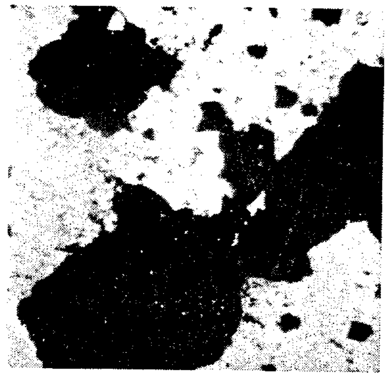
Residues of Gasification

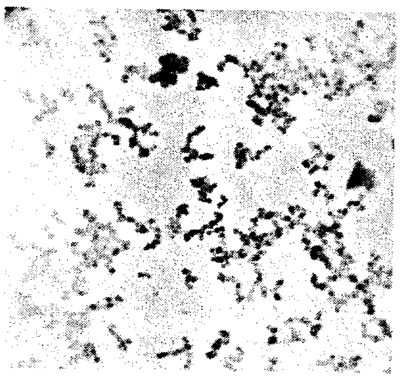
The carbonaceous residues recovered in the gasification of both Wyoming No. 9 and Sewickley seam coals were similar - extremely fine and fluffy. Their complete recovery from the synthesis gas was especially difficult when the coal charged was very finely pulverized (90 percent minus 200 mesh).

The size distribution of the residues, determined by air elutriation, is shown in table 6. The increasing fineness of the residual dust particles collected in the various dust-recovery units in the order of their respective positions in the train, is clearly seen by comparing them on the basis of the percent proportion of minus 7.5-micron size particles. The residue recovered in the filters is the finest, 70 to 80 percent of it being less than 7.5 microns in size.

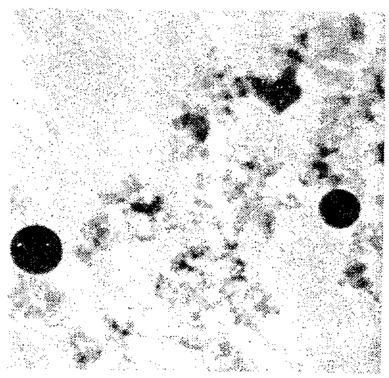
1000 X
Original Coal
91 percent through 200 mesh



1000 X
Carbonaceous residue
from "Dust Collector"



10,500 X
Carbon Black
Explosion of Acetylene
and Natural Gas



11,100 X
Carbonaceous residue
from
"Dust Collector"

Figure 13. - Photomicrographs of carbonaceous residues obtained in pulverized-coal gasification.

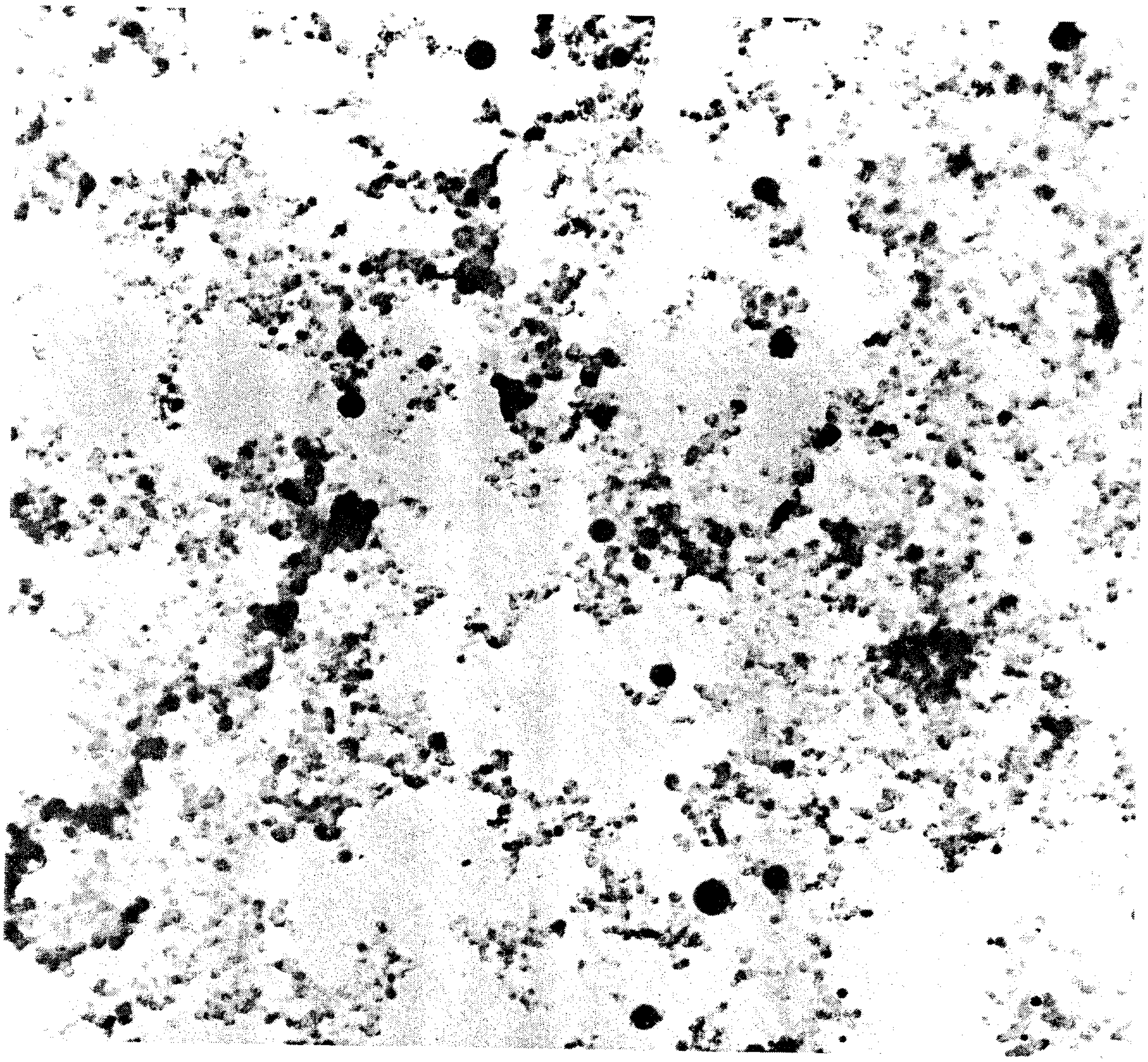
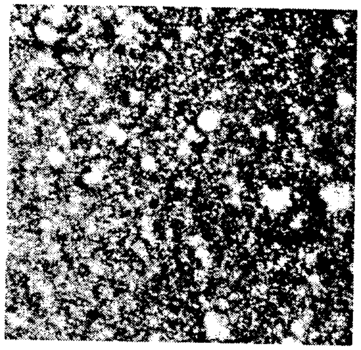
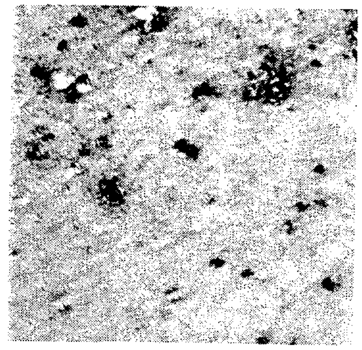


Figure 14. - Electron micrograph of finest carbonaceous residue at high magnification (44,000 X).

PHOTOMICROGRAPHS

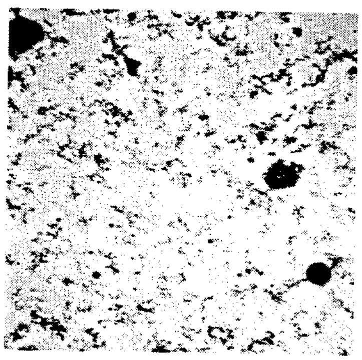


400 X
Residue from 2" aerotec
Run 49
Ultropak-reflected light

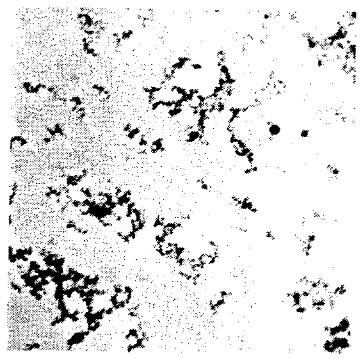


400 X
Residue from 2" aerotec
Run 49
Transmitted polarized light

ELECTRON PHOTOMICROGRAPHS



5,400 X
Residue from 2" aerotec



11,000 X
Residue from 2" aerotec

MICROSCOPIC VIEWS OF CARBONACEOUS RESIDUE
OBTAINED IN PULVERIZED COAL GASIFICATION

Figure 15. - Electron micrographs of carbonaceous residue from pulverized-coal gasification.

TABLE 6. - Size consist of residues

Analysis of residues by elutriation, run 33A

Size range, microns	Total residue (carbonaceous residue and ash), percent, from: Dust collector	Knockout chamber	Aerotec No. 1 - 3"	Aerotec No. 2 - 2"	Filter No. 1	Filter No. 2
+ 60	24	8	2	2	2	2
- 60 + 40	14	14	2	2	0	0
- 40 + 30	10	16	4	2	0	0
- 30 + 20	12	14	12	6	2	0
- 20 + 15	8	8	6	8	4	2
- 15 + 10	12	14	18	12	8	4
- 10 + 7.5	8	8	12	16	16	10
- 7.5	12	18	44	52	68	82
Total	100	100	100	100	100	100

The bulk densities of the residues recovered in the dust collector and knock-out chamber (a + b), in the Aerotec tubes (c), and the filter vessels (e) were 11-12, 1.5-2.0, and 2.0-2.5 pounds per cubic foot, respectively. This is considerably less than the bulk density of coal in fluidized bed, which usually ranges from 25 to 30 pounds per cubic foot. The bulk density in storage of Wyoming No. 9 coal, ground so that 91.1 percent passes the 200-mesh screen, was found to be 32 pounds per cubic foot. In spite of their low bulk densities, the true specific gravity of a residue sample from a 3-inch Aerotec tube (in run 33A) was found to be 1.34, falling in the range of magnitude of the specific gravities of coals.

Photomicrographs of the pulverized coal charged and residue obtained in the "dust-collector unit", in comparison with carbon black made from acetylene and natural gas by the explosion process, are shown in figure 13. There appears to be a distinct resemblance of the finest particles of the residue to carbon black, in that they occur in chains and appear quite spherical in many cases. The few larger isolated black spheres are probably cenospheres of fly ash.19/ This is seen more clearly in figure 14, which shows an electron micrograph of the finest residue, recovered in the filter unit at the end of the train, at a higher magnification (44,000 X).

The distribution of the ash in the residue from an Aerotec tube (run 49) is shown considerably clearer in figure 15. The upper left electron micrograph (400 X) was made in Ultropack reflected light and shows the larger particles of residue light on a dark background, whereas the black spots in the field are larger particles of ash. The upper right electron micrograph (400 X), made of the same field in transmitted polarized light, shows the larger particles of ash bright, whereas the larger residue particles appear

19/ The microscopic investigations of the residues were carried out by cooperation of W. A. Selvig and J. T. McCartney at the Coal Constitution Section of the Central Experiment Station of the U. S. Bureau of Mines.

as black spots on the field. The lower pair of electron micrographs of the same sample (5,400 X and 11,000 X) allows a view of the predominating very fine particles, which cannot be seen on the upper photomicrographs.

Owing to the close resemblance of the finer portion of the carbonaceous residue to carbon black, examination of several samples from the viewpoint of possible industrial utilization is in progress. One carbon black and carbide manufacturer reported that the residue examined "bears some resemblance to acetylene black as far as size and structure are concerned. It has, however, a lower electrical conductivity and a lower oil-absorption value." An important tire and rubber company is examining samples submitted for possible use as a filler in compounding rubber.

Whether or not the carbonaceous residue of gasification has any value as industrial raw material, it can be recycled back into the generator without any difficulty, either alone or in admixture with fresh powdered coal, for the production of synthesis gas. One run was made (run 52) with the residue collected in a previous run (run 49), unmixed with fresh coal but sieved through a 40-mesh screen before charging it into the generator. The ash content of the recycle feed increased from 29.1 to 43.6 percent, as compared to 12.1 percent ash in the original coal, which corresponds to a gasification efficiency (residue gasified on dry, ash-free basis) of 62 percent.

The residue from the recycle feed was just as light and fluffy as the recycle feed itself. For feeding a fuel of so low bulk density it was necessary to increase the ratio of carrier air to fuel about fourfold when transmitted pneumatically from the "continuous feeder" to the generator. Thus, only about 40 pounds of recycle feed was carried per pound of air, as compared to 150 to 200 pounds of powdered coal conveyed per pound of air in runs when fresh coal is gasified.

Material and Heat Balances

Material balances for the three typical runs are shown in table 7. The unaccounted-for losses are due principally to sulfur compounds removed from the gas and to small quantities of slag adhering to the generator wall.

Heat balances constructed on the basis of the material balances are shown in tables 8 and 9. The losses due to radiation and unaccounted-for losses, ranging from 6.8 to 12.9 percent, had to be balanced by the combustion heat of excess carbon, otherwise the generator temperature would have dropped below that favorable for efficient gas production.

Thermal efficiencies are shown in table 8 on two different bases: (1) with no credit given for the residue recovered and (2) crediting the process with the full heat of combustion of the residue. If the residue is used for generating steam, perhaps credit should be taken for only part of the heat of combustion of the residue. Other possible outlets include blending in coke-oven mixes or briquetting.

TABLE 7. - Typical material balances

(Basis: 1,000 cu. ft. of gas made)

	Run 33A	Run 46	Run 49
Input, pounds:			
Coal charged (dry basis)	51.86	49.43	48.22
Oxygen introduced	35.59	27.06	31.55
Steam from moisture in coal	2.45	1.01	0.98
Total	89.90	77.50	80.75
Output, pounds:			
Gas produced	62.20	52.80	57.08
Carbonaceous residue and ash (dry) from:			
(a) Dust collector and knockout chamber.	14.20	12.24	9.44
(b) Aerotec tubes	3.05	3.86	5.36
(c) Filter vessels	1.94	7.71	3.31
Moisture in residue	.61	.17	.26
Water vapor carried by make-gas	.86	.86	.63
Undecomposed steam	6.67	4.05	4.13
Unaccounted for losses 1/	.37	- 4.19	.54
Total	89.90	77.50	80.75
Unaccounted for losses expressed as percent of total input	- 0.41	2/+ 5.41	- 0.67

1/ Includes small quantities of slag adhering to generator wall and sulfur compounds removed from the gas.

2/ Material gain might be due to detached pieces of slag that had accumulated in previous runs. Another reason for the poor material balance might be the oxidation of iron in the coal ash to Fe_2O_3. (An analysis made of the ash from raw Sewickley coal disclosed 22.0 percent Fe_2O_3.)

TABLE 8. - Typical heat balances

(Basis: 1,000 cu. ft. of gas made. Reference temperature: 60° F.)

	Run 33A	Run 46	Run 49
Heat input, B.t.u.:			
Potential heat in coal	659,870	629,690	614,270
Sensible heat in coal	310	280	270
Sensible heat in oxygen	120	80	100
Total	660,300	630,080	614,540
Heat output, B.t.u.:			
Potential heat in gas made	293,800	294,000	316,100
Potential heat in residue	224,680	240,610	172,310
Sensible heat in gas made 1/	39,030	35,440	38,190
Sensible heat in residue 1/	11,430	13,400	9,960
Sensible heat in undecomposed steam 2/	6,370	3,670	4,240
Radiation and unaccounted for losses	84,990	42,960	73,740
Total	660,300	630,080	614,540

TABLE 8. - Typical heat balances (Cont'd.)

	Run 33A	Run 46	Run 49
Thermal efficiencies:			
No credits (heat of combustion of gas per each 100 B.t.u. in coal input)3/	44.6	46.7	51.5
Credit for heat of combustion of residue (heat of combustion of gas plus residue per each 100 B.t.u. in coal input)2/	78.7	87.0	80.0

1/ At the point of exit from generator.
2/ Enthalpy at exit temperature above the enthalpy of water vapor at 60° F.
3/ Net heating values taken for coal, gas, and residue.

TABLE 9. - Typical heat balances

(Percentage basis)

	Run 33A	Run 46	Run 49
Heat input, percent:			
Potential heat in coal1/	99.9	99.9	99.9
Sensible heat in oxygen	.04	.04	.04
Sensible heat in coal	.06	.06	.06
Total	100.00	100.00	100.00
Heat output, percent:			
Potential heat in gas made1/	44.5	46.7	51.4
Potential heat in residue1/	34.0	38.2	28.1
Sensible heat in gas made2/	5.9	5.6	6.2
Sensible heat in residue2/	1.7	2.1	1.6
Sensible heat in undecomposed steam3/	1.0	.6	.7
Radiation and unaccounted for losses	12.9	6.8	12.0
Total	100.0	100.0	100.0

1/ Net heating values taken for coal, gas, and residue.
2/ At the point of exit from generator.
3/ Enthalpy at exit temperature above the enthalpy of water vapor at 60° F.

TABLE 10. - Typical water balances

(Basis: 1,000 cu. ft. of gas made.)

	Run 33A	Run 46	Run 49
Input, pounds:			
Moisture in coal charged	2.287	0.989	0.984
Steam formed from H_2 in coal	22.451	22.244	22.138
Steam added	nil	nil	nil
Total	24.738	23.233	23.122

TABLE 10. - Typical water balances (Cont'd.)

	Run 33A	Run 46	Run 49
Output, pounds:			
Moisture in residue	0.926	0.587	0.422
Steam condensed from make gas	5.398	4.071	3.532
Water vapor carried by make gas	1.450	0.844	2.124
Steam decomposed	16.964	17.731	17.044
Total	24.738	23.233	23.122
Percent of total H_2O input decomposed	68.6	76.3	73.7

The typical water balances shown in table 10 indicate H_2O decompositions ranging from 68 to 74 percent. These values have been computed on the arbitrary basis of assuming that all of the hydrogen in the coal burns to H_2O and part of the steam thus formed decomposes. In most of the runs covered by this report, no steam has been added beyond that formed from the natural moisture content of the coal.