Decaking of Coal in Free Fall

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INTRODUCTION

Most bituminous coals mined near Eastern populous areas are caking. Yet these are the areas which require large quantities of high-Btu pipeline gas. Our object has been to find a practical way to convert these strongly caking coals to noncaking fuel suitable for fixed-bed gasification--a preliminary step in making pipeline gas. A fixed-bed gasifier applicable to production of synthesis gas containing methane has been used commercially in several parts of the world.

In previously reported experiments we have converted caking coals of 1/8-1½-inch size to noncaking coal char by treating it for 3 hours in a static bed,[4/] coal of 18-100 Tyler mesh for 5 minutes in a fluidized bed,[2/] and coal of 4-8 Tyler mesh for 2 seconds in free fall.[3/] Nitrogen and carbon dioxide, steam, or a mixture of all three with small amounts of oxygen was the heating and treating gas in these studies.

In recent experimental work we have converted strongly caking bituminous coal from the Pittsburgh-seam of 1/4-3/8 inch size, in addition to coal of 4-8 Tyler mesh, to a noncaking form in about 2 seconds by dropping it through a countercurrent flow of steam containing oxygen. In all cases the treated or decaked coals had a free-swelling index (FSI) of 2.0 or less, which is indicative of a weakly-to-noncaking coal. Furthermore, when the treated coals were exposed to hydrogen at 600° C and atmospheric pressure for 5 minutes they showed little or no tendency to cake.

APPARATUS

The experimental work was done in the pilot plant shown in figure 1; a schematic flow diagram of the system is shown in figure 2. The system contains a steam generator, feed and receiver hoppers, a screw feeder, and a treatment vessel. This vessel, called a treater, is a 2-inch diameter, schedule 80 pipe, 20 feet long, and made of 304 stainless steel. It is surrounded by 16 individually controlled electric heaters that compensate for radiation loss and supply additional heat when needed. The main supply of heat for the treatment is from steam; a little comes from partial oxidation of the coal. Temperature is measured by thermocouples

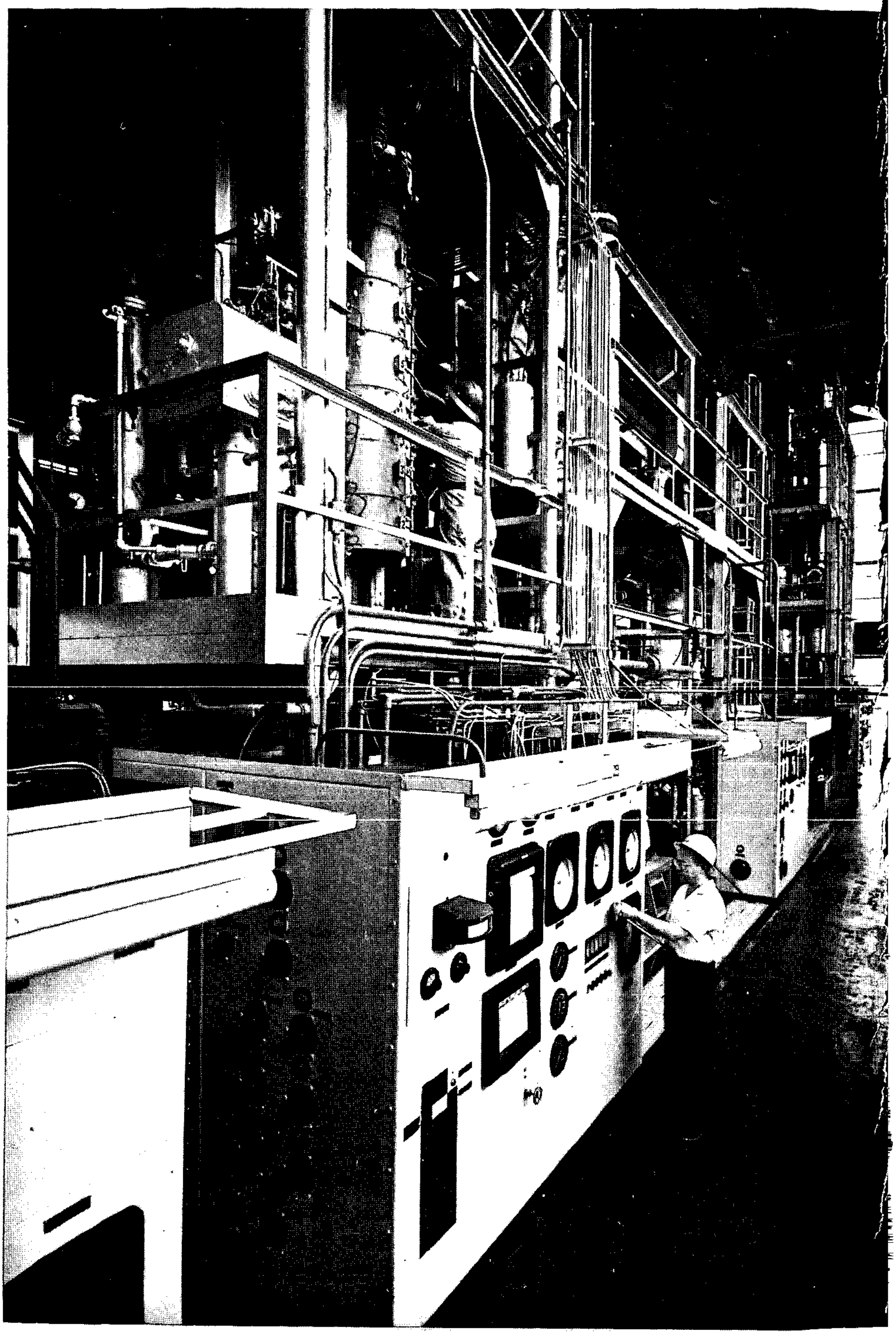

Figure 1. A View of the Pilot Plant for Decaking Coal.

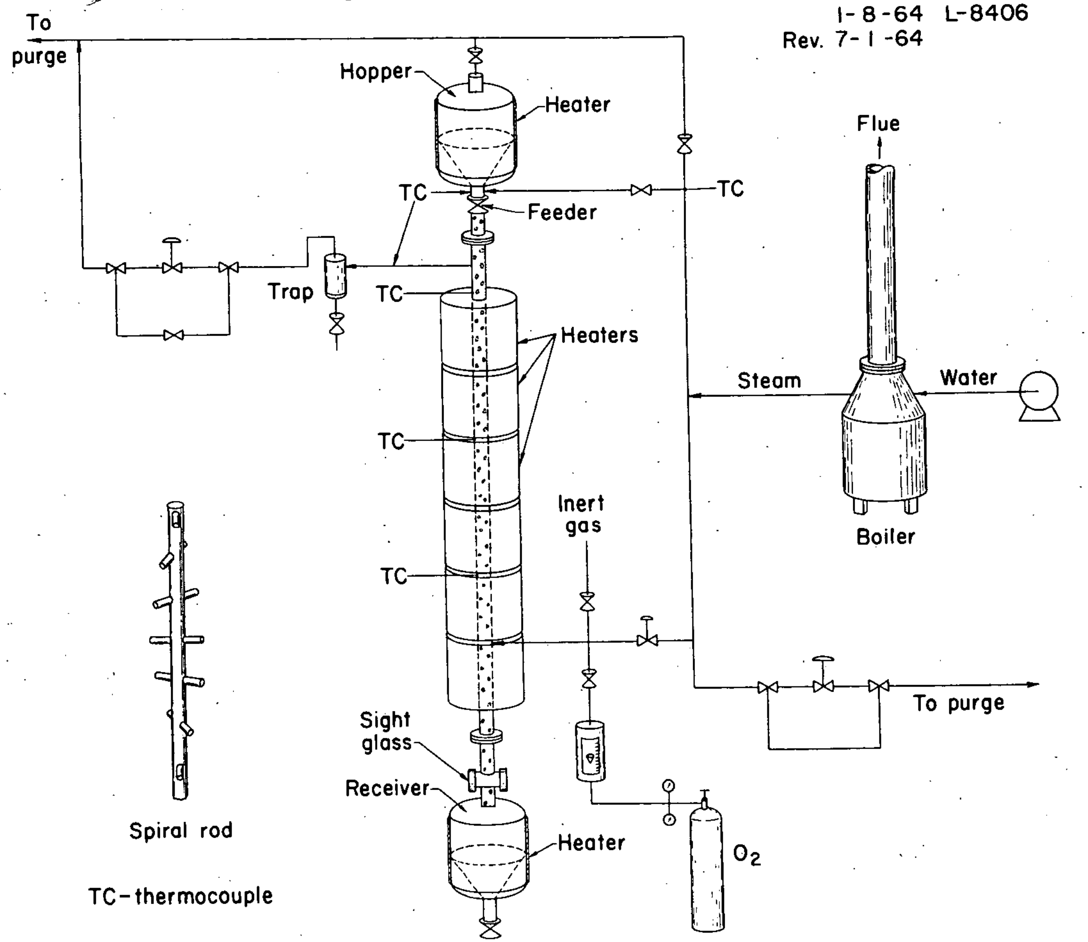

Figure 2. Schematic of Pilot Plant for Decaking Coal in Free Fall.

located at 6-, 12-, and 16-foot levels of the treater. In some early tests a spiral rod, shown in figure 2, was inserted into the treater to increase the coal-to-gas contact time, but coal particles tended to stick to the spiral rod, and it was removed.

Coal

Pittsburgh-seam coal was selected for the tests on account of its commercial importance, its reputation as a typically strong caking coal and easy access at our experimental mine at Bruceton, Pa. The maximum size of the coal treated (3/8 inch) was limited by the inside diameter the treater (1.939 inches). During treatment the coal tends to become sticky while swelling to about 1-1/2 times its original size.

Procedure

A weighed amount of coal of 4-8 Tyler mesh or 1/4-3/8-inch size wa charged to the feed hopper and heated rapidly with steam to just below the softening temperature of the coal, which for Pittsburgh-seam coal i 350° C. This temperature was previously[4/] determined as that temperatur at which a fixed bed of coal offered an increase in resistance to gas flow. The heated coal was fed from the hopper at a controlled rate by a screw feeder into the 20-foot long treater where it fell freely throu a countercurrent flow of steam containing oxygen to a receiver where it was quenched with inert gas. The inert gas contained about 88 percent nitrogen and 12 percent carbon dioxide. The falling coal was in contac with the steam-oxygen mixture for about 2 seconds. To determine the degree of decaking, the treated coal was exposed to hydrogen for 5 minu at 600° C. If it did not cake during hydrogen exposure, the decaking w considered successful. Correlation of hydrogen-exposure results with free-swelling indices (ASTM Test D-720-57) indicated that decaked coal produced from coal of initial high FSI values was noncaking during the hydrogen exposure when its FSI had been reduced to 1.5 or less, and onl weakly caking when its FSI was 2.0.

Results

Tests 77, 115, 917, and 1028 (Table 1) are typical of experiments performed to date. In test 77, 2 pounds of 1/4-3/8-inch coal was heate to 330° C in 10 minutes with steam. Before the coal could be treated effectively, it had to be heated to just below its softening temperatur During this preheating the coal showed only a loss of moisture. Then i dropped through the 20-foot long treater at a rate of 60 pounds of coal per hour (3,000 lb/hr-sq ft). It fell through a countercurrent flow of steam containing 5.5 mole-percent of oxygen at an average temperature o 680° C and 250 psig. The steam-to-coal weight ratio was 2.0, and the oxygen-to-coal weight ratio was 0.21. Each coal particle expanded about 50 percent and fissured as shown in figure 3. The treated coal did not cake when exposed to hydrogen for 5 minutes. It had a FSI of 1.0 and was considered decaked. Its volatile-matter content was 24.9 percent.

TABLE 1.- Conditions for treating a Pittsburgh-seam coal in free-fall

Test No.	Pressure, psig	Size of coal: inch	Size of coal: Tyler mesh	Coal feed, lb/hr	Treating gas rate, lb/hr: Steam	Treating gas rate, lb/hr: O_2
77	250	1/4-3/8	-	60	120	12.4
115	300	-	4-8	50	40	10.4
917	300	-	4-8	40	56	10.4
1028	330	-	4-8	70	40	6.0

Test No.	Gas-to-coal ratio, lb/hr: Steam	Gas-to-coal ratio, lb/hr: O_2	Average reactor temp., °C	Coal heat cycle: Temp., °C	Coal heat cycle: Time, sec	Weight loss of coal, pct
77	2.0	0.21	680	330-430	2	15.3
115	0.8	.21	560	310-430	2	4.0
917	1.4	.26	605	310-430	2	10.2
1028	0.57	.12	605	310-430	2	6.9

In test 115, a 4-8 Tyler mesh coal was heated to 310° C in 10 minutes with steam and then dropped through the treater at a rate of 50 pounds of coal per hour through a countercurrent flow of steam containing 12.7 mole-percent oxygen at 560° C and 300 psig. The steam- and oxygen-to-coal weight ratios were 0.8 and 0.21, respectively. The treated coal caked very slightly when exposed to hydrogen at 600° C. It had a FSI of 2.0. Its volatile-matter content was 30.8 percent.

In test 917 the same size coal was similarly heated and then dropped through the treater at a rate of 40 pounds of coal per hour. Steam containing 9.4 mole-percent oxygen flowed countercurrent to the coal at 605° C and 300 psig. The steam- and oxygen-to-coal weight ratios were 1.4 and 0.25, respectively. The treated coal did not cake when exposed to hydrogen at 600° C. It had a FSI of 1.5. Its volatile-matter content was 26.7 percent.


0
1
2
3
4
5
6
Scale, inches

In test 1028, a 4-8 Tyler mesh coal was similarly preheated to 310° C and then fed to and through the treater at a rate of 70 pounds of coal per hour. Steam containing 7.8 mole-percent oxygen flowed countercurrent to the coal at 605° C and 330 psig. The steam- and oxygen-to-coal weight ratios were 0.57 and 0.12, respectively. The treated coal caked only slightly when exposed to hydrogen at 600° C. It had a FSI of 2.0. Its volatile-matter content was 31.9 percent. Analyses of the coals before and after treatment are shown in Table 2.

TABLE 2.- Analysis of coal and decaked coal

Test No.	Proximate, percent				Ultimate, maf, percent					Free-swelling index
	Moisture	Volatile matter	Fixed carbon	Ash	H	C	N	O	S	
Pittsburgh-seam coal	2.0	35.6	54.4	8.0	5.6	84.3	1.7	7.0	1.4	8.0
77	0.3	24.9	67.2	7.6	4.5	85.4	1.7	7.1	1.3	1.0
115	.3	30.8	63.8	5.1	4.6	84.6	1.6	7.5	1.7	2.0
917	.5	26.7	63.8	9.0	4.9	83.9	1.8	8.2	1.2	1.5
1028	.6	31.9	62.3	5.2	4.8	84.2	1.8	7.7	1.5	2.0

DISCUSSION

To effectively alter or destroy the caking property of a strongly caking coal of small lump size in free fall, both treatment temperature and gas composition must be kept within fairly narrow limits. We decaked coal, which had been preheated to 310°-330° C, in a 20-foot treater in 2 seconds at 560°-680° C with steam containing 5.5-12.7 mole-percent oxygen. When either the preheat or reaction temperature was too low, the coal never reached decaking temperature during the 2 seconds that it took to fall 20 feet. Thus the caking property of the coal remained unchanged. When the reaction temperature was too high or the oxygen was insufficient, the coal agglomerated and plugged the treater.

Results with 4-8 Tyler mesh and 1/4-3/8 inch size coals indicate that larger size coal would require higher temperature and more oxygen.

This decaking technique offers promise as part of an integrated coal pretreatment and high pressure steam-oxygen coal gasification process which requires nonagglomerating feed.[5] Incorporating decaking with gasification should be simple. Both processes are at the same pressure and use the same gases. The process would be economical because the steam-to-coal weight ratio for decaking is equal to or less than that required by the commercial Lurgi[1/] gasifier; also the oxygen-to-coal weight ratio is less than that required in the Lurgi gasifier. Furthermore, the gases and tars produced from volatile matter in the coal during decaking can be fed directly to the gasifier as fuel, thus conserving energy and also solving the problem of effluent or off-gas from the pretreatment. The treater might serve as feed lock hoppers for pressure gasifiers, thus minimizing additional capital investment.

CONCLUSIONS

A pilot-plant study has shown that the caking property of bituminous coal of small lump size can be altered or destroyed by rapidly heating the coal to or through its plastic temperature range while it falls freely through a countercurrent flow of high-temperature steam-containing oxygen. Larger-sized particles require more severe treating conditions as evidenced by a comparison of treatment of 4-8 mesh and 1/4-3/8 inch sizes. Conditions required to decake coal could be met at commercial coal gasification plants with little additional expenditure of energy. However, gasification plants commonly use coal of particle size larger than were used in our study. We were limited to a maximum size of 3/8 inch by the swelling of the coal and the diameter of the treater. A treater of larger diameter would be required to determine the optimum conditions for larger particles.

Because with larger sized particles of 3/8 inch, the size of the expanded coal particle was an appreciable part of the free tube cross section. Additional studies should be made in a larger pretreater to determine optimum conditions of operation.

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