 B.t.u. in gas per pound of coal. Of the subbituminous coals, the subbituminous B coal from the No. 6 bed, Old Suntrana mine, was second in importance to the high-volatile A bituminous, Eska mine, coal as a potential source of fuel oil; it yielded nearly as much tar and light oil - 37.3 compared to 40.9 gallons - but considerably less carbonized residue - 47.8 compared to 68.8 percent - and only 640 compared to 970 B.t.u. in gas per pound of coal.

A tipple sample of No. 4-bed coal from Suntrana mine was carbonized at 500° and 600° C. by the BM-AGA method, and yields and quality of carbonization products were determined. Data for a similar subbituminous coal from Weld County, Colo., obtained by the Bureau of Mines in 1939, were included for comparison. Yields, on the as-carbonized basis, of carbonization products of the Suntrana coal at 500° and 600° C., respectively, were (a) 48.8 and 44.8 percent of char, (b) 11.8 and 9.46 gallons of tar and light oil per ton of coal, (c) 32.7 and 32.3 percent of liquor, and (d) 910 and 1,440 B.t.u. in gas per pound of coal. The corresponding yields for the same products from the Colorado coal were (a) 56.7 and 51.8, (b) 11.1 and 8.75, (c) 30.3 and 29.1 and (d) 810 and 1,490. The yield of tar and light oil from the Suntrana coal was appreciably lower and that of B.t.u. in the gas considerably higher than corresponding values found by the Fischer assay tests on three samples from this same coal. These differences are due to the long time required for heating in batch in the BM-AGA retort at low temperatures which cause extensive cracking of the liquid products. Industrial methods which heat internally by the sensible heat in inert gases where the rate of heating is high are more practicable for large-scale production, and the liquids can then be removed before much cracking can take place.

Gasification of Subbituminous Coal and Lignite

A small pilot plant was operated for about 1,000 hours at Golden, Colo., to study the technology of gasifying low-rank fuels in an externally heated retort. A large pilot plant of the same general design was built at Grand Forks, N. Dak., and preliminary tests were made. The process was developed in connection with Bureau of Mines investigations on raw materials resources for steel production as a means to supply reducing gas for reduction of iron ore. A report of this investigation was prepared.[80]

Figure 18 taken from this report shows the design of the small pilot plant. An alloy retort is suspended in a combustion chamber specially

80/ Parry, V. F., Gernes, D. C., Goodman, J. B., Wagner, E. O., Koth, A. W., Patty, W. L., and Yeager, E. C., Gasification of Lignite and Subbituminous Coal Progress Report for 1944 (I) Carbonization and Gasification of Lignite in Laboratory Retorts; (II) Gasification of Lignite in Glover-West Retorts; (III) Gasification of Lignite Char Briquets in a Water-Gas Machine; (IV) Gasification of Subbituminous Coal and Lignite in the Golden, Colo., Pilot Plant: Bureau of Mines Rept. of Investigations (in press).

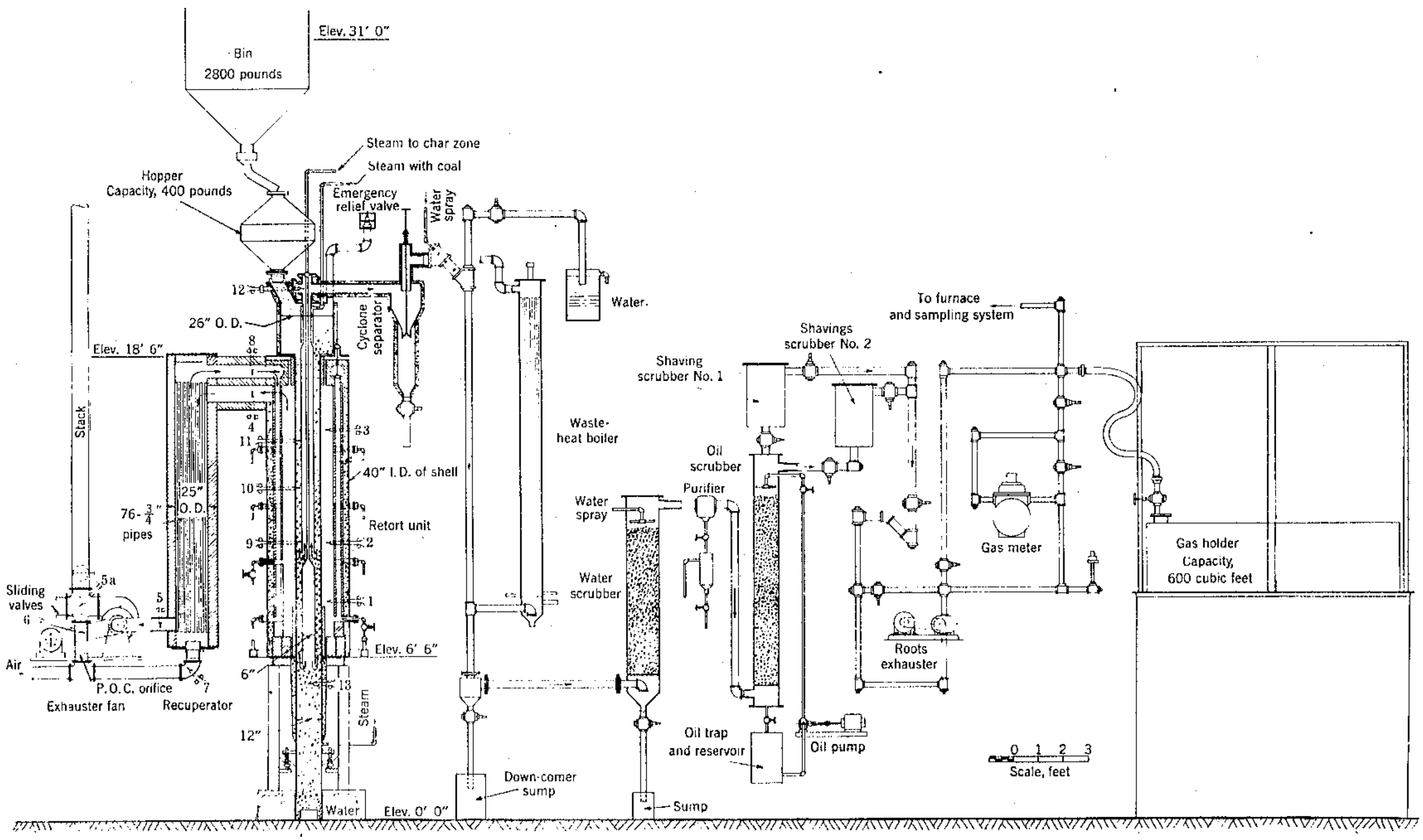

Figure 18. - Pilot plant for complete gasification of coal, Parry retort, Golden, Colo.

built to connect with a recuperator and a fan which recirculates products of combustion. Preheated air mixed with about 3 volumes of products of combustion is passed back into the furnace and joins the heating gas at the burner ports. A low-temperature flame swirls around the metal tube and produces a uniform source of heat for the retort. Lignite or subbituminous coal passes through the retort in an annular space about 3 inches wide, and the products of gasification are drawn from the system through the center of the charge. Products of distillation, consisting of bed moisture, water from decomposition of the coal, tar, and hydrocarbon gases and vapors, are forced to leave the system through the hottest section of the retort. They undergo decomposition and reaction to form various grades of water gas, depending upon the temperature of the system and the concentration of steam. Carbon residues not gasified in the upper annulus pass downward into a lower annulus, where they contact steam and are gasified. The process is continuous; and gasification is carried to a point where the carbon residue, when further gasified to make producer gas, will furnish enough heat to keep the system in balance. Under these conditions, the net yield of water gas from raw subbituminous coal is 48,000 to 52,000 cubic feet per ton, and the net yield from raw lignite is 33,000 to 36,000 cubic feet per ton.

Gases of the following composition, in percent, were made from raw lignite:

	Gas A	Gas B
CO_2	26.8	8.8
Illuminants	.5	.1
CO	8.9	33.8
H_2	58.6	55.4
CH_4	4.2	1.4
C_2H_6	.5	.0
N_2	.5	.5
	100.0	100.0

Water gas of the quality designated as gas A may be useful for the production of industrial hydrogen by scrubbing out the CO_2 and CO, and the gas indicated as gas B might be used for direct beneficiation of iron ore or for the manufacture of synthetic liquid fuels.

Table 16 gives a brief summary of the scope of tests conducted in the small pilot plant during 1945. Depending upon conditions of operation, the quality of water gas from either subbituminous coal or lignite varies considerably. The maximum capacity was reached in test 4B when making 66 cubic feet of water gas per square foot of retort surface per hour. The gas contained 3.57 parts of hydrogen to 1.0 part of carbon monoxide. In other tests, both the rate of gas generated and the rate of charging coal were varied to study the effect of various temperatures. The experimental work on the small pilot plant supports the following general conclusions:

1. Subbituminous coal or lignite can be gasified to any degree up to about 92 percent by reaction with steam at relatively low temperatures. In the present system, gases containing H_2:CO ranging from 1.6:1 to 12.0:1 were made by adjusting the concentration of steam when the retort was heated over the temperature range of 1,750° to 2,050° F.

2. Subbituminous coals, because of their better physical and chemical properties are slightly easier to gasify than the lignites. However, there is little difference between the two fuels if dried to the same moisture content. Steam-dried lignite containing about 10 percent moisture appears to have better gasification properties than raw subbituminous coal.

3. The maximum capacity obtained was 66 cubic feet of gas per square foot of heated retort surface. This capacity was reached when operating the retort at an average furnace temperature of 1,720° F. while producing water gas having a H_2:CO ratio of 3.57 to 1. During this test, the maximum temperature at the hottest section of the furnace was 2,050° F. Under these conditions the rate of transfer of heat through the walls of the retort was approximately 4,500 B.t.u. per hour per square foot. It is indicated that higher rates can be attained by adjustment of the width of the annulus and by better distribution of temperature in the furnace.

4. Although about 92 percent of complete gasification can be attained in a single pass through the retort, it is not advisable to carry out gasification to that extent because of troubles with fine ash and resistance from the fuel bed. In commercial operation, it would be desirable to remove enough carbon or char residue for subsequent gasification in a producer to furnish heat for the externally heated retort. If this were done, it can be shown theoretically that about 10 pounds of ash-free residue, having a potential heating value of about 140,000 B.t.u., should be extracted for each 1,000 cubic feet of water gas produced. Under these conditions the net yield of water gas from a ton of raw subbituminous coal will range between 48,000 and 52,000 cubic feet per ton, whereas the net yield from raw lignite will be 33,000 to 36,000 cubic feet per ton.

5. When gasifying raw lignite with steam, the net heat passing through the walls of the retort to effect gasification is 83 to 85 B.t.u. per cubic foot of gas generated, if the products of gasification leave the retort at 1,000° F. This is the theoretical net heat required for the reaction. The heat required for gasification changes little, even though the H_2:CO ratio may range from 2:1 to 9:1, because the heat carried away in the excess steam increases with this H_2:CO ratio, whereas the heat of reaction decreases. In the Golden, Colo., pilot plant, the heating efficiency was 45 to 50 percent, requiring 164 to 190 B.t.u. to make 1 cubic foot of water gas. In a large plant where heat losses can be minimized, the heating efficiency should be about 65 percent, and the net heat required for gasification of raw lignite should be between 120 to 130 B.t.u. per cubic foot of gas made.

A commercial-size pilot plant about six times as large as the first pilot plant was built and tested during the fiscal year 1945 at Grand Forks, N. Dak.[81] The arrangement and schematic design of this plant is shown in figure 19. The purpose of building this larger plant was to obtain data on operation and costs which could not be ascertained in the smaller unit. The plant design was about the same as the small unit, but improvements were made to increase efficiency and to streamline handling of materials. Two 10-day tests were made and the results are summarized in table 17.

81/ Chemical and Engineering News, A Staff Report, Lignite Gasification Plant Shown at Grand Forks, N. Dak.: Vol. 23, July 25, 1945, pp. 1242-1244.

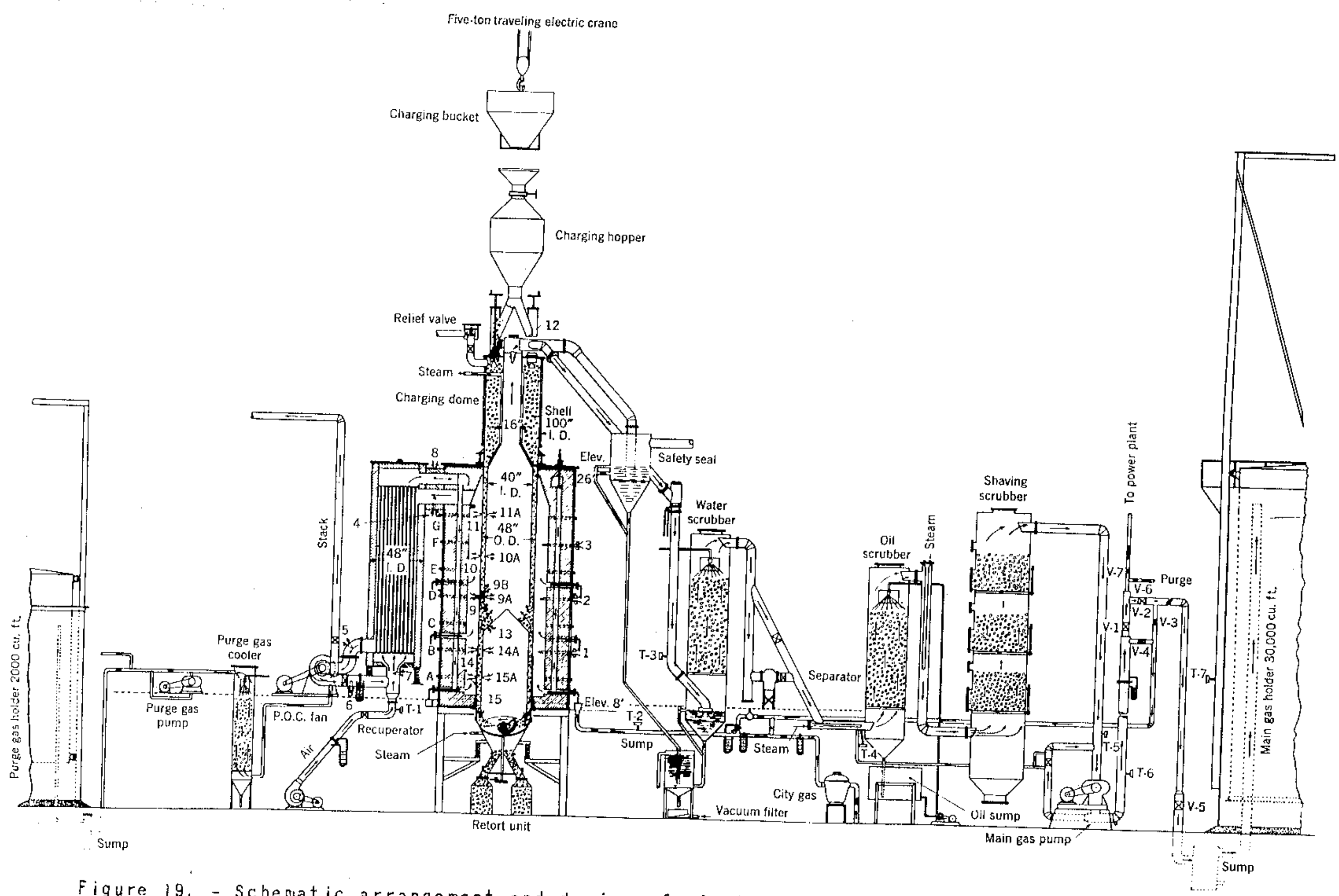

Figure 19. - Schematic arrangement and design of plant as operated during preliminary tests at Grand Forks, N. Dak., March 1945.

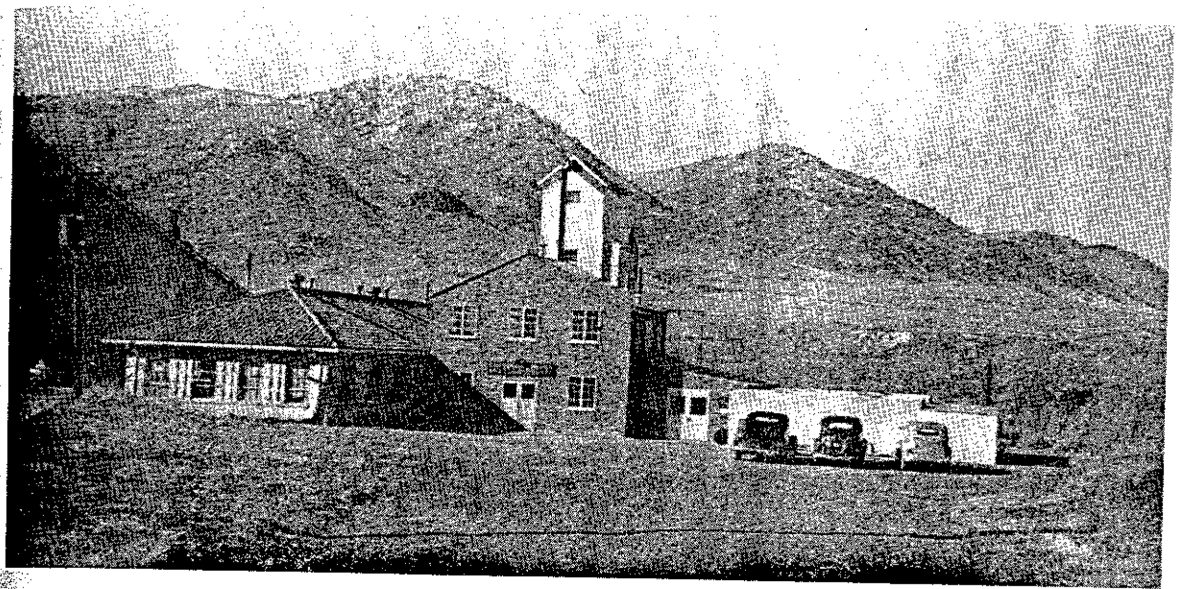

Figure 20. - Golden, Colo., station and gasification pilot plant.

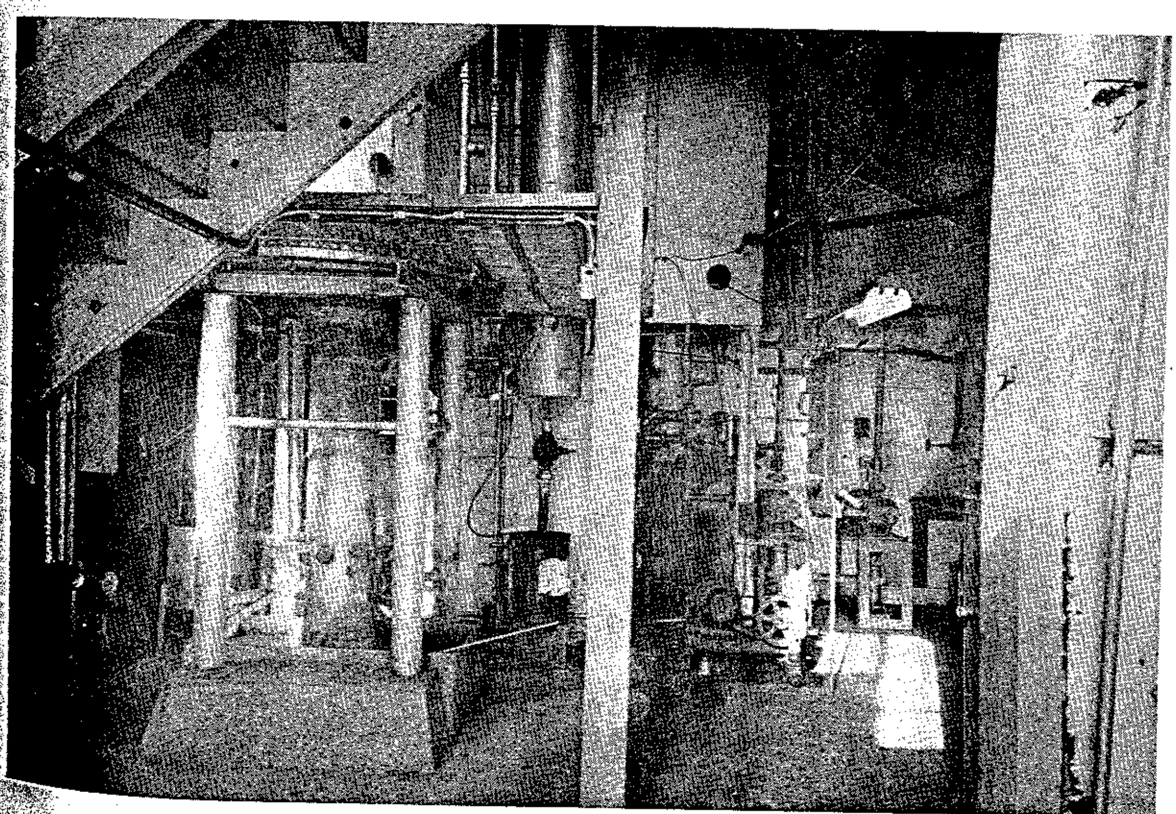

Figure 21. - Pilot plant for gasification of subbituminous coal, Golden, Colo.

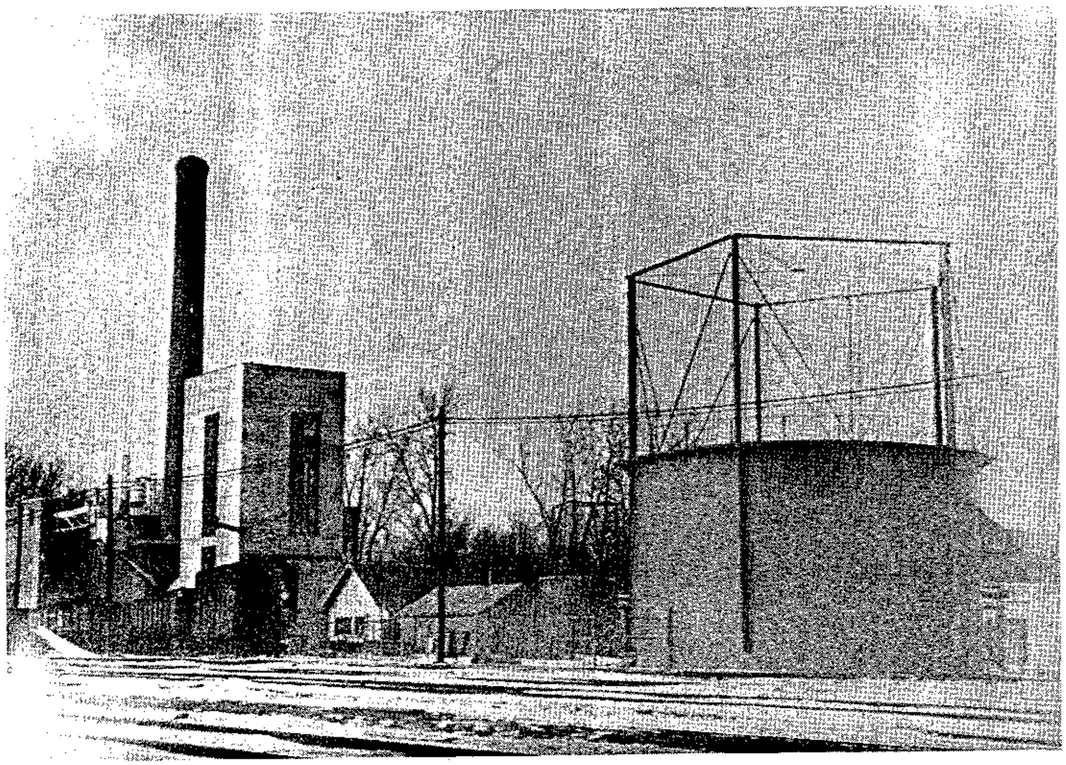

Figure 22. - Commercial-size pilot plant for gasification of lignite, Grand Forks, N. Dak.

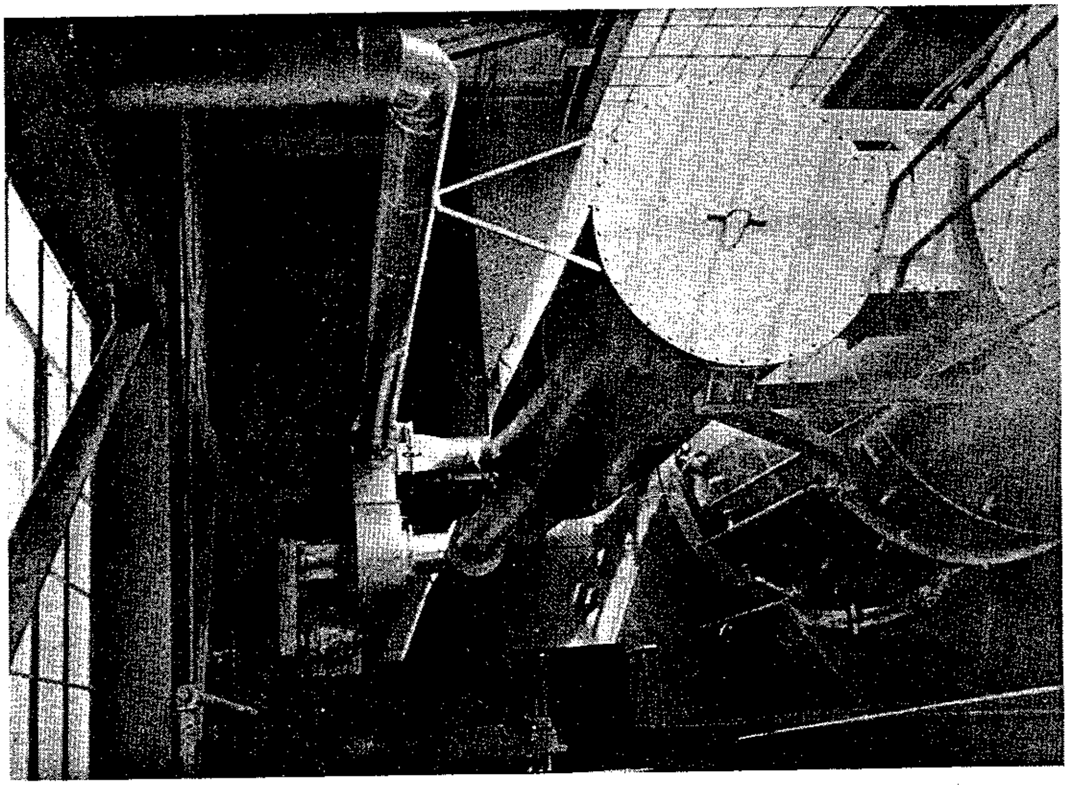

Figure 23. - Generator and recuperator of lignite-gasification pilot plant, Grand Forks, N. Dak.

TABLE 16. - Summary of gasification tests in the small pilot plant, Golden, Colo.

Test No.	Gas made			Coal charged		Temperature of furnace	
	M.c.f. per ton	Rate1/	Ratio H_2:CO	Kind	Rate2/	°F. Maximum3/	°F. Average4/
4A	71.54	59.2	4.75	Subbit.	1.65	1,980	1,655
4B	75.32	66.0	3.57	do.	1.75	2,050	1,720
5A	68.98	48.1	4.01	do.	1.39	1,910	1,590
5B	67.05	46.6	7.18	do.	1.39	1,850	1,540
5C	84.37	50.4	4.73	S. Dak. lig.	1.20	1,880	1,605
5D	78.59	50.3	3.28	do.	1.28	1,895	1,650
6A1	-	36.1	12.4	Subbit.	-	1,830	1,400
6A2	-	38.1	8.72	do.	-	1,855	1,435
6A3	-	39.0	4.42	do.	-	1,885	1,500
6A4	-	42.9	7.58	do.	-	1,855	1,510
6A1-4	51.10	38.7	-	do.	1.52	-	-
6B1	-	40.6	6.84	do.	-	1,840	1,485
6B2	-	40.3	9.74	do.	-	1,860	1,430
6B3	-	38.7	7.75	do.	-	1,840	1,425
6B4	-	41.0	5.48	do.	-	1,860	1,490
6B1-4	57.2	40.3	-	do.	1.41	-	-
7A	58.91	43.7	11.7	do.	1.48	1,845	1,500
7B	25.31	36.8	6.56	Lignite	2.91	1,850	1,460
7C	50.62	45.8	4.10	S. Dak. lig.	1.81	1,860	1,540
7D	56.85	40.8	1.64	do.	1.44	2,000	1,510
7E	66.74	47.9	1.97	do.	1.44	2,000	1,510
8A	75.00	39.2	2.45	Subbit.	1.05	2,000	1,660
8B	55.05	38.7	2.72	Lignite	1.41	2,000	1,690
9A	77.31	32.8	2.41	Subbit.	.84	2,000	1,720
9B	70.95	40.9	3.63	do.	1.05	1,995	1,705
9C	61.57	45.5	3.45	do.	1.48	2,000	1,700
9D	61.78	50.3	3.04	do.	1.63	2,000	1,700

1/ Cu. ft. per hour per sq. ft. of retort area (31.0 sq. ft.).
2/ Pounds per hour per sq. ft. of retort area.
3/ At thermocouple 1.
4/ Average at thermocouples 1, 2, 3, and 4.

Photographs of the small pilot plant at Golden, Colo., and the commercial-size unit at Grand Forks, N. Dak., indicate the scope of this investigation. Figure 20 is an external view of the Golden laboratory and pilot plant, and figure 21 shows the lower section of the pilot plant with auxiliary equipment. Figure 22 is a general view of the Grand Forks plant, showing the retort building, the laboratory, and gas holders. The plant is built adjacent to the power plant at the University of North Dakota. Figure 23 is a top view of the generator in the large plant.

TABLE 17. - Summary of results of tests on a commercial-size pilot plant for gasification of lignite, Grand Forks, N. Dak.

	Preliminary test 1/		Test Number 1 2/		
	Period A	Period B	Period A	Period B	Period C
Raw lignite charged.................. pounds per hour	600	639	598	681	540
Moisture in lignite .... percent	37.5	37.5	37.8	37.8	37.5
Ash in lignite .... do.	6.0	6.0	5.2	5.2	6.0
Residue extracted .... pounds per hour, dry	153	159	152	152	138
Ash in residue .... percent	24	24	16.3	15.4	18.0
Net heating value of residue per cu. ft. of gas made .... B.t.u.	180	158	221	187	192
Gas made .... M.c.f. per ton 3/	30.1	33.6	27.7	28.9	30.3
Gas made .... M.c.f. per hour 3/	9.02	10.68	8.26	9.85	8.17
Gas made .... cu. ft. per hr. per sq. ft. of retort surface	41.7	49.5	38.3	45.6	37.8
Analysis:					
CO_2 .... percent	21.4	20.8	22.4	23.9	23.5
Illuminants .... do.	.4	.3	.4	.2	.4
CO .... do.	16.0	17.8	15.5	12.7	14.2
H_2 .... do.	55.5	55.7	56.6	58.2	57.1
CH_4 .... do.	4.8	4.5	3.7	4.2	3.9
C_2H_6 .... do.	.0	.0	.9	.3	.4
N_2 .... do.	1.9	.9	.5	.5	.5
Heating value .... B.t.u. per cu. ft.	281	282	289	280	280
Net heat used .... B.t.u. per cu. ft. of gas made	144	151	138	130	128
Steam used .... total pounds per pound of lignite	.66	.92	.67	.83	.35
Temperature of steam .... °F.	212	212	435	455	495
Temperature of furnace at hottest part .... do.	1,980	1,995	1,815	1,805	1,800
Average temperature of furnace .... do.	1,826	1,884	1,705	1,670	1,695
Temperature of gases leaving retort .... do.	600	645	615	605	580
Ratio, products recirculated to primary air	2.62	2.6	3.0	2.7	3.3

1/ In this test length of upper annulus was 10 ft. 2 inches and bottom annulus was 6 ft. 1.0 inch.
2/ In this test length of upper annulus was 13 ft. 2 inches and bottom annulus was 5 ft. 0.0 inch.
3/ Gas saturated with water vapor at 60° F. and under 30 inches of mercury pressure.