The ash content of the very fine residues is such that the waste waters probably can be clarified by settling. Preliminary small-scale test work has shown that continuous centrifuges will effect virtually 100-percent clarification of the scrubber waste waters.

As the work proceeds, more information will be obtained on the amounts of carbon dioxide and sulfur removed by the scrubbing waters. At present exit-water temperatures, the amounts of these materials removed are small.

DISCUSSION OF OPERATING EXPERIENCE WITH INDIVIDUAL EQUIPMENT ITEMS AND IMPLICATIONS AS TO FUTURE DEVELOPMENT

Coal-Feeding Equipment

The operation of the coal feeder has been generally very good, and the control and safety devices have functioned well. Several problems have developed that will require further investigation before large-scale units can be designed. It is probable that tail gas from the synthesis processes will be used for fluidization, instead of inert gas,[12] in large units. Furthermore, the increase in feedline sizes in larger scale operation will make feed control much easier and more accurate.

However, it will be necessary to obtain more exact data at higher pressures on the effect of the static pressure level in the feeder on coal-feed rate, optimum extraction funnel design, vessel shape as it affects optimum fluidizing rates, dedusting of fluidizing gas, and recycle compressor design and materials of construction.

It will also be advisable to determine the effect on the reaction- and product-gas composition of changes in the CO_2 content of the fluidizing gas. Certain work at low pressures has indicated that fine coal adsorbs large quantities of CO_2. This adsorption also appears to affect the flow characteristics of the fluidized coal.

Recycle Compressors

The original recycle compressor was built by the Sawyer-Bailey Co. on the basis of designs worked out by them and our engineering section. This unit is a high-speed centrifugal compressor with variable-speed drive through an electric motor. The special feature of its design is its ability to handle a wide range of flows at varying static pressures. The problem of effectively sealing the rotating shafts against gas leakage has been satisfactorily handled by an adaptation of the "Dura" seal. The unit has operated satisfactorily to date and shows but little wear from the small amount of very fine dust carried over in the recycle gas.

A second recycle compressor has been installed as a spare unit. This is a standard "Sutorbilt", positive, displacement-type blower built into a shell capable of withstanding 600 p.s.i.g.

Coal Preheater

As previously mentioned, the coal preheater is a simple pipe coil heated by steam. No trouble has been experienced in heating the coal- inert-gas mixture.

Flow Control

The method of coal-flow measurement - that is, use of differential pressure measurement across a calibrated coil section in the feed line - was found to be

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[12] See footnote 4.

inherently sound. However, in a few of the tests, the indicated coal rate was incorrect owing to the inadequacy of certain auxiliary equipment (inert-gas supply and compressors), which made exact pressure control impossible. These items are being corrected. In each case, all the coal used was weighed so that the indicated coal-feed rates could be verified.

Steam-Oxygen Superheaters

Original Steam Heater

The first steam superheater was constructed using both stainless-steel and carbon-steel tubing welded into a continuous coil. Preliminary testing of the condensed steam from the University heating plant had indicated that this would be suitable feed for the unit.

In the early tests, the pressure drop through the unit was excessive; to improve this situation, sections of the lower carbon-steel coil were removed. Later leaks developed in the upper carbon-steel coil - the superheating section - and the unit was rebuilt.

The leakage appeared to be due to corrosion attack from the inside at points where the coil had been tack-welded together. Some deposition of solids from the feed water occurred, although the concentration of solids in this water was under 20 p.p.m. Analysis of this material showed a high zinc content. It appears that the steam from the heating plant was acting on the galvanized line used to bring it to the condenser. This trouble was eliminated but not before the superheater coil had been damaged.

Present Steam-Oxygen Superheater

This unit (fig. 13) has functioned well. Tests of the feed water show low concentration of solids and dissolved oxygen of about 1.5 p.p.m. It is indicated that even the steam condensate will need further treatment to secure satisfactory life of coils at the operating temperatures, 600° to 1,000° F.

Oxygen-Steam Flow Regulation

When the oxygen or combined oxygen-steam flow rates are changed to suit the conditions in the gasifier, there is a short period of erratic flow while the unit is "balancing" out. However, use of a downstream, pilot-operated, pressure regulator, combined with a hand-operated needle valve in the oxygen-inlet line, has kept the flow steady enough for test purposes. As more operating and design experience is obtained, this difficulty may be eliminated.

The equipment now available does not allow preheating of the gasifier under operating pressure conditions. Consequently, the steam superheater must be raised to operating temperatures while exhausting steam to the atmosphere. This has made it necessary to use control valves on the hot oxygen-steam line from superheater to gasifier. Valves entirely suitable for this purpose have been difficult to find. One valve that has operated satisfactorily for over 50 hours on 600° F. steam-oxygen mixture and has been used previously for over 200 hours on 600° to 1,000° F. steam shows no evidence of wear. This is an outside screw globe valve; body material, type 304 alloy steel, drop forged; disk and seat, type 304 modified alloy steel with Stellited surfaces. The outside screw type reduces chances for binding in threads owing to temperature. No lubricant can be used in these valves.

In the original piping and control valve layout for controlling the cold oxygen entering the heater, one control valve burned out. This was a carbon-steel body, stainless-steel trim valve, diaphragm operated, in which a silicone grease had been specified for stem lubrication. The exact cause of ignition is not known, but the evidence points to the following: When the valve was opened after having been freshly lubricated, a spark was struck by a small metal particle carried in the oxygen stream. (All lines had been washed out.) This ignited the grease, and the high temperature generated caused the carbon steel to burn through and the valve broke or exploded. Subsequent auxiliary tests showed that silicone grease could be ignited in oxygen.

Since this accident, only brass valves have been used for this service with no lubrication.

Gasifier

Refractory Linings

The early runs on the gasifier showed conclusively that direct impingement of coal-oxygen stream on the refractory lining, such as resulted from tangential injection, could not be tolerated. When the gasifier was relined (fig. 7), it was thought that heat losses could be kept fairly low by using brick of low thermal conductivity and retaining the lining. The results of the test runs on this lining (tests P-10 to P-14), however, showed that it would be necessary to arrive at a working balance between the necessary heat release for adequate carbon gasification - 85 to 90 percent - and heat lost to the wall coil to keep the refractory face at a temperature slightly under 3,000° F. The present lining of Carbofrax (silicon carbide brick) has been used for nine test runs. Data on the latest ones at 300 p.s.i.g. are not included in this report owing to time limitations.

Throughput rates have been varied from 588 to 869 pounds of coal per hour at 85 percent or higher carbon gasification, and the interior volume of the gasifier has been maintained at 1.45 cu. ft. plus or minus 5 percent. Owing to the present construction of the gasifier wall-cooling coil, a completely accurate estimate of the heat losses through the refractory-lined section could not be obtained for these tests but will be secured later. However, estimates based on refractory thermocouple temperature readings indicate losses of 400,000 to 550,000 B.t.u. per hour or 600 to 900 B.t.u. per pound of coal fed. These heat losses should decrease markedly in larger units of greater diameter, with resultant improvement in the requirements of materials per unit of synthesis gas produced.

Cooling Coils

The cooling coils are made of 1-1/2 carbon steel tubing with a 0.165-inch wall thickness. Visual examination of the exposed sections of the coils (fig. 5) indicated no particular corrosion. The coils were coated with Apexior No. 1 protective coating when the unit was installed. After each test the coils were found heavily coated with moist dust. (This dust coating is slightly basic - pH 7.2 to 7.5.) The Apexior coating requires periodic renewal. The coil placed behind the refractory has not been examined for some time.

It is expected that the coil and the gasifier shell wall in this area may be subjected to acid attack, owing to condensation of sulfur- and CO_2-bearing gases. Present plans call for remodeling the wall and support coil (fig. 6) so that the section behind the refractory will be separate from the lower part. This will enable us to obtain accurate heat-loss data for the unit. When this is done, the coil and shell can be completely checked for corrosion results.

When test conditions are more stabilized than they are at present, prestressed metal samples will be placed in the gasifier and scrubber to check on corrosion. Periodically the shell thickness of these units is checked with an Audigage, which uses a high-frequency sound wave to determine metal thickness from one side. No evidence of general attack has yet been found. The thermocouple connections on the gasifier, which are subjected to the action of condensed moisture during startup of the unit, have not shown any corrosion.

Preheating Method

The gasifier is preheated by using a natural-gas - oxygen mixture at near atmospheric pressure. As a result, as noted in the section on operating procedure, the refractory surface cools rapidly when the gasifier is being pressurized. As shown in the flowsheet (fig. 2), present plans call for installing a natural-gas compressor so that gas under operating pressure may be passed through the coal tube for combustion. This procedure should make the startup of the unit easier and remove any possibility of ignition failure. The unit can also be brought closer to stable operating temperatures before coal feed is begun.

Cross-Over Line

The gas-outlet line from the gasifier to the scrubber was designed to carry both gas and water primarily to minimize the thermal stresses in the gasifier shell. It was felt that separate lines for gas and water would cause stresses that might not be foreseen at the time of the design.

The connecting pipe between the shells is water jacketed, and a high-pressure spray is used to assist in keeping the material moving through the line. So far in the operation of the pilot plant, there has never been any trouble from line stoppages.

Waste-Heat Recovery

This construction is obviously not a prototype of large-scale units. The whole problem of recovery of waste heat from the product gas will require further study. The present gasifier is constructed so that design data for the gasification section may be secured; and, at some later date, the shell can be modified to allow experiments on waste-heat recovery.

Slag Collection

The collection and removal of slag have not caused difficulties. The spray causes the molten material to disintegrate into small particles or pieces resembling glass wool. The finer materials carried over by the water stream have not proved particularly abrasive. The circular shield placed in the bottom of the scrubber (fig. 10) shows no signs of wear.

Scrubber

Water-Letdown Valve

The valve now in use (fig. 11) was designed and built in our shops. It was expected that the life of this unit might be short because of the gritty material passing through it; however, the heavier slag particles settle out quickly in the gasifier and scrubber bases, and the finer material is not too abrasive. The valve is eroded slowly, but it appears that, by using special alloys, a reasonably long life can be expected. Other valve designs will be tried at a later date; 2 are venturi-throat types designed for handling abrasive materials and 1 a standard butterfly type.

The problem of automatic level control, using the letdown valve, requires more study. The present float control is subject to plugging from accumulations of fine sludges in the float chamber. Two other types of level controllers will be investigated. This has not interfered with the test work, since water-flow conditions are quickly stabilized and hand control is easy.

Packing

The scrubber is filled with ceramic Raschig rings - 1 inch long, 1 inch o.d., with an 1/8-inch wall. No difficulty has been experienced with stoppages in the packing, and the gas is remarkably clean. Exact determinations of the dust content of the gas have been difficult to obtain. However, the flame at the flaring stack is virtually nonluminous, and 1 test showed approximately 5 grains of dust per 100 cu. ft.

Gas-Letdown Valve

This is a standard-diaphragm, motor-operated, control valve with positioner. The valve seat and disk are Stellited. This valve has not been difficult to operate, and the pressure on the gasifier has shown virtually no fluctuation. Since in large-scale units such a valve would be placed so that only clean gas would be handled, it does not appear that any problem exists here.

RESULTS

Principal Calculated Results

Table 1 presents the principal calculated results of runs P-6 through P-22 on the high-pressure gasifier. The first five runs (through P-5), although very useful for training personnel and testing equipment operation, did not last long enough for obtaining data for extended calculations and have not been included in the table. Runs P-6 through P-9 were also too short to establish equilibrium conditions but provided good indications of temperature, pressure, and output relationships; hence, their results have been included in the table but have been omitted from the graphs discussed later. Results for runs P-6 through P-8 were calculated from carbon balances based on observed weights and analyses of coal charges and residues because no product-gas measurements were made; results for all the other runs are averages of calculations from flow data and residue data, because these averages, explained later in the discussion of accuracy of results, are believed more reliable than either set of figures.

Runs P-6 through P-9 were made at 100 p.s.i.g. gasifier static pressure, using a 12-inch i.d. "Carbofrax" silicon carbide tube (fig. 5) backed by insulating cement. The first 2 of these runs employed horizontal, tangential injection of all reactants (coal, steam, and oxygen); the next 2 employed horizontal injection of steam and vertical or axial injection of coal and oxygen.

Runs P-10 through P-14 were made at 100 p.s.i.g. static pressure, but used a 12-inch i.d. inner lining of B. & W.-80 firebrick (fig. 7). Also, the four inner turns of the gasifier "support coil" were removed before these runs to prevent excessive cooling of the gasifier slag throat, such as had occurred in previous runs.

TABLE 2. - Principal results on pilot-plant high-pressure gasification runs P-6 through P-22[1]

Run No. (with basis for calculating results)[1]		Gasifier static pressure, p.s.i.g.	Estimated average gasifier volume, during run, cu. ft.[2]	Duration of run, hr.	Raw-coal rate, lb./hr.	Process-oxygen rate (100%), std. c.f./hr.	Process-steam rate, lb./hr.	Coal inlet temperature, °F.	Calculated inlet temperature of steam-oxygen mixture, °F.	Oxygen (100%)/lb. raw coal, std. c.f.	Steam introduced /lb. raw coal, lb.	Product-gas analysis, percent[3]				
												CO_2	H_2	CO	CH_4 + Ill.	N_2
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
P-6	R	100	3.64	1.17	200	2,270	81	80	538	11.3	0.41	25.3	27.3	44.2	1.2	2.0
P-7	R	100	3.64	.95	223	2,840	71	74	436	12.7	.32	18.9	23.3	54.6	1.1	2.0
P-8	R	100	3.64	1.35	195	2,390	113	80	619	12.3	.58	14.9	29.7	51.6	1.5	2.0
P-9	A	100	3.64	.67	300	3,070	86	78	502	10.2	.29	12.4	28.0	56.5	.9	2.0
P-10	A	100	2.78	2.88	339	3,130	113	272	583	9.2	.33	7.4	31.3	57.8	1.2	2.0
P-11	A	100	3.09	5.15	350	3,320	106	313	538	9.5	.30	8.3	34.9	54.2	.4	2.0
P-12	A	100	3.30	4.50	440	4,160	132	306	521	9.5	.30	8.5	34.8	53.4	1.0	2.0
P-13	A	100	3.57	8.00	475	4,320	140	264	495	9.1	.29	8.4	34.5	53.8	1.1	2.0
P-14	A	100	3.95	10.00	463	4,350	140	321	450	9.4	.30	7.1	34.4	55.4	.9	2.0
P-16	A	250	1.44	3.00	640	5,580	185	290	545	8.7	.29	9.3	36.5	50.2	1.9	2.0
P-17	A	250	1.44	9.35	588	5,500	164	310	526	9.4	.28	7.9	33.9	54.9	1.2	2.0
P-19	A	300	1.45	3.00	678	6,790	0	326	35	10.0	.00	9.4	32.4	54.7	1.3	2.0
P-21	A	300	1.46	6.00	744	7,330	210	290	627	9.9	.28	9.2	33.1	53.8	1.6	2.0
P-22	A	300	1.49	6.75	683	6,600	210	326	626	9.7	.31	8.3	34.9	53.6	1.1	2.0

Run No. (with basis for calculating results)[1]		Calculated net heating value of product gas, B.t.u./std. c.f.	Product gas flow, thousands of std. c.f./hr.	(CO + H_2) flow, thousands of std. c.f./hr.	H_2-CO ratio, std. c.f./std. c.f.	Carbon in coal gasified, percent[4]			Coal throughput, lb./(hr.)(cu. ft. gasifier volume)	CO + H_2 output std. c.f./(hr.)/(cu.ft. gasifier volume)	Material requirements per 1,000 std. c.f. of CO + H_2			Average ash content of residue, dry basis, percent (residue data)	Average total carbon content of residue dry basis, percent (residue data)
						Flow data	Residue data	Average			Coal, pounds	Process oxygen std. c.f.	Process steam, pounds		
1		17	18	19	20	21	22	23	24	25	26	27	28	29	30
P-6	R	230	5.4	3.9	0.62	-	87	-	55	1,100	51	580	20.0	43	52
P-7	R	255	6.0	4.7	.43	-	91	-	61	1,300	47	600	15.1	64	31
P-8	R	264	6.2	5.0	.50	-	99	-	54	1,400	39	480	22.6	90	6
P-9	A	269	9.2	7.0	.50	95	99	97	82	2,100	38	390	11.0	96	4
P-10	A	286	10.2	9.1	.54	90	97	94	122	3,300	37	340	12.4	65	14
P-11	A	275	10.8	9.6	.64	88	93	90	113	3,100	36	350	11.0	67	32
P-12	A	279	13.6	12.0	.65	89	93	91	133	3,600	37	350	11.0	73	28
P-13	A	283	14.3	12.6	.64	87	92	89	133	3,500	38	340	11.1	69	29
P-14	A	284	14.2	12.8	.62	82	92	87	117	3,200	36	340	10.9	-	-
P-16	A	284	18.0	15.6	.73	73	79	76	445	10,800	41	360	11.9	39	55
P-17	A	286	18.2	16.2	.62	82	93	88	409	11,300	36	340	10.1	64	35
P-19	A	282	19.7	17.2	.59	94	86	85	468	11,900	39	390	.0	48	50
P-21	A	282	24.2	21.0	.62	99	94	97	508	14,400	35	350	10.0	73	25
P-22	A	281	21.3	18.9	.65	87	93	90	460	12,700	36	350	11.1	70	27

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[1] "R" indicates that items in columns 18, 19, and 24-28 were calculated from carbon balances based on residue data, and "A" indicates that these items are averages of calculations from carbon balances using product-gas flow data and residue data. Product-gas flow data were inadequate for runs P-6, P-7, and P-8. Data for runs P-6 through P-9, although included in this table, should not be used for material balance calculations. The duration of these runs was too short and the methods of residue collection were not sufficiently developed to yield information other than that for guidance during this early stage of development. In general, accuracy of results improved as more runs were made.

[2] Indicated volumes for runs 6-9 were those at the beginning of each run, values for runs P-10, P-11, P-14, P-17, P-21, and P-22 were averages of measurements taken before and after each run, and remaining values were estimated from measurements for adjacent runs.

[3] Product-gas analyses, flows, and heating values have been corrected for inert feed gas with the coal and purge gas to the gasifier, assuming 2.0 percent as the upper limit for N_2 from coal and process oxygen.

[4] Columns 21 and 22 showing the percentages of carbon gasified, based on flow data and on residue data, have been included to give an idea of the agreement by the two methods.

Following run P-14, the gasifier internal volume was reduced by relining with "Carbofrax" silicon carbide arch brick to give an 8-inch i.d., and runs P-15 through P-22 were made with this new lining (figs. 8 and 9). Runs P-15 through P-17 were made at 250 p.s.i.g. gasifier pressure and runs P-18 through P-22 at 300 p.s.i.g. P-15 and P-20 have been omitted from the table because of reactant-nozzle failure and P-18 because of a leak in a high-pressure steam flange. Run P-19 has been included, even though a leak in the steam superheater just before the scheduled start of the run made it necessary to operate without process steam.

Referring to table 1, column 1 shows the run number with the basis for calculating results, column 2 the gasifier static pressure, and column 3 the average volume of the refractory-lined space during each run. Columns 4 through 9 give run conditions, columns 10 and 11 input ratios, and columns 12 through 20 "product-gas" data. The separate percentages of carbon gasified, based on flow data and on residue data, are shown in columns 21 and 22. Although separate values, based on flow data and on residue data, are not given in the items shown in columns 18 and 19, and 25-28, these separate values have the same relationships to the average values shown as the individual values for carbon gasified (columns 21 and 22) have to the average values (column 23).

Columns 24 and 25 are of interest as indicating the effect of gasifier pressure on capacity. Columns 26 through 28 express the comparative economy of the process by showing the coal, oxygen, and steam requirements per 1,000 std. c.f. of synthesis gas ($CO + H_2$). Columns 29 and 30 list the ash and total carbon contents of the residue, experimentally determined from residue samples.

In view of the generally poor agreement between the quantity of reacted steam, as calculated from flow data, and that calculated from residue data, the amount of reacted steam is not shown in table 1. The average quantity of reacted steam calculated for runs P-10 through P-22 (omitting run P-19) was about 25 percent of the process steam introduced. The steam-coal ratio for these tests was essentially constant at 0.3 pound per pound. The amounts of reacted steam for individual runs ranged from 16 to 38 percent of the process steam introduced.

Coal and Residue Data

Table 2 presents chemical analyses, calorific values, and ash fusibilities of the various batches of Sewickley-bed coal used for runs P-6 through P-22 and chemical analyses and weight distributions of residues for the same runs. The figures shown are averages for groups of runs of the same type, rather than for individual runs. It may be seen that, except for variations in ash content, the quality of coal was reasonably constant, and such differences as did exist probably would not have had much effect on the operating results. The ash-fusibility determinations were made in a reducing atmosphere. Tests using an oxidizing atmosphere have shown fusibility temperatures 100° to 200° F. higher.

The residue data show that, for each 100 pounds of raw coal fed to the gasifier, 16 to 21 pounds of residue (dry basis) were collected or accounted for. Averages for groups of runs, rather than individual values for separate runs, have been used to indicate general trends rather than undue emphasis on isolated runs. Chemical analyses of the residue (dry basis) show 50 to 75 percent ash, 25 to 45 percent total carbon, and less than 1.0 percent hydrogen.

It may be seen (from table 2) that the percentage of total residue collected in the slag pot at the bottom of the gasifier varied widely - from about 22 percent in runs P-16 and 17 to about 78 percent in runs P-6 to 9. This percentage distribution was strongly influenced by the length of run. For example, in short runs, such as P-6 through P-9, a high percentage of the total residue remained in the gasifier slag pot, whereas in longer runs a higher percentage of the residue passed in and out of the gasifier slag pot and scrubber and was measured in the overflow water from the scrubber.

TABLE 2. - Chemical analyses, calorific values, and ash fusibilities of Sewickley-bed coal, and chemical analyses and weight distribution of residue for runs P-6 through P-22

Runs averaged		P-6 to 9	P-10 to 14	P-16 to 17	P-19 to 22
Coal analysis, as-fired basis					
Proximate	Moisture	1.6	1.6	1.2	1.4
	Volatile matter	35.0	34.2	34.7	34.5
	Fixed carbon	49.9	49.4	52.6	50.9
	Ash	13.5	14.8	11.5	13.2
Ultimate	Hydrogen	4.9	5.1	5.0	4.7
	Carbon	70.2	1/69.0	72.3	1/70.3
	Nitrogen	1.5	1.3	1.5	1.5
	Oxygen	5.5	5.6	5.8	6.9
	Sulfur	2.8	2.6	2.7	2.0
	Ash	13.5	14.8	11.5	13.2
	Moisture	1.6	1.6	1.2	1.4
Calorific value, B.t.u./lb.:					
	Gross	12,760	12,610	13,320	12,930
	Net	12,280	12,120	12,840	12,460
Ash-fusibility temp., °F.:					
	Initial deformation	2,270	2,170	2,200	2,220
	Softening	2,300	2,250	2,240	2,270
	Fluid	2,340	2,330	2,320	2,340
Total weight of residue collected and accounted for, dry basis:2/					
	Lb./100 lb. raw coal	16	16	21	19
	Percent of ash in coal accounted for in residue	83	82	86	89
Chemical analysis of residue, dry basis, percent:					
	Volatile matter	4	2	4	2
	Fixed carbon	23	26	45	34
	Ash	73	72	51	64
	Total carbon	24	28	45	34
	Hydrogen	0.5	0.5	0.5	0.5
	Sulfur	0.5	1.5	2.5	1.5
Distribution of residue, weight percent:					
	Bottom of gasifier	78	60	22	42
	Bottom of scrubber	3	6	3	6
	Overflow water	19	34	75	52

1/ Values of total carbon for individual runs, differing from the averages shown and used in the preparation of figure 20, were as follows, in percent: Runs 10, 11 and 12, 68.2; run 13, 68.5; run 14, 71.6; run 19, 715.; run 21, 69.4.

2/ Does not include ash deposited on interior walls of gasifier, or residue leaving the scrubber as dust with the product gas.

Table 3 presents screen analyses of Sewickley coal used and residues collected for selected runs on the high-pressure gasifier. The minus-325-mesh material was determined in most instances by extrapolation, using Rosin-Rammler size-distribution graphs, and minor adjustments in percentages of other sizes were made by use of Rosin-Rammler relationships. Although it is realized that these size-distribution relationships for a prepared coal do not necessarily apply for a residue, the figures on the residues obtained by this method will certainly indicate relative size trends and probably are more accurate than those obtained by using a 325-mesh screen. It is seen that, except for run P-11, the Sewickley coal had almost the same size consist, and the effect of this minor difference was probably insignificant in this run.

TABLE 3. - Screen analysis of Sewickley coal used and residues collected for selected runs on high-pressure gasifier

Run No.		8	11	14	17	19
Source	Screen size[1]	Size distribution, weight-percent				
Raw-coal feed	+50-mesh	0.0	0.0	Trace	0.1	0.1
	-50+100	1.1	3.0	2.0	2.6	2.3
	-100+140	4.4	6.5	3.0	2.5	2.6
	-140+200	7.5	12.0	6.9	8.2	7.7
	-200+325	17.0	19.5	11.6	13.5	12.3
	-325	70.0	60.0	76.5	73.1	75.0
Residue collected at bottom of gasifier	+1/2"(slag)	69.0	.0	.0	.0	Negl.
	-1/2"+10	18.5	1.3	13.0	20.0	6.0
	-10+50	6.5	22.1	31.4	28.0	41.0
	-50+100	1.6	16.6	13.8	10.5	17.5
	-100+140	.9	7.5	4.4	4.0	7.3
	-140+200	.7	9.0	6.6	4.5	5.7
	-200+325	.4	8.5	5.3	5.5	7.0
	-325	2.4	35.0	25.5	27.5	15.5
Residue collected at bottom of scrubber	-1/2"+10				.9	2.5
	-10+50	(2)			20.4	35.3
	-50+100				15.5	20.7
	-100+140				7.0	8.0
	-140+200				9.3	7.8
	-200+325				9.2	7.2
	-325				37.7	18.5
Residue collected in overflow water from scrubber	-1/2"+10			1.6	.0	4.5
	-10+50			11.2	7.2	32.4
	-50+100			9.8	16.3	19.3
	-100+140			5.7	10.5	6.1
	-140+200			5.9	12.7	7.1
	-200+325			7.3	13.7	7.1
	-325			58.5	39.6	23.5
Weighted average screen anal. of residue	-1/2"+10			6.8	6.9	4.9
	-10+50			20.4	14.9	34.9
	-50+100			11.6	14.3	20.0
	-100+140			5.1	8.1	6.8
	-140+200			6.2	9.7	6.6
	-200+325			6.4	10.7	7.1
	-325			43.5	35.4	19.7

[1] The minus-325-mesh material was determined in most instances by extrapolation using Rosin-Rammler size-distribution graphs, and minor adjustments in percentages of other sizes were made by use of Rosin-Rammler relationships.

[2] Unfilled columns not determined.

The coarsest residue shown in table 3 was that collected at the bottom of the gasifier for run P-8. This run was made at a high oxygen-coal ratio of 12.3 std. c.f. per pound, and 69 percent of the residue at the bottom of the gasifier occurred as plus-1/2-inch slag. The residue in all instances is seen to be coarser than the raw-coal feed. As was expected (see data on runs P-17 and P-19), that collected in the overflow water was finer than that collected in the scrubber, which in turn was finer than that collected at the bottom of the gasifier.

ACCURACY OF RESULTS

Initially, the major emphasis in the high-pressure gasification tests was directed toward obtaining an operable test combination, that is, steady feeding of coal, oxygen, and superheated steam, producing synthesis gas of acceptable quality, and securing slag flow without excessive refractory erosion. The exact measurements of temperatures, pressures, and flows, although always considered important, were placed secondary to making the gasifier operate. After the first few runs had indicated equipment and procedure changes, which when incorporated made possible successful operation of the gasifier, the emphasis was shifted gradually toward improved efficiency of operation and collection of data. Steps were taken to increase the accuracy and reliability of temperature, pressure, and flow measurements so as to provide sounder foundations for secondary calculations and analyses of results to determine optimum operating conditions.

Probable Accuracy of Measurements

The most important measurements during coal-gasification runs are undoubtedly the flow measurements of input reactants, product gas, and residues. When the major emphasis was toward making the gasification process function and test runs were brief, a 5-percent, or even a 10-percent error in the flow measurement, though undesirable, was not considered serious. About the time of run P-15, systematic steps were taken to increase the accuracy and reliability of the flow data. Although flow calibration tests had been made for earlier runs, independent checks on flow quantities were not followed and should be continuous if possible. Measurements of individual flows are discussed as follows:

Oxygen Flow

Before run P-15, orifice meters used for measuring oxygen flows were calibrated against rotameter-type flow-rate indicators, and the resulting calibration curves were probably accurate within about 5 percent. Commencing with run P-15, theoretical oxygen flows have been adjusted by calibration against a flow-prover-type meter, and the resulting curves should be accurate to about 2 percent. For the last several runs, oxygen rates have been checked by comparison with the consumption indicated at the oxygen Cascade storage unit, to provide a means of guarding against accidental errors in oxygen metering. Following run P-19, the accuracy of metering was improved by installing orifice plates and pipe of sizes that conformed better to the necessary flow rates.

Steam Flow

The theoretical curves for orifice meters used to measure water input to the steam generator and superheater (or combined steam generator and steam-oxygen superheater) are corrected by collecting and weighing the water passed through the line, and this weight of water is assumed to equal the weight of steam leaving the superheater. Water flows measured by the calibrated orifice meter should be accurate to about 2 percent, except where a lower-than-expected flow causes the flow curve to register at a low point on the meter chart, when the probable error is somewhat greater.