COALS CHARGED

Two different types of coals have thus far been tested - a noncoking, high-volatile, bituminous coal from Rock Springs, Wyo. No. 9 bed, and a strongly coking, high-volatile, bituminous coal from Bunker mine, Cassville, W. Va., Sewickley bed. The former is a low-ash, low-sulfur coal of high oxygen content, i.e., lower-rank (younger) bituminous coal, and the latter is a high-ash, high-sulfur coal of low oxygen content, i.e., a low-grade bituminous coal of geologically higher rank (older). Table 2 shows the proximate and ultimate analyses, heating values, ash-softening temperatures, and screen analyses of the two coals used on "as-charged" and "moisture-free" bases.

During the described first stage of process development, Wyoming No. 9 coal was gasified exclusively (runs 1-12); the use of this coal was continued throughout the greater part of the second stage (runs 13-37). Gasification of the Sewickley-bed coal was then begun and continued during the remainder of the second stage (runs 38-41) and throughout the entire third stage (runs 42-50) of process development.

TABLE 2. - Analysis of coals charged

Analysis	Run 33A, Wyoming No. 9 Bed		Runs 46 and 49, Sewickley Bed	
	As charged (moist), percent	Moisture-free, percent	As charged (moist), percent	Moisture-free, percent
Proximate:				
Moisture	4.5	-	2.0	-
Volatile matter	37.0	38.7	34.0	34.7
Fixed carbon ..	53.6	56.2	51.9	53.0
Ash	4.9	5.1	12.1	12.3
Total	100.0	100.0	100.0	100.0
Ultimate:				
Moisture	4.5	-	2.0	-
Hydrogen	4.8	5.0	4.8	4.9
Carbon	71.6	74.9	71.6	73.0
Nitrogen	1.5	1.6	1.5	1.6
Oxygen	11.9	12.5	5.2	5.3
Sulfur	.8	.9	2.8	2.9
Ash	4.9	5.1	12.1	12.3
Total	100.0	100.0	100.0	100.0
B.t.u.	12,620	13,210	12,940	13,200
Ash-softening temperature:	2,280°		2,210° F.	

Screen analysis	Wyoming No. 9 Bed, Run 33A	Sewickley Bed, Run 46	Sewickley Bed, Run 49
Mesh sizes:			
+ 50 ..	0.1	1.2	0.1
- 50 + 150 ..	2.4	14.2	5.2
- 150 + 200 ..	6.4	13.3	5.6
- 200	91.1	71.3	89.1
Total	100.0	100.0	100.0

RESULTS

Operating Data and Results

More than 50 runs have been made, each lasting from 1 to 12 hours. Long runs have been divided into several periods, marked by A, B, C, etc., after the run number, signifying changes made in the operating conditions during the run. However, very few of the runs are truly comparable in the sense of differing with respect to not more than a single variable. The reasons for this are: (1) Partial or complete lack of control during the progress of development over some of the variables, such as feed rate of the pulverized coal, which was extremely difficult to keep constant until the pneumatic feeding system was installed. (2) Gradual increases made in the coal throughput from 5 to 50 pounds per hour resulted in errors in measurements, as various instruments reached the limits of their capacities. (3) The task of developing the process and the solution of numerous difficulties, such as the removal of the entrained, extremely fine, carbonaceous residue from the make gas, necessitated frequent changes in the experimental set-up. Consequently, most of the runs were carried out under different experimental conditions, such as temperature and pressure in the generator, oxygen-to-coal ratio, air leaked into the system, etc.; therefore, they cannot readily be compared with each other nor grouped together and averaged.

Nevertheless, the first 50 runs furnished much information that guided the process development to the point that, in its present stage, all phases of the operation are completely controlled and the results obtained are reproducible. Furthermore, it is possible to select a few runs that may be designated as typical of the coal gasified and are more or less comparable with each other. Such typical operating data and results are shown in tables 3, 4, and 5.

In these tables, one run (33A) is shown for Wyoming No. 9 coal and two runs (46 and 49) are listed under the Sewickley coal. Runs 33A and 49 were made with very finely pulverized coal, about 90 percent minus 200 mesh. In run 46, on the other hand, a more coarsely pulverized coal,18/ about 70 percent minus 200 mesh, was gasified. Thus, runs 33A and 49 are comparable from the viewpoint of operating results shown for two different coals of the same degree of fineness. Similarly, runs 46 and 49 are comparable for operating results shown for the same coal pulverized to two different degrees of fineness.

Operating results of various individual runs, carried out during the course of the development of the process, are listed in the appendix. The occasional lack of data and frequent doubtfulness of values are due to faulty measurements or lack of control over some of the operating variables. From time to time, progressive alterations and improvements were made, both in the generator and purification train, as suggested by the experimental results obtained. Many baffling operating difficulties have thus been eliminated, one by one, the effects of the alterations being tested by the subsequent runs made. Among the most important improvements, which after some 50 runs resulted in a controllable, smoothly operated unit, are (1) the substitution of a 6-inch I. D. silicon carbide lining in the generator for the former 3-inch I. D. tube, (2) improved cooling of the inlet tube down to the point of entry of coal and oxygen into the generator head, which made possible charging strongly coking coals into the generator, and (3) replacement of former methods of feeding the coal by an especially developed pneumatic feeding system from a fluidized coal bed.

18/ This degree of pulverization is generally used in commercial boilers fired by powdered coal.

TABLE 3. - Typical operating data and results

Item	Operating data and results	Run 33A, April 1948	Run 46, Jan. 1949	Run 49, Feb. 1949
1	Type of coal gasified, name of bed	Wyoming No. 9	Sewickley	
2	Size of coal, percent through 200 mesh	91.1	71.3	89.1
3	Duration of run, hours	1.10	2.95	3.20
4	Rate of coal feed, lb./hr.1/	15.9	44.6	37.5
5	Oxygen input, cu. ft./hr.2/	123.1	282.6	284.0
6	Steam input, lb./hr.3/	.72	.89	.75
7	Oxygen-to-coal ratio, lb./lb. dry, ash-free coal	.725	.624	.746
8	Steam-to-coal ratio, lb./lb. dry, ash-free coal3/	.050	.023	.023
9	Air (carrier) to coal ratio, cu. ft./lb. coal1/	5/	.075	6/
10	Amount of coal transported, lb./lb. air1/	5/	174.0	6/
11	Output of synthesis gas, cu. ft./hr.	292.9	884.2	762.0
12	Oxygen input, cu. ft./MCF gas	420.3	319.6	372.7
13	Oxygen input, cu. ft./MCF CO + H_2	548.9	353.5	424.5
14	Steam input, cu. ft./MCF gas3/	51.3	21.2	20.7
15	Coal charged, lb./MCF gas1/	54.3	50.4	49.2
16	Coal actually gasified, lb./MCF gas4/	32.6	25.6	29.5
17	Residue output, lb./hr.1/	5.8	21.2	14.0
18	Gas yield, cu. ft./ton of dry coal charged	38,590	40,460	41,470
19	Yield of CO + H_2, cu. ft./ton of dry coal charged	29,560	36,580	36,410
20	Fuel throughput rate, lb. coal per cu. ft. generator volume per hour	11.6	32.5	27.3
21	Gas output rate, cu. ft. CO + H_2 per cu. ft. generator volume per hour	163.5	582.6	487.6
22	Percent completion of gasification:			
	Weight basis 7/ (pounds coal gasified per each 100 pounds raw coal input)	64.8	52.8	63.2
	Dry, ash-free weight basis 4/ (pounds coal gasified per each 100 pounds dry, ash-free coal input)	66.3	59.2	69.8
	Carbon basis (pounds C gasified per each 100 pounds C in coal)8/..	60.1	54.9	65.1
	Fixed carbon basis (pounds F. C. gasified per each 100 pounds F. C. in coal)	47.5	36.7	54.1
	Energy or heat of combustion basis 9/ (B.t.u. in gas per each 100 B.t.u. in coal input)	44.6	46.7	51.5

TABLE 3. - Typical operating data and results (Cont'd.)

Item	Operating data and results	Run 33A, April 1948	Run 46, Jan. 1949	Run 49, Feb. 1949
23	Thermal efficiencies:			
	No credits (heat of combustion of gas per each 100 B.t.u. in coal input)9/........	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)9/	78.7	87.0	80.0

1/ On moist (i.e., on as-charged or as-recovered) basis.
2/ All gas data refer to 60 °F., 30 in. Hg, dry.
3/ Consists of steam originating from moisture in coal. No steam was injected in any of the runs shown.
4/ Dry, ash-free residue deducted from dry, ash-free coal charged.
5/ Syntron feeder employed. No air used as carrying medium.
6/ Not determined.
7/ 100 (lb. raw coal minus lb. dry residue)/lb. raw coal.
8/ Average of values calculated from the carbon content of the residue and of the gas output.
9/ Based on net (lower) heating values for coal, gas, and residue.

TABLE 4. - Typical operating data and results

	Run 33A Apr. 1948	Run 46 Jan. 1949	Run 49 Feb. 1949
24. Temperatures of generator wall (av. during run), °F.			
At 10 inches from top	2,457	2,419	2,365
At 29 inches from top	2,312	1,979	1,919
At 43 inches from top	1/	1,927	1,876
At 61 inches from top	1,831	1,641	1,610
At 73 inches from top	1,774	1,563	1/
25. Gas temperature at outlet, °F.	1/	1,820	1,800
26. Gas analyses, percent:			
CO_2	17.0	7.1	7.3
O_2	.5	-	.3
Unsat. HC	.9	0.9	2.2
H_2	25.5	35.0	28.6
CO	51.1	55.4	59.2
CH_4..............................	5.0	.6	1.4
N_2	-	1.0	1.0
Total	100.0	100.0	100.0
B.t.u. (60, 30, dry, gross)2/	312.6	313.2	334.1
Specific gravity (air = 1)2/	.81	.69	.75
27. Analysis of carbonaceous residue collected:3/			
Proximate analysis, percent:			
Moisture	3.1	0.7	1.4
Ash	13.2	25.5	29.1
V.M.	6.5	4.7	5.7
F.C.	77.2	69.1	63.8
	100.0	100.0	100.0
B.t.u.4/	1/	10,420	9,580
Ultimate analysis, percent:			
Moisture	-	0.7	1.4
Ash	-	25.5	29.1
C	-	71.2	67.2
H_2	-	.2	.1
S	-	2.4	2.2
$O_2 + N_2$	-	-	-
Total	-	100.0	100.0

1/ Not determined.
2/ Calculated from gas analysis.
3/ On weighted average sample from all dust-removing units.
4/ Per pound dry sample, gross.

TABLE 5. - Typical operating data and results

	Run 33A	Run 46	Run 49
28. Carbonaceous residue collected in various units, percent:			
Gas-purifying units:			
(a) Dust collector	39.8	24.0	16.3
(b) Knock-out chamber	34.2	27.4	35.8
(c) Aerotec tubes	15.9	16.2	29.6
(d) Dust extractor	1/	14.6	9.6
(e) Glass-cloth filters	10.1	17.8	8.7
	100.0	100.0	100.0
Total dry residue collected, lb./hr.	5.6	21.1	13.8
Combustible residue, lb./hr.2/	4.9	15.6	9.7
Dry residue output, lb./MCF gas	19.1	23.9	18.1
Combustible residue output, lb./MCF gas2/	16.7	17.6	12.7
29. Size consist (mesh/inch) of carbonaceous residues, percent:3/			
+ 50	14.4	2.9	3.5
- 50 + 150	33.5	24.1	14.8
- 150 + 200	12.2	16.8	15.7
- 200	39.9	56.2	66.0
	100.0	100.0	100.0

1/ Purification train contained no dust extractor (perforated-plate type) in run 33A.
2/ On dry, ash-free basis.
3/ On weighted average sample from all dust-removing units.

A series of runs was carried out to determine, among the effects of variables, the desirable oxygen:coal ratio, which has been tested and used subsequently both in this unit and in pilot-plant gasification. Similarly, it had taken a number of runs to approach the maximum coal feed rate, which proved to be especially important in small-scale gasification for the elimination of excessive heat losses. Precisely due to these reasons, some of the operating results shown, such as the oxygen requirement in cubic feet per MCF of synthesis gas made, appear to be so unfavorable for the process. Subsequent runs made after the stage of precision has been reached, the results of which will be shown in another Report of Investigations now in preparation, proved that considerably better operating results can be obtained with a proper combination of expediently selected variables.

The most important operating variables on which the quality (%CO_2 and %CO + H_2) and yield of synthesis gas, percent of the coal gasified (gasification efficiency), percent of steam input decomposed, and thermal efficiency depend, appear to be:

(a) Temperature of preheated generator at the start of each run.

(b) Type of coal gasified.

(c) Degree of pulverization of the coal charged.

(d) Feed rate of the coal charged.

(e) Oxygen-to-coal ratio.

(f) Steam-to-coal ratio.

(g) Pressure maintained in the generator chamber.

Some information as to the effects of several of these variables on the operating results may be obtained from tables 3, 4, and 5. Several diagrams were plotted in an attempt to correlate the operating results and experimental variables, but, owing to the aforementioned reasons, the trends of the curves obtained were not conclusive. Nor did it appear justified to extrapolate to distant points with assumed zero and 100 percent gasification and thermal efficiencies.

Runs are being carried out in the developed unit with the object of determining the effects of the variables listed above by maintaining all experimental conditions constant except the variables whose effect is being determined. The effect of pressures ranging from atmospheric to about 500 p.s.i. also will be studied in an apparatus now under construction.