Temperatures corresponding to equilibrium for the water-gas shift reaction and the carbon-carbon dioxide reaction are recorded in columns 60 and 61. Those for the water-gas shift reaction were found from the synthesis-gas analysis and the undecomposed steam by calculating the ratio $(CO_2)(H_2)$: $(CO)(H_2O)$ and by using values of the equilibrium constant determined by the National Bureau of Standards.[21] Equilibrium temperatures for the carbon-carbon dioxide reaction were found similarly.

Heat balances on the process are presented in columns 62 to 75 and thermal efficiencies in columns 76 to 79. The net heat of combustion of the coal used was corrected for the sulfur present, since it is assumed that no SO_2 is formed. The heat loss as calculated from the heat balance is compared with the heat loss calculated from conduction through the generator wall and from the rise in wall temperature. The heat loss by conduction was determined by using the average temperature measured by the thermocouples between the silicon carbide brick and the chrome brick and the average surface temperatures of the shell, using the thermal conductivities supplied by the brick manufacturers. During the course of a run, the inside brick temperature rose slowly. The heat absorbed by the brick work in the generator was calculated from the average temperature of each course of brick at the start and at the end of the run.

Oxygen Requirement

The calculated oxygen requirement, compared with the actual oxygen input, given in table 4, was calculated based on the assumption that the water-gas shift reaction reaches equilibrium at the exit-gas temperature and using the steam:coal ratio, the percent carbon gasification and the calculated heat loss obtaining for each run. The agreement between the calculated and the measured oxygen input is in general satisfactory.

Slag Distribution and Generator Brickwork Condition

The characteristic slag formation found in the generator when the Sewickley and Wyoming coals were gasified is shown in figure 25. This may not be an exact picture of the slag condition existing during a gasifying run in the generator for the following reasons:

1. During the shorter lay-over periods between runs and, in most cases, before generator shut-downs, the heat-up burner was used. This meant that a large area in the generator was kept above the ash-softening point and the slag in the lower part could flow down.

2. The necessary steam purging of the entire unit on shut-downs would allow for gasification of any occluded carbon in the slag. The procedure at the conclusion of all the gasifying runs was to steam-purge the entire unit and then, with the generator vent open, to further steam-purge the generator before lighting the heat-up burner. It was noted, on several occasions, that during steam purging of the generator or when at the conclusion of the coal run operation of the stoves was continued to secure more data, blue gas was being generated and burned at the vent for 1/2 to 3/4 of an hour.

[21] Wagman, D. D., and others, Heats, Free Energies, and Equilibrium Constants of some Reactions Involving O_2, H_2, H_2O, C, CO, CO_2, and CH_4: Nat. Bureau of Standards Research Paper 1634, February 1945, 19 pp.

TABLE 4. - Comparison of calculated input with measured input of oxygen to the generator for each run

Run No.	Oxygen input, S.C.F./hr. Calculated	Measured
1	1,077	1,180
2A	1,104	1,116
2B	1,281	1,469
3	1,675	1,634
4A	1,879	1,664
4B	1,769	1,692
4C	2,778	1,887
5	2,053	1,785
6A	971	1,170
6B	1,641	1,460
7	1,731	1,740
8	1,360	1,220
9A	1,361	1,066
9B	1,017	954
9C	839	869
10	1,035	850
11	775	853
12	832	853
13	1,334	1,150
14	995	1,153
Ave.	1,375	1,288

Run No.	Oxygen input, S.C.F./hr. Calculated	Measured
15A	3,171	2,792
15B	2,672	2,723
15C	2,253	2,644
16A	3,417	2,654
16B	3,156	2,659
16C	3,266	2,659
17	2,722	2,550
18	2,521	2,370
19	2,075	2,171
20	5,262	4,830
21	3,893	3,968
22A	4,710	4,061
22B	5,674	4,069
23A	3,776	3,725
23B	3,255	3,526
24A	3,334	3,322
24B	2,450	3,193
25A	3,776	3,785
25B	4,377	4,420
Ave.	3,460	3,270

Run No.	Oxygen input, S.C.F./hr. Calculated	Measured
26A	4,379	3,605
26B	4,109	3,657
27	3,505	3,520
28	3,795	3,571
29	3,549	3,310
30A	3,716	3,775
30B	3,761	3,761
31A	3,967	3,967
31B	3,241	3,882
Ave.	3,780	3,672

This distribution is significant, however, in that it follows the temperature gradient in the generator. As a result of the tangential introduction of the reactants, no build-up of slag will occur on the wall, nor will slag block the offtakes. It appears that the slag from the heavier particles is thrown out on the wall where the temperature is high enough to keep the slag fluid enough to run slowly down the wall, while that from the very fine particles is kept in suspension until thrown out in the solid state in the dust-collection system.

The condition of the generator lining at various stages of the operation is shown in figures 26,A, through 33, B.

In general, the silicon carbide lining remained good after a total of 56,000 pounds of coal throughput. Incipient failure of the Thermolith cement showed at the joints, however, the penetration being 1/2 inch in some cases. The condition of the silicon carbide tubes in which the water-cooled coal-injection tubes are inserted also remained good, although the Thermolith cement around them eroded badly.

Figure 26A. - Steam inlet from stove "A" before firing generator, May 1948.

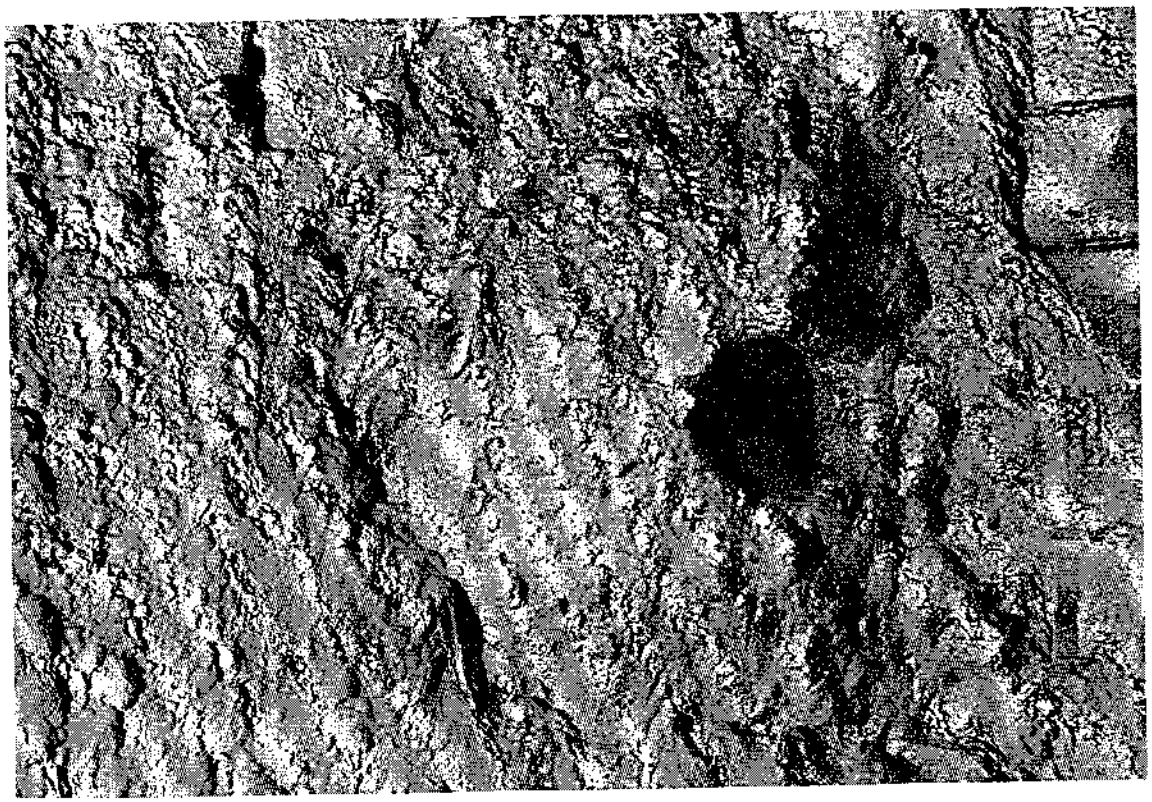

Figure 26B. - Steam inlet from stove "A", showing slag attack, May 1949.

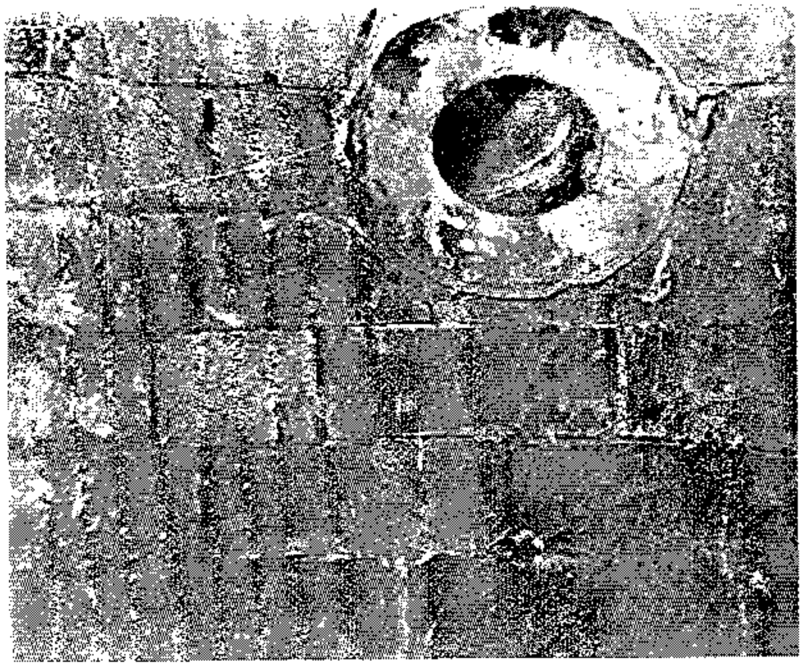

Figure 27A. - Sight-hole tube before firing generator, May 1948.

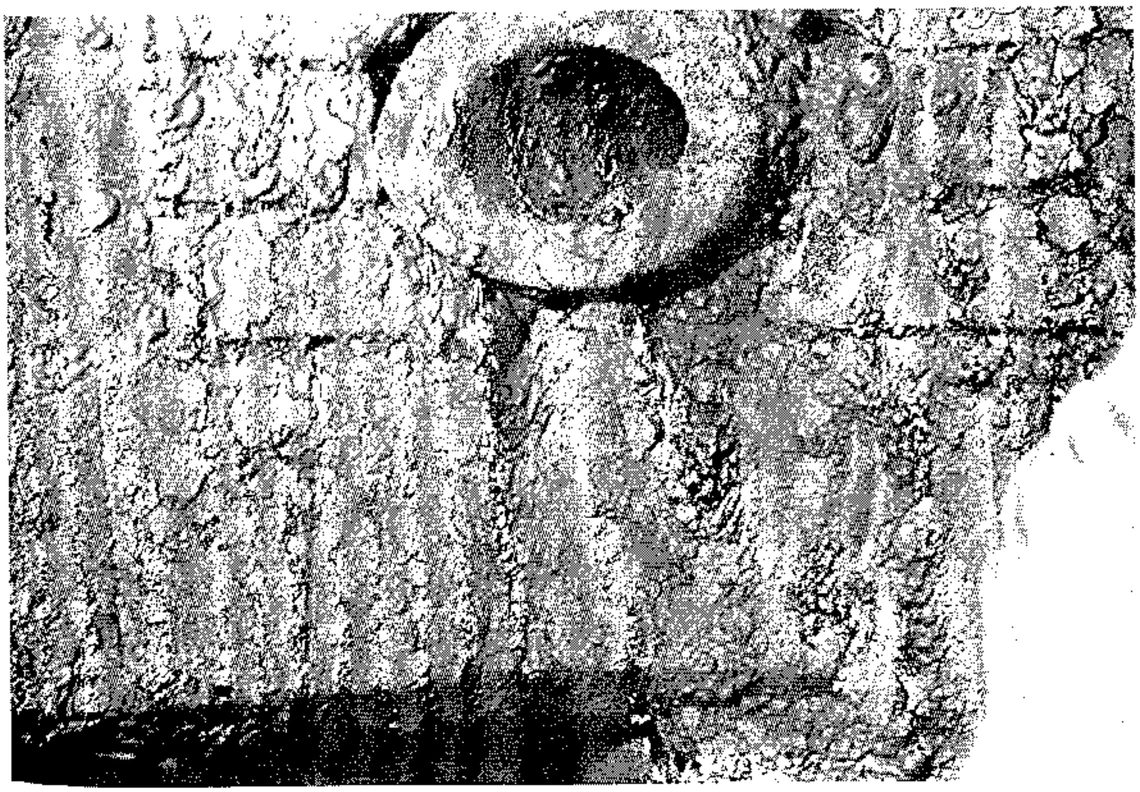

Figure 27B. - Sight-hole tube, showing slag attack, May 1949.

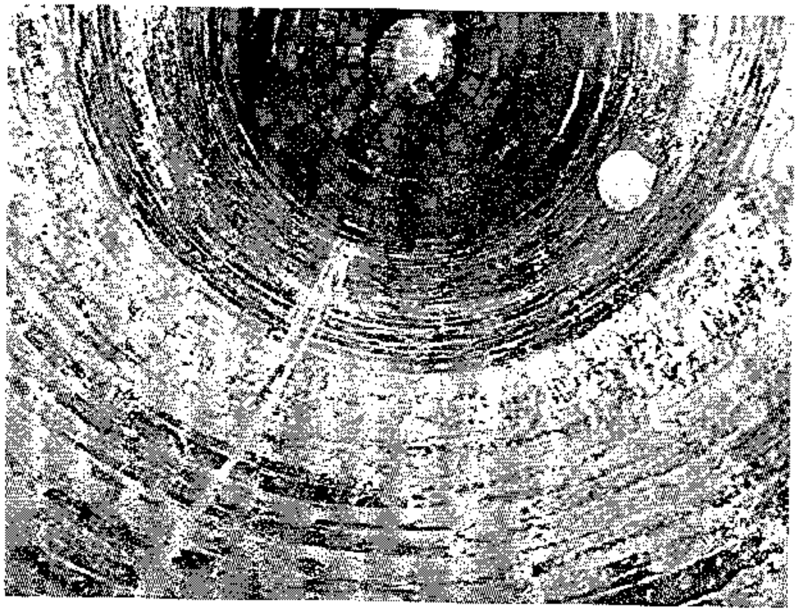

Figure 28A. - Inside generator looking up to outlet before firing, May 1948.

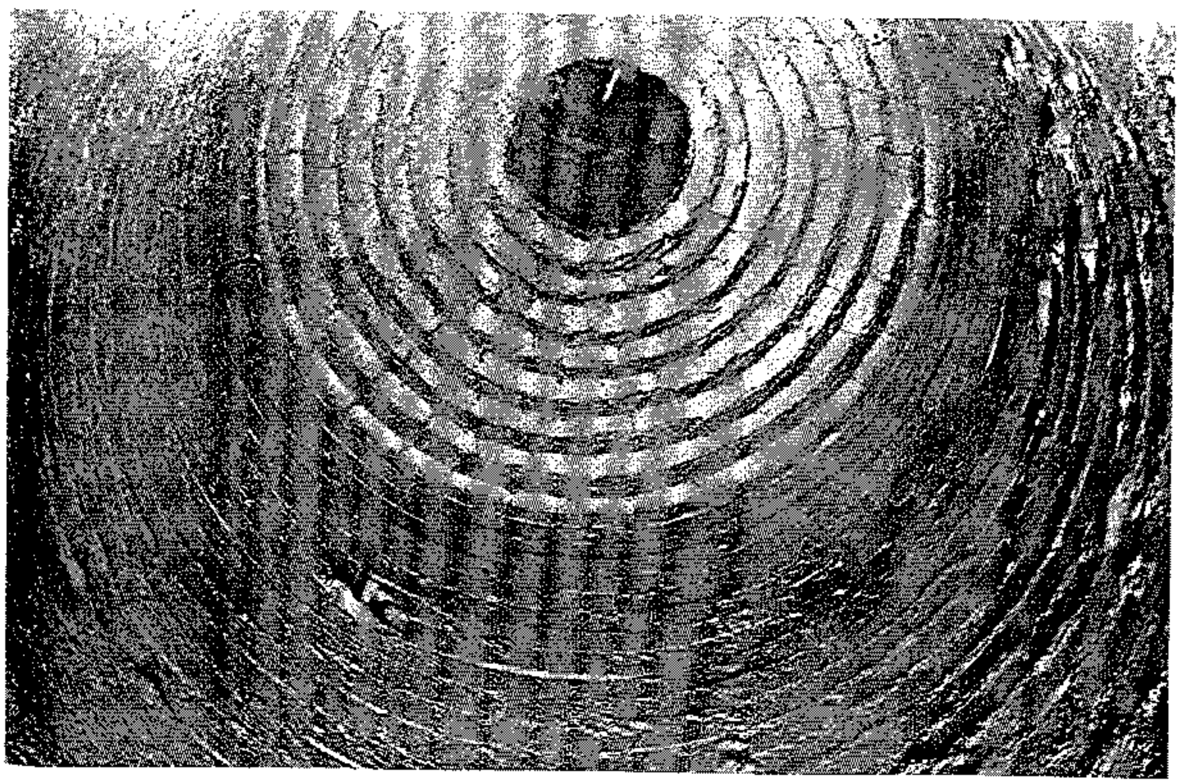

Figure 28B. - Inside generator looking up to outlet, showing slag on walls, May 1949.

Figure 29. - Coal-inlet tube with water-cooled nozzle inserted, showing slag attack, September 1949.

Figure 30A. - Typical slag formation on generator wall, May 1949.

Figure 30B. - Typical slag formation on generator wall, September 1949.

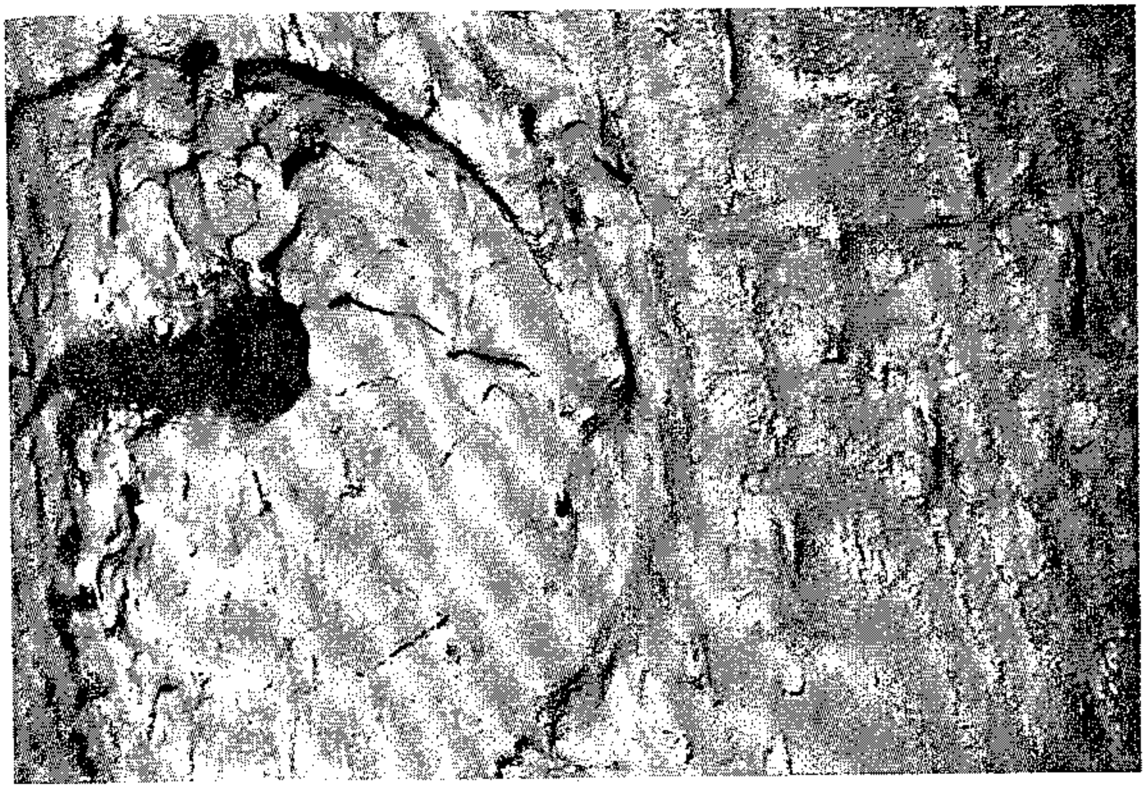

Figure 31A. - Steam inlet from stove "A", showing slag attack, September 1949.

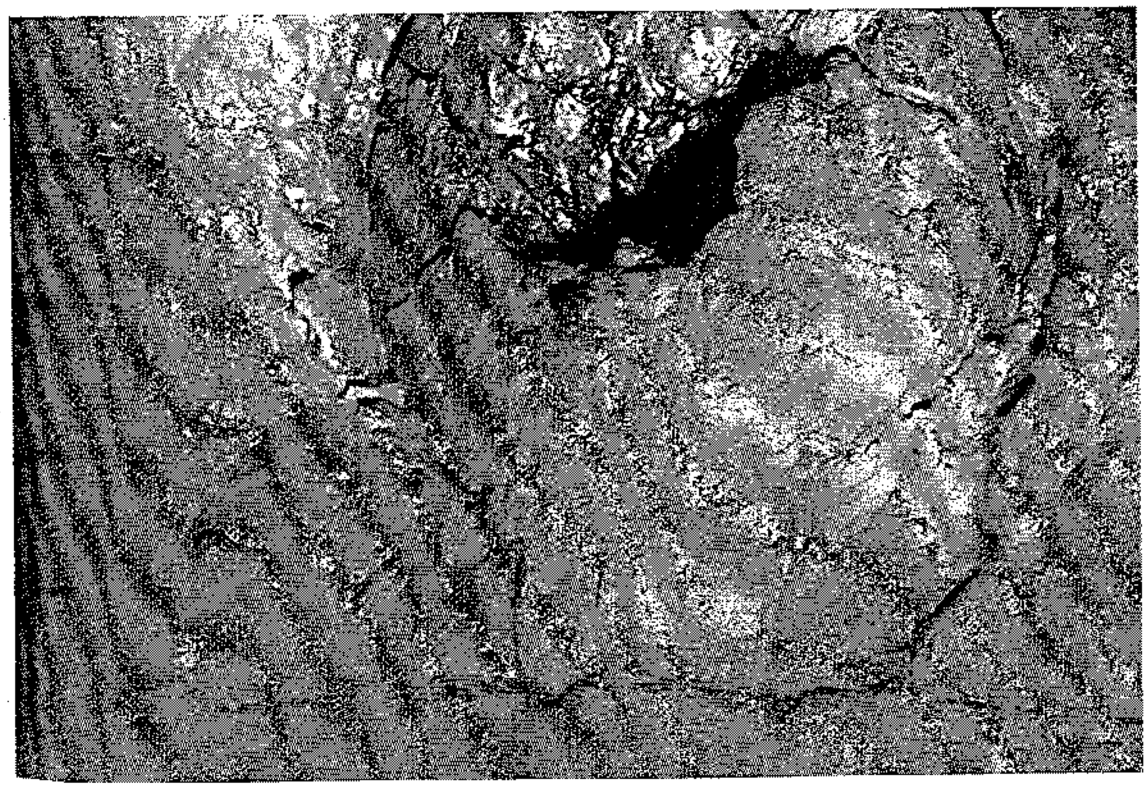

Figure 31B. - Steam Inlet from stove "B", showing slag attack, September 1949.

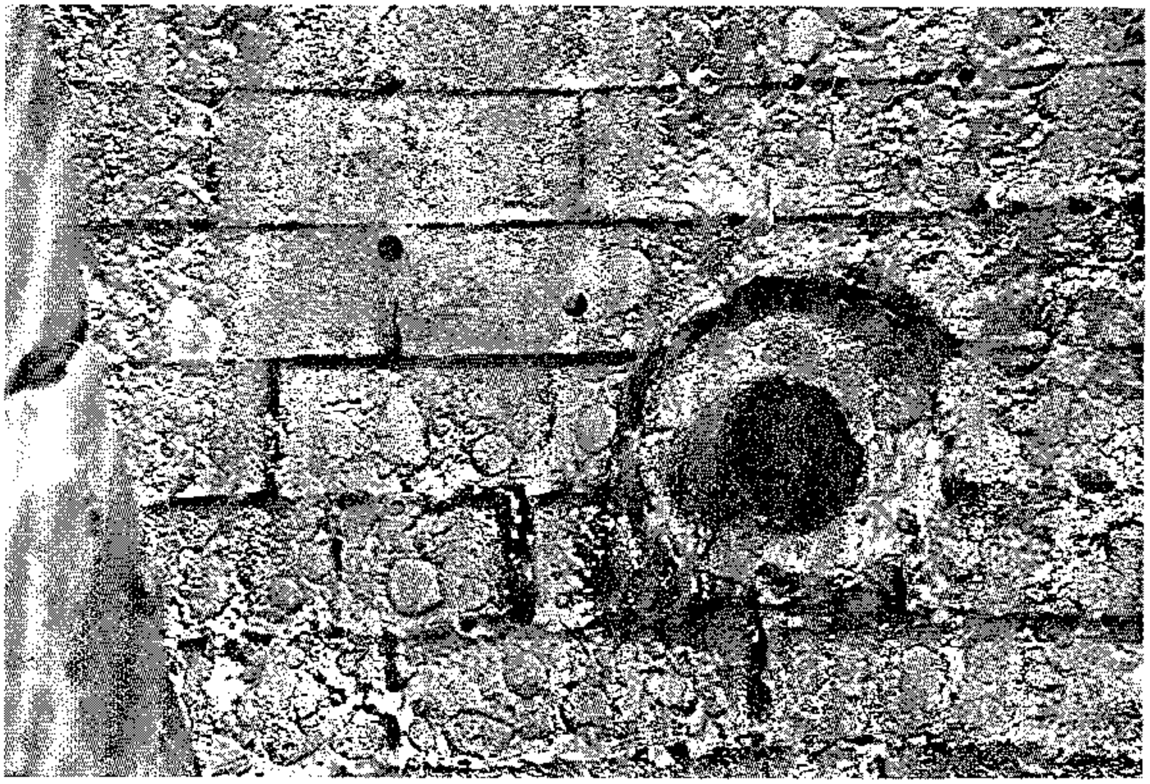

Figure 32A. - Coal-feed tube "C", January 1950.

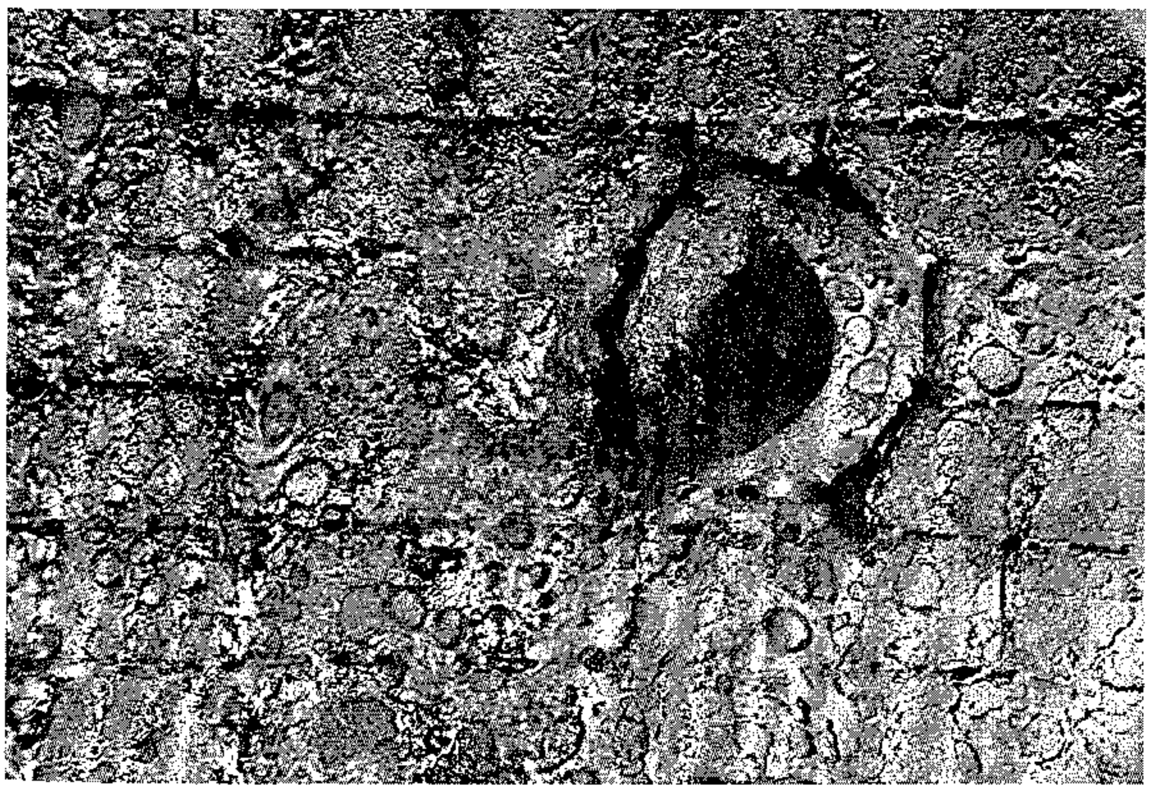

Figure 32B. - Coal-feed tube "D", January 1950.

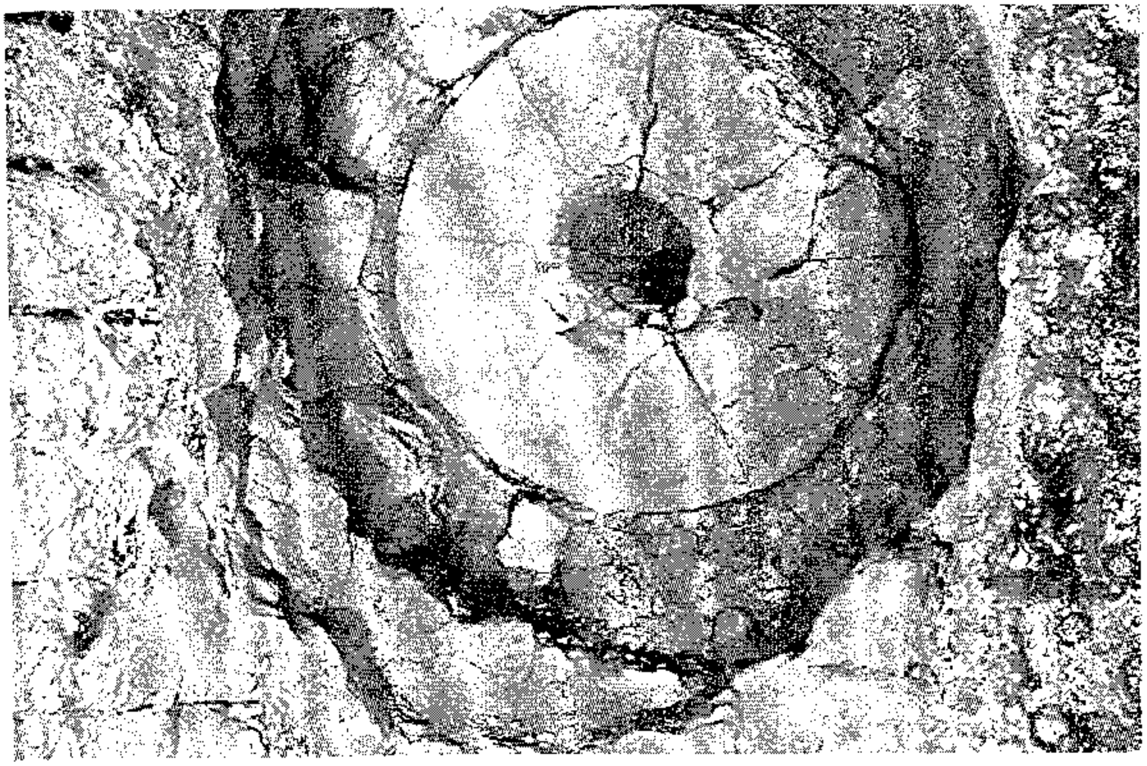

Figure 33A. - Steam inlet from stove "A", January 1950, after cleaning away slag and damaged tube.

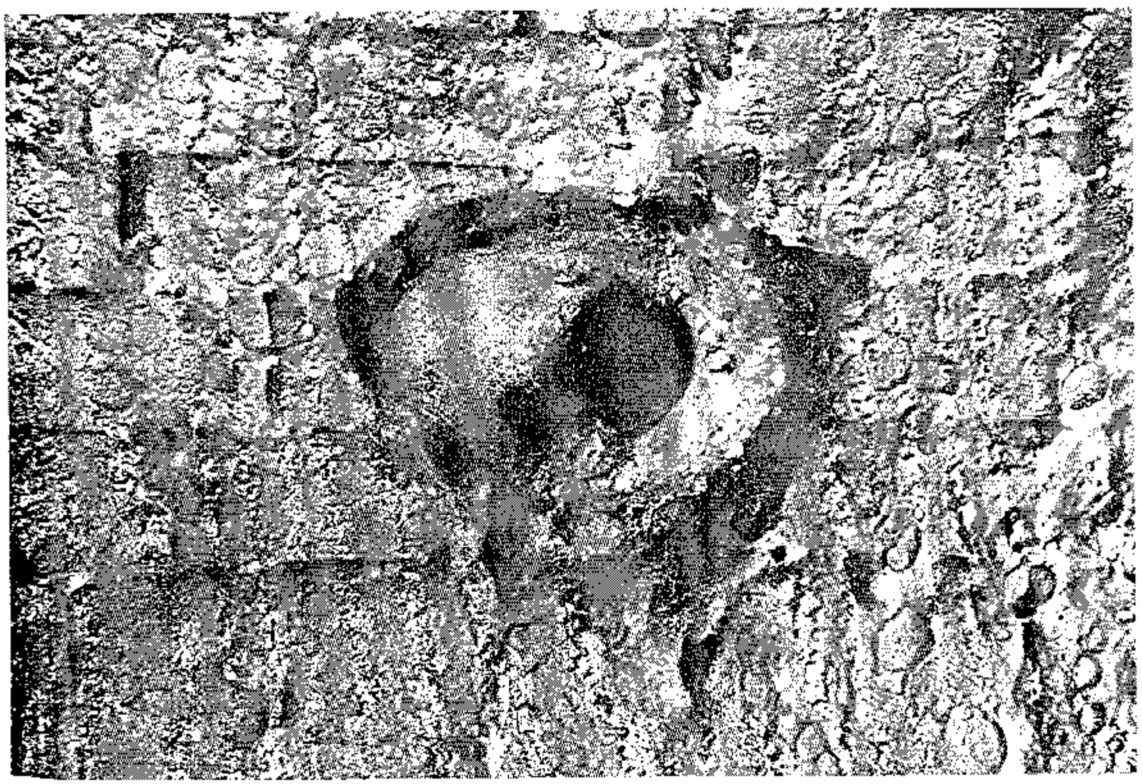

Figure 33B. - Thermocouple tube "E", January 1950.

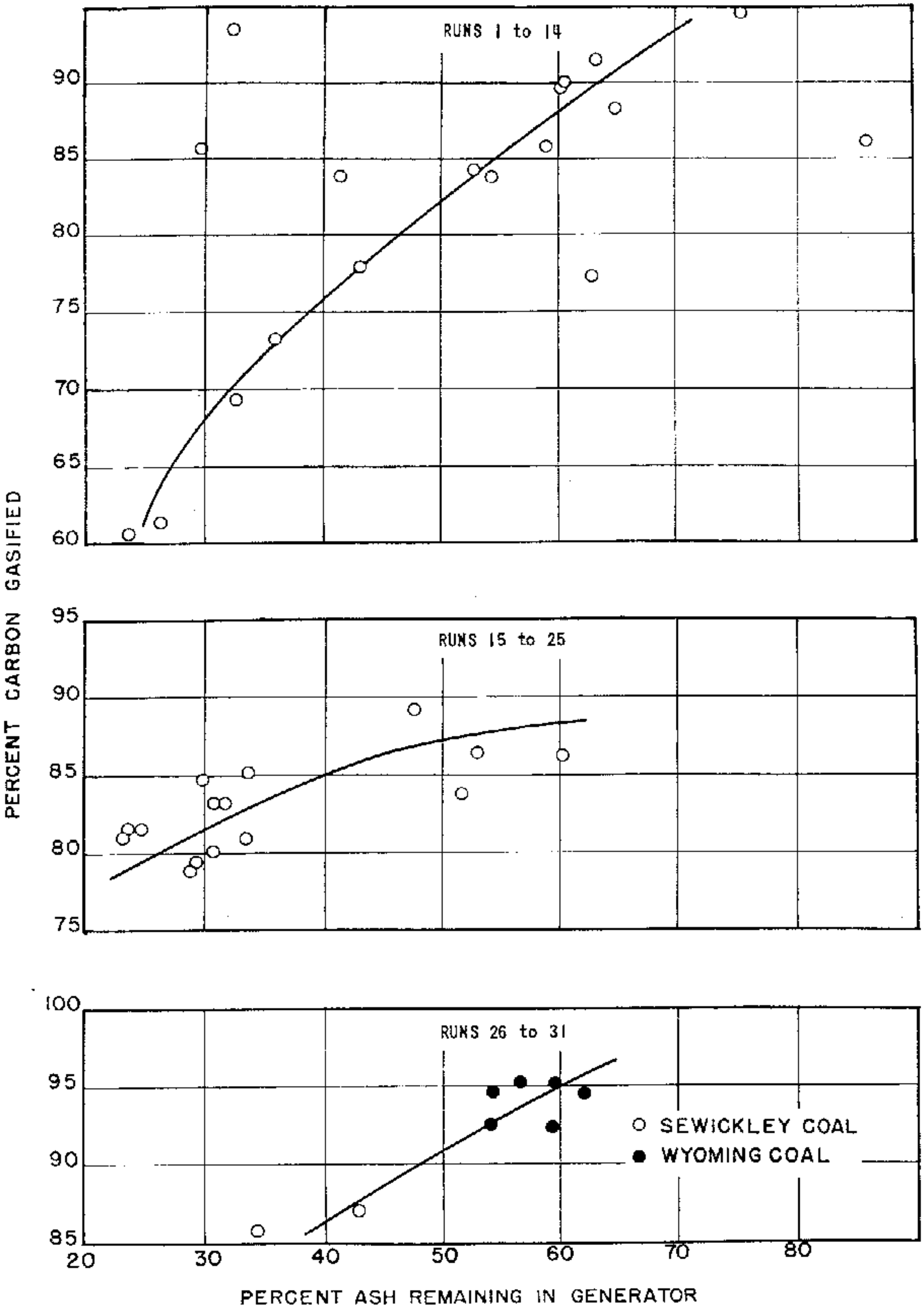

Figure 34. - Plot of percentage of total ash remaining in generator against percentage of total carbon gasified.

On conclusion of the runs using steam at line temperature, 240°F., the wall areas surrounding the steam inlet tubes and the tube ends were found badly deteriorated from slag attack and probable reaction between the chrome and silicon carbide brick. According to correspondence, laboratory tests have shown that fluxing of silicon carbide and chrome brick will occur at 2,750°F. Deterioration of the magnesite tube probably was caused by slag attack, as test results made on a small funace have shown rapid slag attack on magnesite brick at about 2,600°-2,700°F.

Table 5 shows the percentage of the total ash in the coal which remained as slag in the generator and the percentage of total carbon gasified in each run, and figure 34 shows these data plotted against each other. It can be seen that the percentage of ash remaining as slag increases in an almost straight line relationship with the percentage of carbon gasified.

TABLE 5. - Percentage of total ash in coal remaining in generator as slag and percentage of total carbon gasified, based on residue measurement, runs 1 - 31

Run No.	Ash remaining in generator as slag, percent	Total carbon gasified, percent	Run No.	Ash remaining in generator as slag, percent	Total carbon gasified, percent
1	49.1	83.9	15A	30.0	81.6
2A	60.5	89.5	15B	28.7	81.1
2B	60.8	89.6	15C	28.9	81.6
3	54.3	83.9	16	44.6	86.1
4A	58.9	85.6	17	34.0	83.3
4B	59.0	85.6	18	37.2	84.9
4C	58.9	85.6	19	33.7	78.9
5	73.9	88.0	20	35.7	85.2
6A	77.8	94.4	21	49.7	89.3
6B	66.5	91.4	22	51.5	86.5
7	62.0	93.5	23	32.4	80.0
8	59.7	86.8	24	32.2	75.9
9A	65.2	88.1	25	50.3	91.0
9B	53.0	84.1	26	44.3	82.0
9C	43.3	78.0	27	36.5	83.2
10	32.8	69.3	1/ 28	55.5	88.5
11	46.0	73.2	1/ 29	60.9	92.3
12	63.0	77.1	1/ 30	61.3	95.2
13	29.5	61.3	1/ 31	55.7	94.9
14	22.5	60.7			

1/ All runs except 28-31 were on Sewickley-seam coal from the Bunker mine, Monongalia County, W. Va., Runs 28-31 were on Rock Springs, Wyo., coal as used at Louisiana, Mo.

The final period only was used in runs 16, 22, 23, 24, 25, 26, 30, and 31, since in that period conditions stabilized and were more nearly accurate.