Pulverized-Fuel-Gasification Pilot Plant

The purpose of the large pilot plant and the general scheme for carrying on the experimental work have been outlined in the report of the Secretary of the Interior on the Synthetic Liquid Fuels Act for the period January 1, 1947, to December 31, 1947.

In 1948 this work has been carried to the point where successful gasifying runs have been made with strongly coking coal from the Upper Freeport bed. The feasibility of producing highly superheated steam between 3,500° and 4,000° F. using fixed refractory pebble beds, has been demonstrated.

In the course of the work this year, it has been found necessary to modify some of the original design and equipment as outlined by L. D. Schmidt, J. P. McGee and M. C. Slone.3/

Changes in Experimental Procedure

The original procedure contemplated the use of dolomite pebbles in the stoves for superheating the steam. Exhaustive tests demonstrated that these pebbles could not be sintered satisfactorily in the equipment available. Unless these pebbles can be sintered or glazed over on the surface, they are not inert to steam or water vapor and disintegrate on standing. Work then was done with pebbles made by the Westvaco Corp. These are known as "Sea Water Periclase Pebbles" and are composed of 90 percent magnesium oxide. Test runs have been made in a small furnace where the pebbles were heated to more than 4,000° F. and subjected to severe thermal shock. Also, similar pebbles have been used successfully in stoves elsewhere at temperatures exceeding 4,000° F. Large enough quantities of these pebbles have been obtained for the stoves at Morgantown. As the refractory material used to line the stoves, a magnesite brick, will not withstand temperatures over 3,500° F., operation has been limited to that temperature for the top of the pebble beds, as noted in the test runs. However, there has been developed recently a superior type of magnesite brick, which is reported to withstand operating temperatures exceeding 4,000° F. Arrangements are being made to obtain these bricks to line the stoves.

In the previous report it was noted that, in the lines connecting the stoves to the gas generator, sliding brick valves had been installed to prevent contamination of the "make" gas with products of combustion from the stoves. These valves have not proved satisfactory; and, while the Askania control system has worked very well in maintaining controlled pressure differentials between the stoves and the generator, it is believed that a valve should also be used. A water-cooled alloy-steel valve is being designed.

Owing to space limitations, the use of a preheater for the combustion air to the stove burners has been eliminated, and the air supply is enriched with oxygen to attain the flame temperatures needed. This makes the experimental work simpler and avoids error, for the equivalent requirements for preheated air can be calculated easily.

Experience indicates that the original burner design for the stoves, while satisfactory for this work, probably will cause difficulty in large-scale operation. New designs are being studied.

3/ Schmidt, L. D., McGee, J. P., and Slone, M. C., A Pilot Plant for Gasifying Powdered Coal Entrained in Oxygen and Steam: Chem. Eng. Prog., vol. 44, October 1948, pp. 737-744.

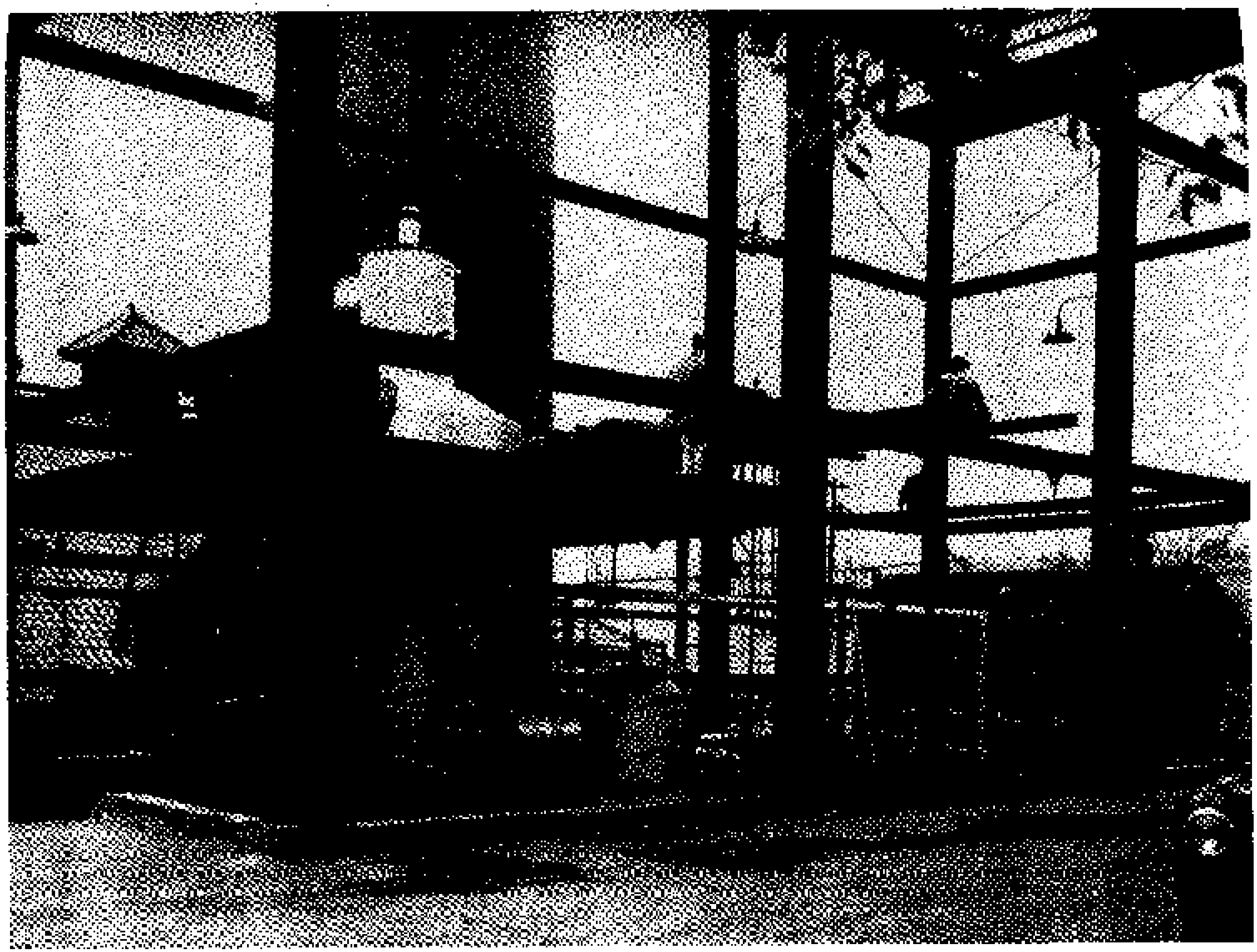

Figure 52. - Pilot plant for making synthesis gas from pulverized coal in oxygen and highly superheated steam, University of West Virginia, Morgantown.

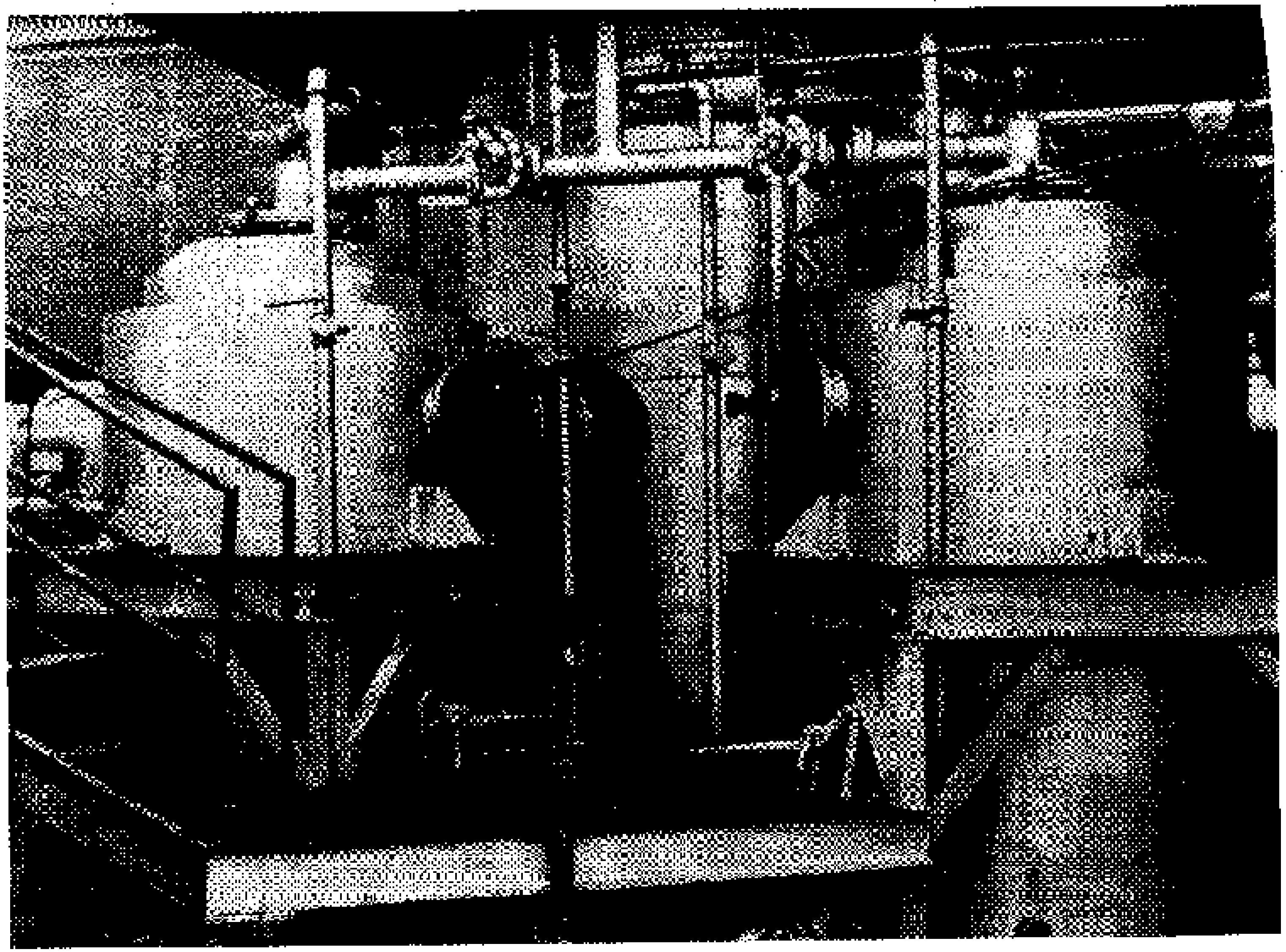

Figure 53. - Royster pebble stoves for superheating steam to exceptionally high temperatures for use in gasifying pulverized coal, University of West Virginia, Morgantown.

Test runs made in October demonstrated the practicability of injecting the coal with the necessary oxygen needed for the process, and the coal will be introduced in this way rather than with carbon dioxide as originally contemplated. However, the generator and coal-feeder design is such that, should the introduction of carbon dioxide be desirable from the standpoint of process control, it also can be used.

Preliminary tests on the fluidized-coal feeder, described more fully later, have been very satisfactory. The use of sight glasses in the coal feed lines lessens danger of feed interruptions. Consequently, it has not been thought necessary to install the hot charcoal chamber in the exit-gas line from the generator. Experience elsewhere has shown that the use of such a chamber would introduce serious operating problems owing to stoppages from the material carried over into the gas stream. The preliminary test runs with coal also indicated that minor fluctuations in the coal feed did not cause serious interruptions in the gas make.

To supply the large volumes of oxygen required in the pilot plant and for other station and experimental use, a Linde Cascade system has been installed. Liquid oxygen is brought in by tank truck and vaporized at 2,200 p.s.i. into large storage cylinders. A Clark mobile unit is being maintained as stand-by equipment.

The pressurized coal-feeding equipment mentioned in the previous report has been received recently but has not yet been placed in service.

To obtain more accurate and continuous records of the temperatures in the stoves, radiation-type pyrometers and recording equipment have been ordered. These also can serve as control units for the heating-gas supply to prevent overheating of the refractories.

For measurement of steam temperatures in the range 3,500° to 4,000° F., no satisfactory commercial instrument is available. In the course of the work, one of the problems being investigated is development of such an instrument. Of course, approximations can be arrived at by using check runs at lower temperatures, calculating the steam temperature from that of the pebble bed, and by measuring the temperature of the refractory lining in the steam lines, but it is believed that better methods can be devised.

Some of the automatic equipment for controlling the various operations has not been received, but preparatory work has proceeded. Protection is being provided for the operating area, and various units are being installed for removing dust and impurities from the gas. Figures 52 and 53 show the pilot plant as it appeared early in the year and the relationship of the pebble stoves to the generator.

Outline of Experimental Data

The steam runs of September 1948 showed very good efficiency, and data on two of them follow in table 13. As previously noted, the pebble-bed temperature was limited to that which the refractory lining could stand. However, the low temperatures of the products of combustion leaving the stoves indicate good heat recovery.

The coal runs of October, data on three of which are presented in table 14, along with data on the stoves in table 15, show that a suitable synthesis gas can be prepared. No attempt was made to record efficiencies in the use of oxygen, for the main purposes of the run were to test the coal-feed device, determine the nature and location of slag deposits in the generator, and obtain some idea of the nature of the material carried over in the gas stream.

TABLE 13. - Results of September 23, 1948, steam runs on stoves A and B

Steam-run number	1		2	
Total length ...... minutes	60		140	
Burner air ...... cu.ft./hr. (60° F., 30-in. Hg, dry)	4,140		4,110	
Burner natural gas ...... do.	650		675	
Oxygen from "Cascade unit" ...... do.	922		920	
Steam introduced ...... lb./hr.	445		569	
Optical pyrometer at top of pebble bed:	A	B	A	B
Temp. at start of run ...... °F.	3,410	3,325	3,562	3,435
Temp. at end of run ...... do.	3,562	3,435	3,540	3,442
Ave. temp. at end of blast period ...... do.	3,502	3,424	3,552	3,456
Thermocouple 13-in. in from side and 13-in. above bottom main shell:				
Temp. at start of run ...... °F.	1,027	887	886	771
Temp. at end of run ...... do.	886	832	657	627
Ave. temp. at end of blast period ...... do.	958	860	763	693
Ave. temp. at end of steam period ...... do.	960	825	728	679
Thermocouple in pebble bed 22-in. above bottom of stove:				
Temp. at start of run ...... °F.	1,741	1,716	1,100	1,111
Temp. at end of run ...... do.	1,421	1,421	433	433
Ave. temp. at end of blast period ...... do.	1,581	1,569	700	719
Ave. temp. at end of steam period ...... do.	1,674	1,369	739	591
Thermocouple in products of combustion outlet at bottom of stove:				
Temp. at start of run ...... °F.	547	757	366	451
Temp. at end of run ...... do.	426	572	247	277
Ave. temp. at end of blast period ...... do.	487	665	292	349
Ave. temp. at end of steam period ...... do.	275	392	227	255
Estimated temperature of superheated steam from stove, assuming same temperature difference between pebble bed and superheated steam as in previous runs .... °F.	3,180	3,102	3,230	3,133

TABLE 14. - Principal results for selected coal runs of October 12 and 13 on pilot-plant generator

Date	October 12	October 13	October 13
Coal run and steam-run number	5	2	3
Coal fed ...... lb.	150	150	150
Net running time ...... minutes	31	58	55
Average feed rate ...... lb. coal/hr.	290	155	164
Oxygen supplied to coal feed line between fluidizer and generator ..... cu. ft./hr., (60° F., 30-in. Hg, dry)	395	1,200	1,202
Oxygen supplied to superheated steam between Royster stoves and generator .... cu. ft./hr., (60° F., 30-in. Hg, dry)	1,325	0	0
Superheated steam from Royster stoves .. lb./hr.	506	448	455
Generator "make"-gas analysis:			
CO_2 ...... percent	18.4	17.8	20.1
O_2 ...... do.	1.3	.6	2.3
Ill. ...... do.	2.7	1.1	2.3
H_2 ...... do.	47.5	41.3	41.0
CO ...... do.	27.7	22.9	19.5
CH_4 ...... do.	.8	2.8	.8
N_2 (difference) ...... do.	1.6	13.5	14.0
	100.0	100.0	100.0

TABLE 14. - Principal results for selected coal runs of October 12 and 13 on pilot-plant generator (Cont'd.)

Date	October 12	October 13	October 13
Coal run and steam-run number	5	2	3
Average temperature of generator at thermocouple points as follows:			
T.C. 5-in. below inside floor and 10-in. above bottom of outside shell .... °F.	2,135	2,167	2,168
T.C. inside generator 5 ft. 9 in. above bottom of outside shell .... do.	2,534	2,530	2,540
T.C. outside of 4-1/2-in. carborundum lining and 5 ft. 9 in. above bottom outside shell .... do.	2,350	2,368	2,385
T.C. inside generator 12 ft. 9 in. above bottom of outside shell .... do.	2,396	2,399	2,420
T.C. inside generator 17 ft. 9 in. above bottom of outside shell .... do.	2,294	2,335	2,350
Residue in "make"-gas wash water. Ash content .... percent	26.6	73.7	73.2

TABLE 15. - Royster stove data for selected coal runs of October 12 and 13 on pilot-plant generator

Date	October 12		October 13		October 13	
Coal run and steam-run number	5		2		3	
Total length steam run .... minutes	60		70		60	
Burner air to Royster pebble stoves ... cu.ft./hr. (60° F., 30-in. Hg, dry)	4,820		5,150		5,180	
Burner natural gas to Royster pebble stoves ... cu.ft./hr. (60° F., 30-in. Hg, dry)	948		930		930	
Oxygen added to burner air .... do.	1,155		980		992	
Steam to Royster stoves .... lb./hr.	506		448		455	
	A	B	A	B	A	B
Optical pyrometer at top of pebble bed:						
Temp. at start of run .... °F.	3,520	3,650	3,550	3,720	3,700	3,690
Temp. at end of run .... do.	3,545	3,720	3,640	3,740	3,620	3,600
Ave. temp. at end of blast period ..... do.	3,552	3,660	3,645	3,691	3,643	3,670
Thermocouple 13-in. in from side and 13-in. above bottom of main shell:						
Temp. at start of run .... °F.	706	826	1,012	879	859	848
Temp. at end of run .... do.	684	740	859	844	787	801
Ave. temp. at end of blast period ..... do.	688	779	932	869	825	817
Ave. temp. at end of steam period ..... do.	692	721	910	865	828	775
Thermocouple in pebble bed 22-in. above bottom of stove:						
Temp. at start of run .... °F.	451	716	1,475	1,371	1,114	1,185
Temp. at end of run .... do.	431	620	1,114	1,185	818	949
Ave. temp. at end of blast period ..... do.	441	659	1,278	1,247	960	1,061
Ave. temp. at end of steam period ..... do.	461	591	1,178	1,133	909	1,024
Thermocouple in products of combustion outlet at bottom of stove:						
Temp. at start of run .... °F.	326	381	512	521	388	468
Temp. at end of run .... do.	310	349	409	468	346	401

TABLE 15. - Reheater stove data for selected coal runs of October 12 and 13 on pilot-plant generator (Cont'd.)

Date	October 12		October 13		October 13	
	A	B	A	B	A	B
Thermocouple in products of combustion outlet at bottom of stove:						
Ave. temp. at end of blast period .... °F.	312	362	465	488	362	437
Ave. temp. at end of steam period ..... do.	238	270	256	322	240	318
Estimated temperature of superheated steam from stove, assuming same temperature difference between top of pebble bed and superheated steam as in first two runs of October 12 . °F.	2,950	3,060	3,050	3,090	3,040	3,070

Projected Program

Based on the work to date, it appears that the fundamental approach to the problem is sound. During the succeeding months, the mechanics of the operation and construction of the pebble stoves will be completed, so that data for large-scale design will be available. It will be necessary to conduct extensive tests to determine the best method of coal, oxygen, and steam injection. Methods for handling slag deposits in the generator must be worked out and the problem of dust removal from the gas stream studied. Adequate supplies of gas for the study of other purification problems will be available early next year.

Pneumatic Feeder for Finely Divided Solids

In the course of development work on the gasification of pulverized coal at the Synthesis-Gas Production Laboratories at Morgantown, W. Va., a mechanism to feed finely pulverized coal to a reactor became necessary. The feeder described in this report was developed to fill that need, but it should be applicable to the feeding of any finely divided solid.

In the gasification of pulverized coal in entrainment, the total residence time of a coal particle in the gasifying zone is probably, at most, about a second; hence, if the coal feed varies over even fractions of a second, then both the ratio of coal to gasifying agents and the gas composition will vary widely, resulting in poor operation. Although this average rate is steady, mechanical feeders are inherently unsteady over short time intervals. Therefore, a pneumatic feeder was desired, with the volume of conveying gas kept to a minimum.

Pulverized coal, when flowing by gravity, often sticks to the walls of the container and arches over the opening. When kept moving slightly by a gas, however, pulverized coal flows easily, even through small-diameter tubes. To make use of this property, the feeder described herein consists of a fluidized bed in which the coal is kept agitated, a fluidizing air outlet, and a coal-delivery tube. The coal and the conveying gas flow through the coal-delivery tube from the fluidized bed to the reactor, while the fluidizing air used is vented from the top of the fluidization chamber.

Operation

A diagram of the experimental apparatus is shown in figure 54. A 4-inch, schedule 40 pipe, 5 feet long, is used as the fluidization chamber. Coal is charged into the apparatus until it is about one-half full. Air enters at the bottom, is