Table IV. Typical Results on Steam–Coal Char Reaction

(Coal char sample weight, 3.4280 grams)

Time of sampling, sec.	0	25	50	75	100	125	150	200	300	500	1000	1567
Temp. at bottom of charge, ° F.	2067	1937	1946	1958	1981	1998	2008	2030	2050	2055	2059	2049
Unit pressure, p.s.i.g.	999	998	1000	1000	998	996	995	995	994	994	995	995
Feed steam rate, SCF/hr.	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Helium sweep gas rate, SCF/hr.	24.7	24.4	24.6	24.7	24.9	25.2	25.4	25.4	25.9	26.0	25.6	25.4
Exit gas rate, SCF/hr.	24.7	38.9	37.5	35.9	34.3	31.8	30.4	27.8	26.6	26.5	25.8	25.7
Exit gas composition, mole %												
N_2	0.53	1.42	0.75	0.78	0.48	...	0.07	0.56	0.46	0.06	0.07	0.88
CO	...	3.80	3.60	2.40	1.70	1.32	1.00	0.10	...	...	...	...
CO_2	0.01	8.88	7.69	7.37	6.65	5.32	4.18	1.78	0.66	0.91	0.13	0.14
H_2	0.93	23.19	22.30	20.64	18.51	14.33	11.40	5.92	1.36	0.91	0.81	0.31
He	98.53	62.71	65.66	68.81	72.66	79.03	83.35	91.64	97.52	98.12	98.99	98.67
Total	100.00	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 carbon, lb./lb. C fed-hr.	...	26.8	23.0	19.1	15.6	11.5	8.6	2.8	1.0	1.3	0.2	0.2
Conversion of carbon fed, %	...	10.0	26.9	41.7	53.5	62.8	69.2	76.3	80.4	86.0	91.9	94.9

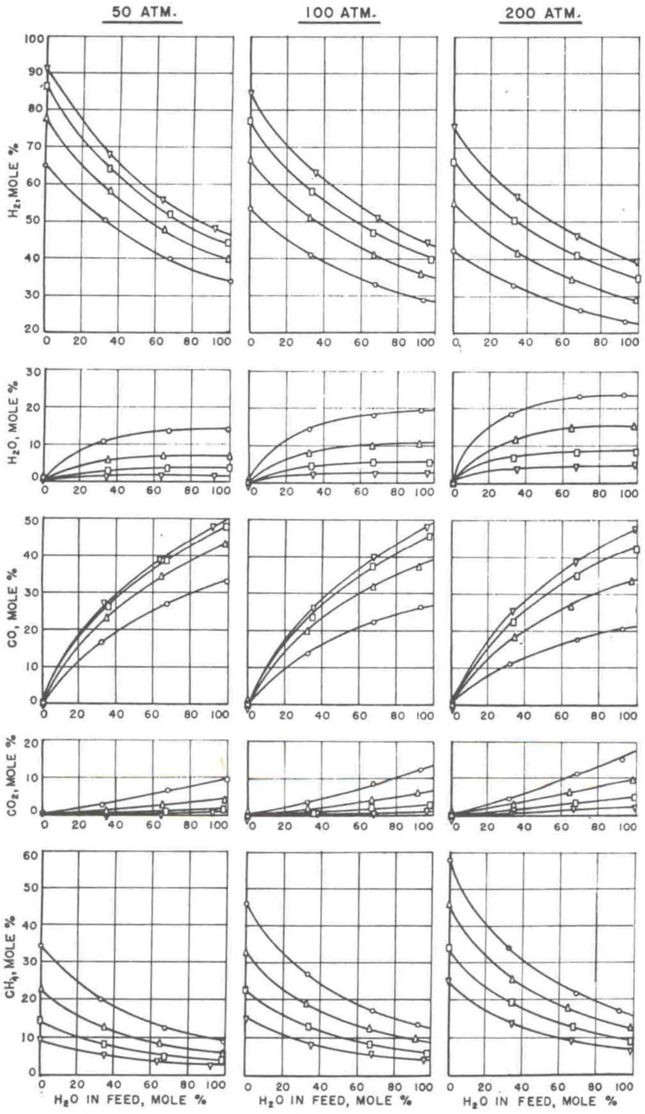

Figure 8. Ideal gas equilibrium compositions for steam-hydrogen gasification of carbon at high temperatures and pressures

Temp., °F.
○ 1700
△ 1900
□ 2100
▽ 2300

sample sizes would be a further reason for using larger coal char sample sizes.

The relationship between gasification rate and the degree of gasification is somewhat different from that with steam-hydrogen mixtures or hydrogen. Here, the rate of gasification is strongly influenced by temperature at all levels of carbon gasification, and the char reactivity decreases with increases in carbon gasification. The reactivity begins to drop very rapidly for all temperatures after about 100 to 150 seconds from the start of the run. A similar, but less pronounced, behavior was observed in a test at 2100° F. with steam-hydrogen feed gas. These results indicate that at higher temperatures the reactivity of the char may be affected by its previous gas environment. This loss in reactivity with steam-containing feed gases may apparently be counteracted by operation at higher temperatures, however, so that this should not be a serious limitation.

The combined results of tests conducted with −16, +20 U.S.S. sieve size char and at a 50-SCF-per-hour feed gas flow rate are presented in Figures 10 and 11. At lower temperatures,

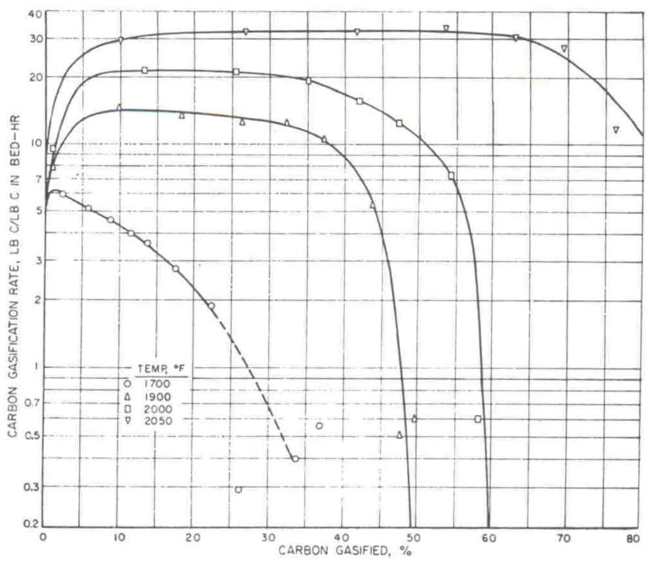

Figure 9. Effect of carbon gasification and temperature on gasification rate with steam

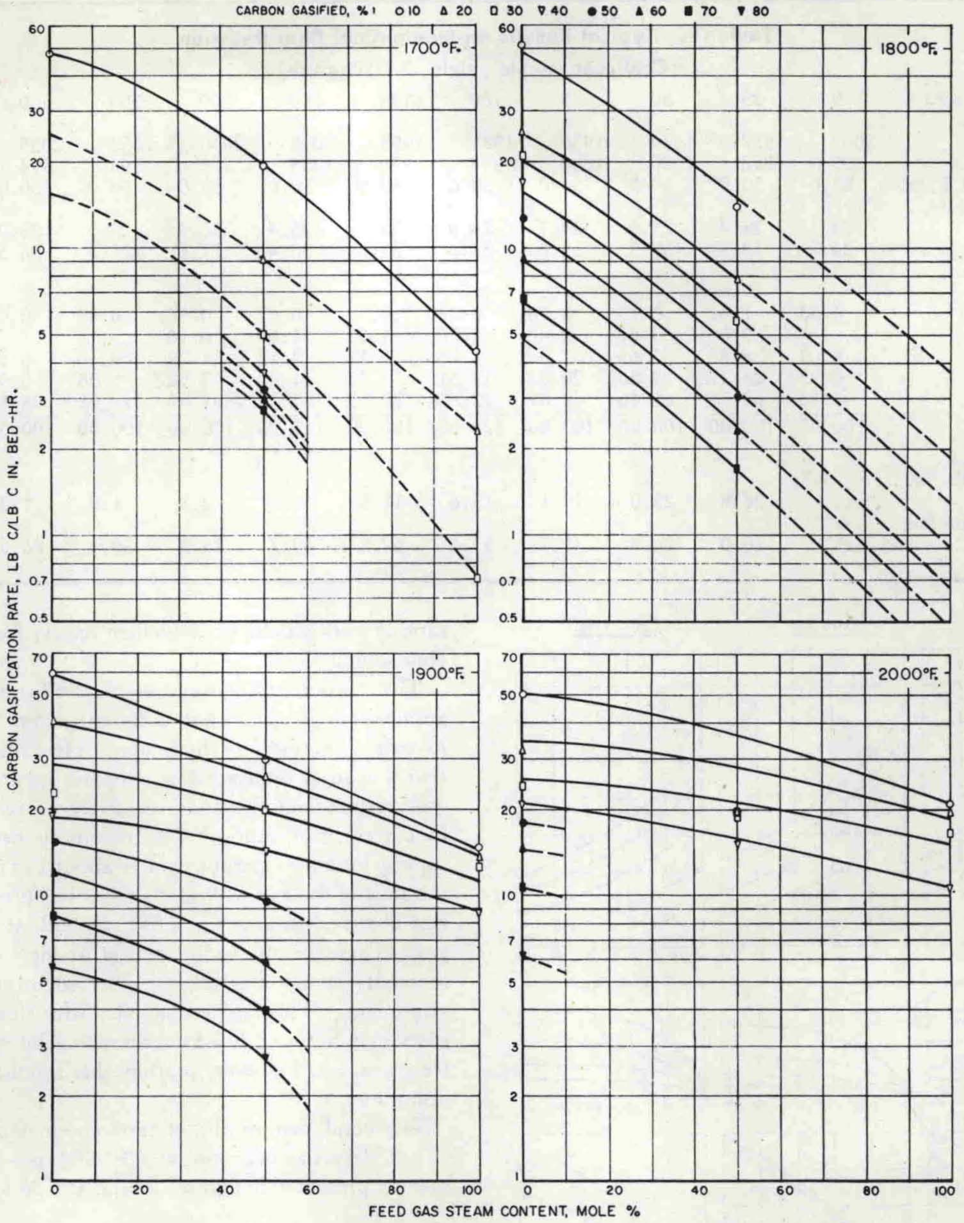

Figure 10. Effect of feed gas steam content and conversion on gasification rate at 1000 p.s.i.g.

the rate of gasification with hydrogen is many times that with steam, but as temperature is increased, the rate of steam gasification approaches that for hydrogen.

The results of these tests differ from those conducted at lower temperatures and pressures with less reactive feedstocks. Previous investigators have found that, at hydrogen partial pressures below 30 atm. and at 1300° to 1700° F., the addition of steam increased the methane formation rate (*3*, *7*, *8*, *16*), but no such "activating" effect was found here. This result is in agreement with previous work conducted at the institute (*6*). From Figure 11, it can be seen that the methane content of the product gas varies almost inversely with the feed gas steam content at higher carbon gasification levels. This decrease in methane yield with increases in feed gas steam content may, of course, be partially due to increased steam reforming of product methane with increases in steam partial pressure, discussed earlier. In addition, the high yields of carbon oxides at low carbon gasification levels and at low feed gas steam concentrations are partly due to devolatilization reactions which occur during the early phases of gasification. The relatively high oxygen content of this coal char (10.07 weight %), along with the fact that these carbon oxide-forming reactions occur very rapidly and in the very early stages of gasification (*6*), would cause the effects of these reactions to be accentuated.

Other investigators have observed an inhibition of the steam char reactions by hydrogen when working with highly devolatilized chars (*3*, *8*, *16*). In recent work with low-temperature bituminous coal chars at 1700° F., this inhibiting effect was also observed during initial stages of gasification (*6*). The results shown in Figures 10 and 11 were studied, therefore, to see whether there was evidence of hydrogen inhibition of the steam char reactions. If a first-order rate relationship for the formation of carbon oxides by steam is assumed—i.e., the rate of formation of carbon oxides proportional to the steam partial pressure—the carbon oxide-formation rates per unit steam partial pressure were apparently no less in the tests with steam-hydrogen mixtures than with pure steam. This result may be due to somewhat different experimental conditions (*6*). In the previous work with coal char the residence times of the exit gas in the heated portion of the reactor were only about one quarter as large as those in