EFFECT OF ADDITIVES UPON THE GASIFICATION OF COAL IN THE SYNTHANE GASIFIER

Albert J. Forney, W. P. Haynes, S. J. Gasior, and R. F. Kenny

Bureau of Mines, U.S. Department of the Interior, Pittsburgh, Pa.

Introduction

The Synthane process (1)[1], developed by the Bureau of Mines of the U.S. Department of the Interior, is a coal-gasification process in which caking coal is successively decaked and gasified in two individual fluidized beds. The decaked coal is fed from the pretreater directly into the gasifier. Based upon this technique, the Lummus Co. designed a 75-ton-per-day prototype plant, which is presently being built by the Rust Engineering Co. near the Bureau's laboratories at Bruceton, Pa., in South Park Township. In a continuing effort to improve the gasification process, tests are being performed in the original 4-inch-diameter gasifier located at the Pittsburgh Energy Research Center at Bruceton, Pa. Results from the latest gasification tests performed with additives are discussed in this report.

Additives Used

Table 1 shows the analysis of the compounds used as additives in the Bruceton gasifier. The additives were mixed with coal and the mixture then fed to the pretreater-gasifier. Table 2 lists typical gasification tests showing data in which following graphs are based. Lignites and subbituminous coal tests are included for comparison purposes but are not shown in the graphs.

Effect on Carbon Conversion

Figure 1 shows results of tests where we operated with and without additives[2] showing carbon conversion vs bed temperatures. We used 2%, 5%, and 10% limestone (dolomitic limestone), 2% and 5% hydrated lime, 2% quicklime, and 5% lignite ash. Results show an average increase of about 10% in carbon conversion for the parameter for additive tests above the parameter shown for nonadditive tests.

Effect on Steam Decomposition

Figure 2 shows the effect of the same additives on the steam decomposition. The steam decomposition was increased 5% to 10% above the parameter for nonadditive tests. The highest increases were with CaO and hydrated lime.

Effect on H_2 + CO + CH_4 Yields

As would be expected because of the increased carbon conversion, the yields of H_2 + CO + CH_4 increased about 1 to 2 scf/lb coal (MAF basis) using the additives as shown in figure 3. Again the use of hydrated lime shows the greatest increase.

Effect on Sulfur in the Char

As shown in figure 4, some additives increase the sulfur in the char. What we were interested in especially was a reduction. Agricultural limestone (showing sulfur in char of 0.4% and 0.6%) showed the greatest decrease in the sulfur. Hydrated lime and CaO showed that their use would increase the sulfur in the char. This is an undesirable effect because a low-sulfur char is needed to raise steam needed for the plant, and the stack gas effluent must meet EPA standards. The line shown in this figure is the average for the nonadditive tests.

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[1] Underlined numbers in parentheses refer to list of references at end of this paper.

[2] All tests using additives were made with Illinois No. 6 coal. All nonadditive tests discussed in figures 1 to 5 were made with Illinois No. 6 coal.

Effect on Slag[3] Formed in the Gasifier

In Figure 5 the amount of slag (cinder) formed in the gasifier is shown as a function of the maximum temperature in the gasifier. The majority of the tests with the additives show no slag formation. This is an important point since if the slagging temperature can be raised, the gasifier could be operated at a higher temperature, thus achieving a higher throughput in the gasifier. This result has been noted in the literature (2) as has other effects of these additives as discussed in this paper (3, 4).

Effect of Additives on the Water Effluent From the Gasifier

The effect of additives on water effluents resulting from gasification of various coals is shown in Table 3, which shows analyses of water effluents from Illinois No. 6 coal, Wyoming subbituminous, Illinois char, North Dakota lignite, Western Kentucky, and Pittsburgh seam coal. Coke-plant effluent was shown for comparison since it has been successfully treated for over 10 years by Bethlehem Steel Co. at Bethlehem, Pa. (5). Since the coke-plant effluent can be treated, we know the gasifier plant effluent can be also. As shown in the table, compared with Illinois No. 6 coal test without additives, the additive caused higher quantities of phenol, ammonia, and COD (chemical oxygen demand). Reasons for such increases are not known at this time.

Effect of Additives on the Gas Made in the Gasifier

Table 4 shows the effect of CaO and dolomitic limestone on components in the gasifier gas. The largest increase is in the BTX (Benzene-Toluene-Xylene) fraction. Reasons for these changes are not known.

We plan also to examine the tars to see if there is a difference in tar quality with additive tests, but such results are not yet known.

Conclusions

Additives such as limestone, hydrated lime, and quicklime all have a positive effect on the gasification rate. Limestone, in addition, raises the sintering temperatures and may lower the sulfur contained in the char from the gasifier. More tests are needed to establish the effect on the water and gas from the gasifier. We also plan to perform tests using ashes and chars from various coals as additives. When we have enough data to assess the advantages of the additives, cost studies will be made to determine economic feasibility.

[3] This material called "slag" is more like a cinder in that it is not a hard slag.

TABLE 1. - Additives used in the Synthane Gasifier

Material	Analysis, wt-pct				
	$CaCO_3$		$MgCO_3$		
Limestone (Dolomitic)	54		44		
	CaO		MgO		H_2O
$Ca(OH)_2$ Hydrated or Slaked Lime........	72 (min.)		0.05		23
CaO Quicklime..................	97				
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5
Lignite Ash....................	12.3	11.5	12.5	0.3	0.6
	CaO	MgO	Na_2O	K_2O	SO_3
	23.0	8.9	3.8	0.4	25.4

TABLE 2. - Typical data from coal gasification tests

Test[1]	11	3	48	83	37	46	W-2	L-7
Coal Type	Ill. #6	Ill. #6	Ill. #6	Ill. #6	Ill. #6	Ill. #6	Sub-bit.	Lignite
Additive	None	None	5% Lime-stone	5% Lime-stone	2% Lime-stone	5% Hydr. lime	None	None
Coal Feed								
lb/hr	18.9	20.4	18.7	25.9	20.7	19.0	38.0	32.4
$lb/hr\text{-}ft^2$	221	239	219	304	242	223	446	379
$lb/hr\text{-}ft^3$	40	43	40	55	44	40	81	69
Steam Rate lb/lb coal	1.06	0.87	1.25	0.97	0.98	1.08	0.55	0.77
Oxygen Rate lb/lb coal	0.30	0.27	0.33	0.25	0.35	0.41	0.14	0.13
Carbon Conversion, %	68	65	68	60	93	81	68	75
Steam Conversion	15	25	15	20	36	30	18	51
$\frac{\text{SCF } H_2 + CO + CH_4}{\text{lb Coal, MAF}}$	13.3	13.9	12.8	12.1	20.4	16.7	12.7	18.2
$\frac{\text{SCF } CH_4}{\text{lb Coal, MAF}}$	3.6	3.9	3.6	3.4	4.5	4.2	3.4	4.2
Max. Temp., ° C	970	960	958	965	1020	1040	925	880
Av. Temp., ° C	928	947	920	900	951	919	867	855
Sulfur in coal, %	3.4	3.4	3.3	3.3	3.2	3.4	0.6	1.3
Sulfur in char, %	0.8	1.2	0.4	0.9	1.3	1.7	0.2	1.6
Slag, % of coal feed	3.0	0.6	0.9	0.0	6.0	2.6	2.7	1.0

1/ All coals are ground to 20 x 0 mesh, ahout 30% through 200 mesh.

TABLE 3. - Byproduct water analysis[1] from Synthane gasification of various coals

	Coke plant	Illinois No. 6	Ill. #6 w/5% lime-stone	Ill. #6 w/20% lime-stone	Ill. char	N. Dak. lignite	W. Ky.	Pgh. Seam	Wyoming sub-bit
pH	9	8.6	8.4	9.2	7.9	9.2	8.9	9.3	8.7
Suspended solids	50	600	136	92	24	64	55	23	140
Phenol	2,000	2,600	3,500	4,950	200	6,600	3,700	1,700	6,000
COD	7,000	15,000	22,000	22,134	1,700	38,000	19,000	19,000	43,000
Thiocyanate	1,000	152	196	102	21	22	200	188	23
Cyanide	100	0.6	0.8	0.5	0.1	0.1	0.5	0.6	0.2
NH_3	5,000	[2] 8,100	15,100	10,400	2,500	7,200	10,000	11,000	9,520
Chloride		500	435		31				
Carbonate		[3] 6,000							
Bicarbonate		[3] 11,000							
Total Sulfur		[4] 1,400							

[1] Mg/liter (except pH)
[2] 85% free NH_3
[3] Not from same analysis
[4] $S^{=}$ = 400
$SO_3^{=}$ = 300
$SO_4^{=}$ = 1,400
$S_2O_3^{=}$ = 1,000

Table 4. - Components in gasifier gas[1]

	Ill. No. 6	Ill. #6 w/5% lime-stone	Ill. #6 w/5% CaO	Ill. #6 w/2% CaO	Ill. char	Wyoming sub-bit	W. Ky.	N. Dak. lignite	Pgh. Seam
H_2S..............	9,800	3,600	7,480	8,100	186	2,480	2,530	1,750	860
COS..............	150	70	10	330	2	32	119	65	11
Thiophene.........	31	134	40	260	0.4	10	5	25	55
Methyl thiophene..	10	50	6	37	0.4	--	--	--	7
Dimethyl thiophene	10	11	5	37	0.5	--	--	11	6
Benzene...........	340	1,890	510	2,790	10	434	100	1,727	1,050
Toluene...........	94	230	85	720	3	59	22	167	185
C_8 Aromatics......	24	36	20	160	2	27	4	73	27
SO_2..............	10	20	9	---	1	6	2	10	10
CS_2..............	10	--	5	---	-	-	-	--	--
Methyl mercaptan..	60	125	50	330	0.1	0.4	33	10	8

[1]PPM by volume.

References

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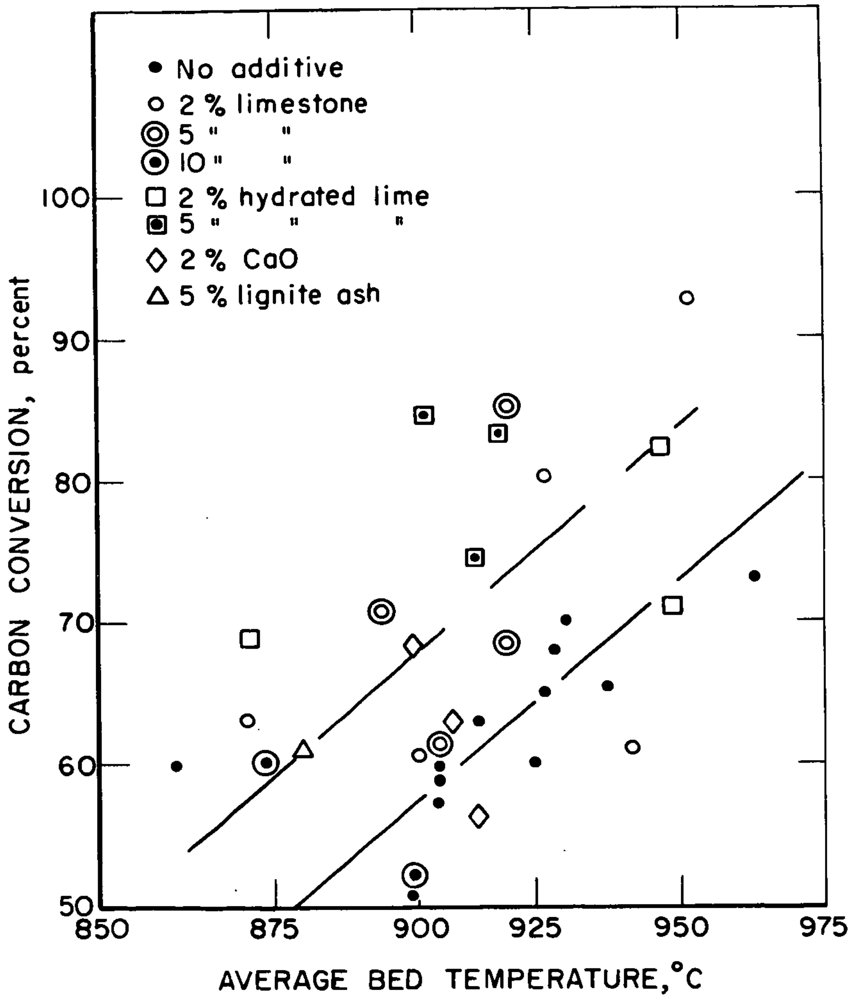

Figure 1. Effect of Additives on Carbon Conversion

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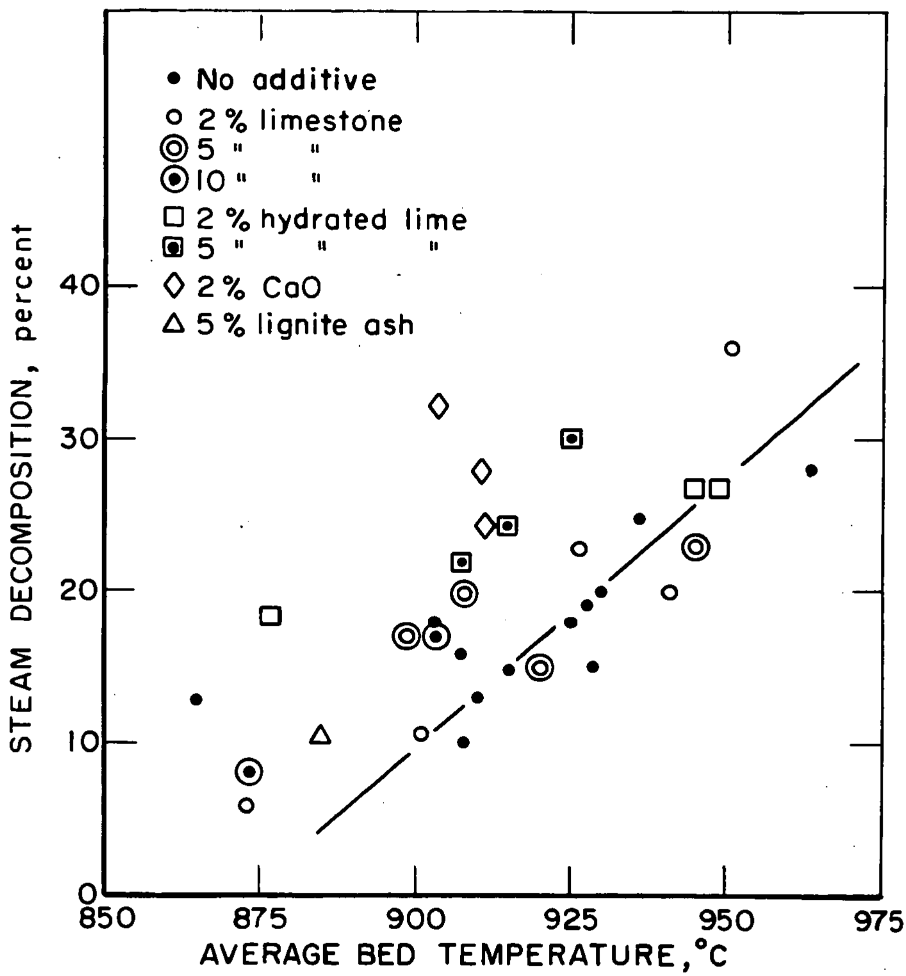

Figure 2. Effect of Additives on Steam Decomposition

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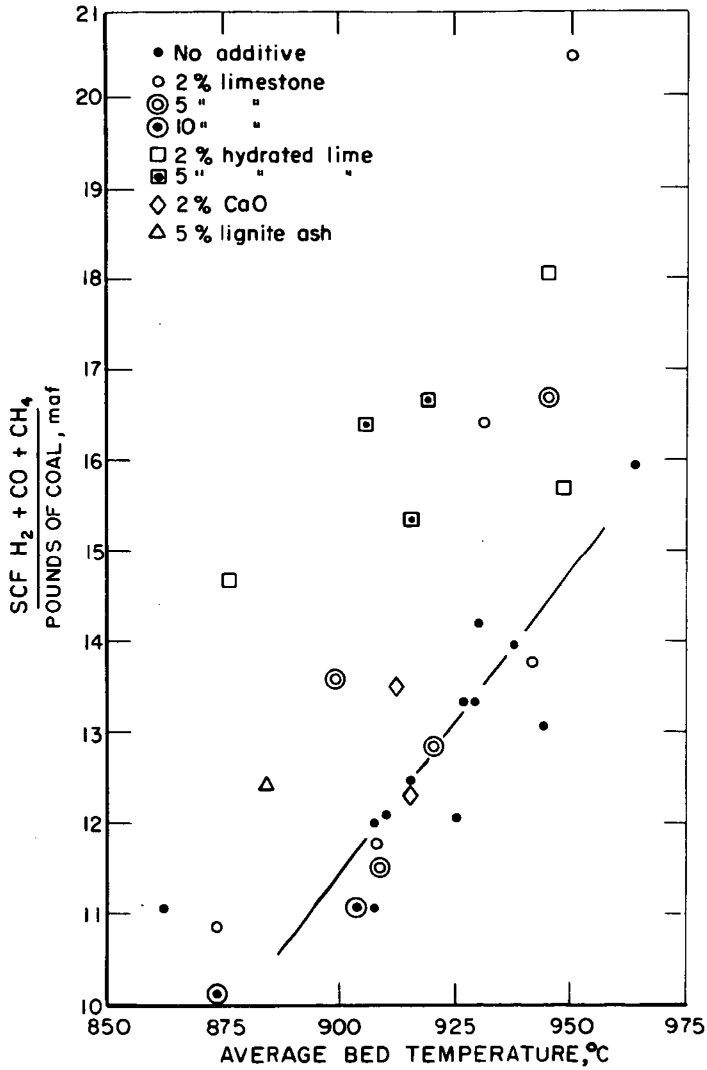

Figure 3. Effect of Additives on H_2 + CO + CH_4 Yields L-13389

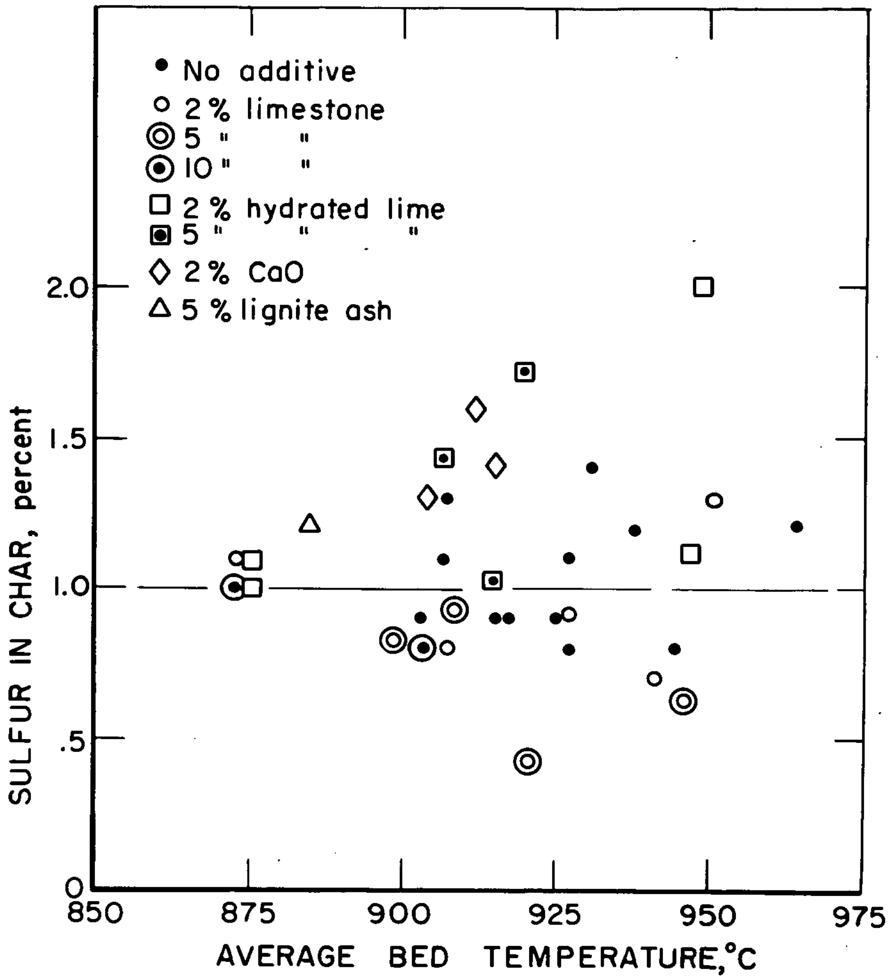

Figure 4. Effect of Additives on Sulfur in Char

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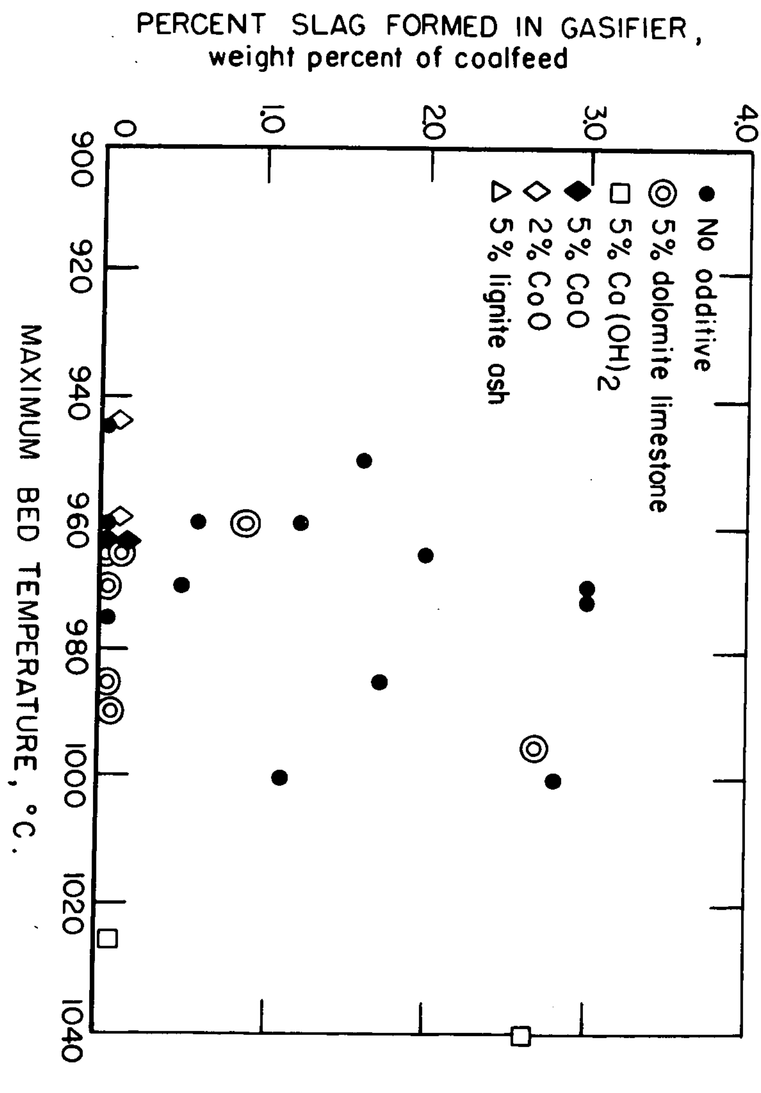

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Figure 5. Effect of Additives on Slag Formation