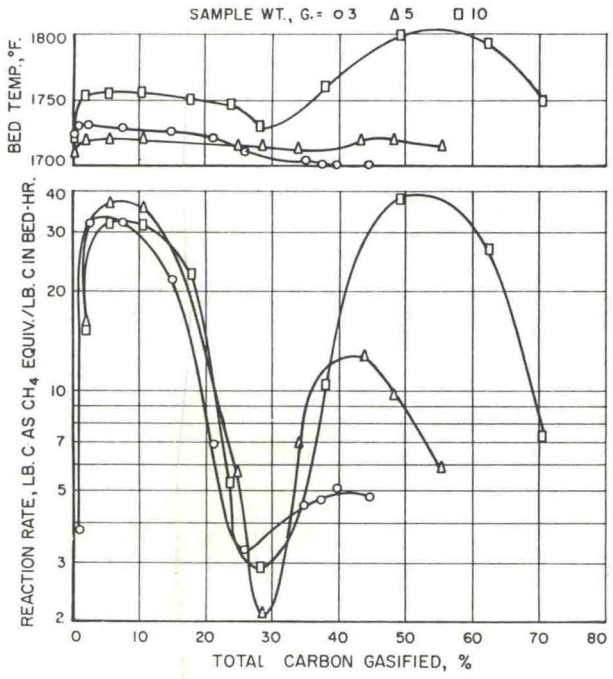

Figure 2. Apparent effect of sample weight on rate of char hydrogasification at 1700° F. and 1500 p.s.i.g.

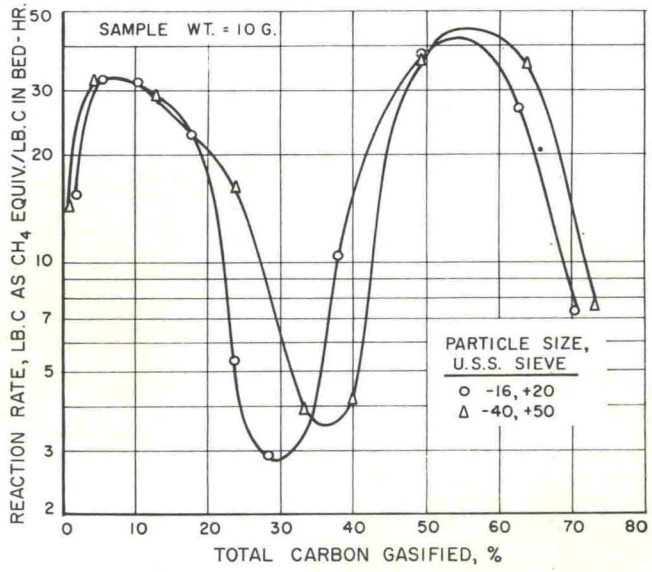

Figure 3. Effect of char particle size on rate of hydrogasification at 1700° F. and 1500 p.s.i.g.

Typical results for the four feeds used in this study are given in Table II.

Effect of Variables. The effects of temperature and extent of conversion on the rate of reaction of low-temperature bituminous coal char and hydrogen were measured in a series of tests conducted at 1500 p.s.i.g. and at 1300°, 1500°, and 1700° F. (Figure 4). During the initial phases, the reaction rate was not significantly affected by temperature in the range studied. Only after approximately 20% carbon gasification did the effects of temperature become apparent. The rate constants for the residual char would be expected to follow the pseudo-first-order relationship:

$$r = kp$$

where r = rate of reaction in pounds of carbon in gaseous hydrocarbons per hour per pound of carbon in bed
k = rate constant
p = hydrogen partial pressure in atmospheres

This expression has been shown by Blackwood (*2*) to be applicable in the temperature range of 650° to 870° C. (1202° to 1598° F.) for the reaction of coconut char with excess hydrogen at pressures up to 40 atm. Birch, Hall, and Urie (*1*) have also applied it successfully to correlate data on the hydrogenation of the residual (aromatic) carbon portion of Australian brown coal with excess hydrogen in a fluid-bed reactor for the temperature range from 750° to 950° C. (1382° to 1742° F.). Zielke and Gorin (*15*) showed that, from 1500° to 1700° F. and at 1 to 30 atm. with devolatilized Disco bituminous coal char, the apparent reaction order is 2 at low pressures and approaches 1 at high pressures.

In Table III, pseudo-first-order hydrogasification rate constants for these chars are compared with the values for low-temperature bituminous coal char after 25 to 30% carbon conversion (Figure 4). Agreement is good, except for the acid-extracted, high-temperature coconut char. The rates for this specially prepared low-reactivity material are up to one order of magnitude lower, as would be expected.

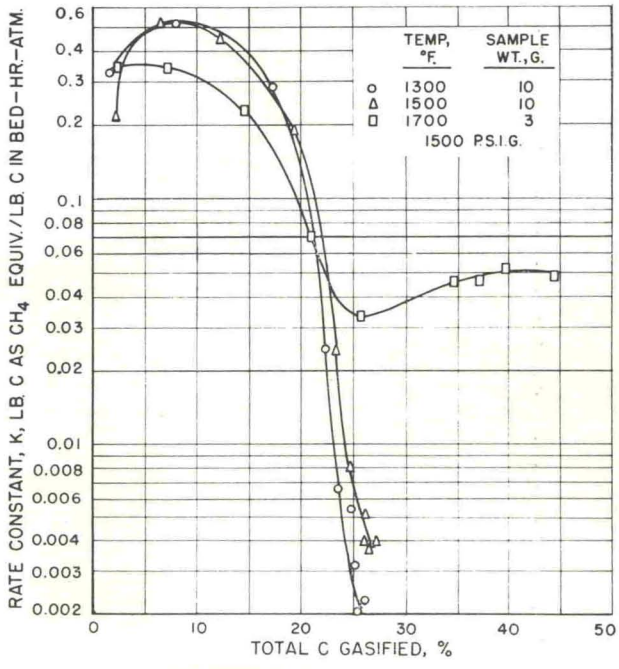

Figure 4. Effect of temperature and conversion on reaction rate constant for bituminous coal char

All of the above results were obtained in differential-bed reactors of various types, except for the data for Australian brown coal, which were obtained in an integral fluid-bed reactor. However, methane concentrations in the product gases were low enough to minimize equilibrium hindrance

Table II. Typical Test Results at 1700° F. and 1500 P.S.I.G.

Feed	5 grams of bituminous coal, −16, +20 U. S. S. sieve size										
Time of sampling, sec.	10	20	25	30	35	40	60	80	120	240	480
Temperature, ° F.	1740	1740	1742	1742	1740	1735	1734	1732	1730	1732	1725
Feed hydrogen rate, SCF/hr.	104.4	104.3	104.3	104.3	104.3	104.3	104.3	104.3	104.2	104.1	103.6
Exit gas rate, SCF/hr.	103.7	102.2	101.5	101.5	100.8	100.8	101.5	100.1	101.4	102.7	100.8
Exit gas composition, mole %											
N_2 + CO	0.05	0.05	0.51	0.89	0.61	0.49	0.12	0.04	0.03	0.04	0.01
CO_2	...	...	0.03	0.02	0.01	0.01	...	...	...	...	...
H_2	99.94	99.94	94.28	87.48	89.36	90.14	96.25	98.22	99.19	98.96	99.58
CH_4	0.01	0.01	5.13	11.49	9.88	9.28	3.55	1.72	0.77	0.99	0.41
C_2H_6	...	...	0.04	0.02	0.02	0.01	...	...	...	...	...
Benzene	...	...	0.01	0.10	0.12	0.07	0.08	0.02	0.01	0.01	...
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rate of formation of gaseous hydrocarbon carbon, lb./lb. carbon fed-hr.	...	...	20.2	46.4	40.4	36.9	15.4	6.9	3.2	4.1	1.6
Total conversion of carbon in feed, %	...	...	0.4	7.0	13.5	17.5	32.6	38.4	43.4	56.6	77.0
Total carbon recovery, %	...	...	...	...	...	...	...	...	...	...	87.9
Feed	5 grams of lignite, −16, +20 U. S. S. sieve size										
Time of sampling, sec.	10	20	25	30	40	50	80	120	240	480	600
Temperature, ° F.	1712	1722	1723	1725	1728	1726	1721	1717	1714	1713	1714
Feed hydrogen rate, SCF/hr.	98.6	98.9	99.0	98.7	99.4	102.1	98.1	98.6	98.9	97.6	95.9
Exit gas rate, SCF/hr.	98.7	98.4	100.1	97.6	95.2	98.3	97.1	97.0	97.8	96.6	94.4
Exit gas composition, mole %											
N_2 + CO	0.06	0.04	0.56	1.82	1.91	1.02	0.08	0.05	0.04	0.06	0.04
CO_2	...	...	0.01	0.05	0.05	0.03	...	...	...	...	...
H_2	99.93	99.94	96.99	89.68	88.84	93.57	98.77	99.38	99.58	99.69	99.75
CH_4	0.01	0.02	2.43	8.38	9.15	5.37	1.15	0.57	0.38	0.25	0.21
C_2H_6	...	...	...	0.01	...	...	...	...	...	...	...
Benzene	...	...	0.01	0.06	0.05	0.01	...	...	...	...	...
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rate of formation of gaseous hydrocarbon carbon, lb./lb. carbon fed-hr.	...	0.1	11.6	39.7	41.7	24.8	5.2	2.6	1.7	1.1	0.9
Total conversion of carbon in feed, %	...	...	0.8	5.9	20.0	32.2	42.1	46.0	53.3	62.9	66.3
Total carbon recovery, %	...	...	...	...	...	...	...	...	...	...	82.3
Feed	5 grams of medium volatility anthracite, −16, +20 U. S. S. sieve size										
Time of sampling, sec.	10	20	25	30	35	40	60	120	240	360	600
Temperature, ° F.	1696	1694	1693	1695	1698	1702	1702	1702	1700	1700	1698
Feed hydrogen rate, SCF/hr.	97.4	97.3	97.3	97.3	97.3	97.3	97.3	97.2	97.0	96.9	97.4
Exit gas rate, SCF/hr.	96.9	95.8	95.3	95.7	93.6	93.1	94.3	95.4	94.5	95.4	96.1
Exit gas composition, mole %											
N_2 + CO	0.04	0.10	0.29	0.24	0.20	0.17	0.07	0.04	0.03	0.03	0.03
CO_2	0.01	0.01	0.03	0.01	...	...	...	...	...	...	...
H_2	99.95	99.67	96.65	94.27	93.97	94.58	97.51	98.90	99.11	99.15	99.52
CH_4	...	0.22	3.01	5.47	5.83	5.25	2.41	1.04	0.86	0.82	0.45
C_2H_6	...	...	0.01	...	...	...	...	...	...	...	...
C_5H_{12}	...	...	...	...	...	...	...	0.01	...	...	...
Mono-olefins	...	...	...	...	...	...	0.01	0.01	...	...	...
Benzene	...	...	0.01	0.01	...	...	...	...	...	...	...
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Rate of formation of gaseous hydrocarbon carbon, lb./lb. carbon fed-hr.	...	0.7	10.1	18.1	18.7	16.7	7.9	3.7	2.8	2.7	1.5
Total conversion of carbon in feed, %	...	0.1	0.7	2.9	5.6	8.1	14.6	24.0	34.8	43.9	57.8
Total carbon recovery, %	...	...	...	...	...	...	...	...	...	...	94.8
Feed	5 grams of low-temperature bituminous coal char, −16, +20 U. S. S. sieve size										
Time of sampling, sec.	10	20	25	30	60	120	240	290	320	400	
Temperature, ° F.	1708	1718	1720	1720	1717	1714	1712	1720	1720	1715	
Feed hydrogen rate, SCF/hr.	98.2	98.2	98.2	98.2	98.2	98.2	98.2	98.2	98.2	98.2	
Exit gas rate, SCF/hr.	96.4	94.9	95.3	93.9	95.7	96.0	96.7	94.9	97.8	96.0	
Exit gas composition, mole %											
N_2 + CO	0.08	...	0.98	0.95	0.08	0.05	0.07	0.04	0.06	0.05	
CO_2	...	0.03	0.01	...	...	...	...	...	...	...	
H_2	99.90	95.63	89.22	90.08	98.72	99.52	98.70	97.99	98.56	99.26	
CH_4	0.01	4.30	9.77	8.95	1.20	0.43	1.22	1.96	1.38	0.68	
C_2H_6	...	0.01	0.01	...	...	...	...	...	...	...	
n-C_4H_{10}	...	0.01	...	...	...	...	...	...	...	...	
C_5H_{10}	0.01	0.01	...	...	...	...	...	...	...	0.01	
C_7H_{14}	...	...	...	...	...	...	0.01	0.01	...	...	
Benzene	...	0.01	0.01	0.02	...	...	...	...	...	...	
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	
Rate of formation of gaseous hydrocarbon carbon, lb./lb. carbon fed-hr.	0.2	15.5	34.5	31.3	4.2	1.5	4.6	7.1	5.0	2.6	
Total conversion of carbon in feed, %	...	1.9	5.4	10.5	24.8	28.5	33.8	43.2	48.2	55.5	
Total carbon recovery, %	...	...	...	...	...	...	...	...	...	86.4	