

EFFECT OF HYDROGEN SULFIDE ON THE SULFUR CONTENT OF BITUMINOUS COKE  
AT 800 TO 1000°C.

T. S. Polansky and E. C. Knapp\*

Department of Fuel Technology, The Pennsylvania State University,  
University Park, Pennsylvania

\* Research Chemist, Shawinigan Resins Corporation, Springfield 2, Mass.

ABSTRACT

Three samples of coke were reacted with two different concentrations of hydrogen sulfide at 800, 900 and 1000°C. for two hours each. The samples represented a bulk sample prepared from a High Volatile A coal in a small laboratory oven at 1100°C. wall temperature. Reduction of the bulk coke to minus 10 mesh and screening gave sample A, 10 x 60 mesh, and sample C, minus 60 mesh. An aliquot of sample A ground to minus 60 mesh produced sample B. Based on the grinding properties and color, coke C was assumed to be less carbonized than coke A.

Increases in sulfur content reached a maximum at about 900°C. with each sample. Organic sulfur is chiefly responsible for the increase. Coke C was most reactive and coke A least. These differences indicate that the reaction begins below 800°C. and that the degree of reactivity is influenced by the nature of the carbon and its ultrafine structure.

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Department of Fuel Technology, The Pennsylvania State University,  
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INTRODUCTION

Hydrogen sulfide is the predominating sulfur-bearing component of bituminous coal gas in the byproduct coke oven process. It usually amounts to over 95% of the sulfur in the crude gas at a concentration range of 0.3 to 3.0 volume per cent, which depends largely on the amount of sulfur in the coal. However, most commercial coal gas contains about 0.6 volume per cent (1). From coke oven and gas retort operations, analyses show that 25 to 30% of the coal sulfur is liberated as hydrogen sulfide (2). The analyses also show that 50 to 60% and sometimes higher, of the coal sulfur is retained in the coke.

The evolution of hydrogen sulfide and other sulfur compounds from coal begins at about 250°C. The reactions which produce these volatiles are largely completed in the range of 500 to 800°C (3). Both the organic and inorganic, mostly pyritic, forms of sulfur, which constitute over 90% of the sulfur in most coking coals, form hydrogen sulfide (4). The sulfate form, which exists only in small quantities, is reduced to the sulfide form in the coking process. The amount of hydrogen sulfide liberated ranges from about 25 to 50% of the organic sulfur in the coal. Pyrite decomposes completely at 600°C. in coal to produce hydrogen sulfide, ferrous sulfide, and pyrrhotite (4). Its decomposition is favored at the temperatures existing in coke ovens, wherein hydrogen and methane are the main components of the coal gas (5).

The reactions occurring in coke ovens are complex, since the primary products evolved from the plastic zone suffer secondary decomposition during their travel of contact with incandescent coke and hot oven walls. Secondary reactions appear to be the most important factor influencing the total amount and concentration of the sulfurous volatiles regardless of the parent sulfur forms in the coal. Moreover, the nature of mineral matter in coal may also be an important factor in affecting the amount and types of sulfurous volatiles liberated (6).

The most marked change determined directly by chemical means occurs with pyrite. The organic form in both coal and coke is obtained by difference. Its form in coke is in stable complex combination with carbon atoms originating partly from the organic form of the parent coal and partly from the sulfur liberated by the decomposition of pyrite and adsorbed during carbonization (4,7). The nature of the stable complex formed by reaction of sulfur produced from decomposition of pyrite with coke was described as analogous to the carbon-surface oxide complex of coal (8).

The constitution of this complex is unknown (7). The organic sulfur in coal partly forms complexes with carbon in the range of 400° to 500°C. which do not exhibit the properties of the original form in coal (4). In coke, the complex was described as a solid solution of carbon and sulfur which includes adsorbed free sulfur (9). X-ray analyses indicated that the solution characterizes a

mixed crystal system in which it is believed a sulfur atom replaces a carbon atom within the graphite-like crystal lattice (10,11,12). The organic sulfur in coke was also considered to exist partly as a solution or as physically held by adsorption and the remainder as chemical combination which compounds were impossible to isolate (13).

Conclusive evidence of the existence of similar complexes has been established in sulfurous carbons formed by interaction of carbons with hydrogen sulfide, sulfur dioxide, sulfur and other sulfurous gases (7,8). Among these the effect of coal ash constituents, iron oxide and silica, on the fixation of sulfur in filter paper char interacted with hydrogen sulfide at 700°C. was investigated (8). Upon heating of the chars to 1200°C, the presence of iron has apparently caused a marked retention of sulfur while silica exhibited very little or no retention. Above this temperature the carbon-sulfur complex interacts with both the iron sulfide formed at lower temperatures and the silica with a consequent loss of sulfur. Similar retention of sulfur in coke was also observed when pyrite, ferrous oxide, metallic iron and other chemicals, which produce stable sulfides, were added to the coal before carbonization (4,14,15). The retention appears attributable to the fact that the affinity of iron for sulfur is greater than that of hydrogen for sulfur at the temperature existing in the coke oven (7). Ferrous sulfide is the chief stable sulfurous compound of coke, and any iron formed by its reduction in the coke oven will generally tend to revert to the sulfide in the presence of hydrogen sulfide (7).

Although no quantitative data are recorded, hydrogen sulfide is recognized to react with hot coke to form the carbon-sulfur complex (7,15,16). When heated alone, hydrogen sulfide decomposes into hydrogen and diatomic sulfur above 650°C. (17). Based on this, it appears that elemental sulfur is very likely an intermediate in the formation of the carbon-sulfur complex in coke. This complex together with the residual organic sulfur of the raw coal and that from reduction of ferrous sulfide constitute the total organic sulfur in coke. In the by-product coke oven process, hydrogen sulfide comes into contact with hot coke during its escape from the plastic state of the coal. Consequently, its reaction with coke may take place at various temperatures.

This investigation is concerned with the interaction of hydrogen sulfide and high-temperature coke in the temperature range of 800° to 1000°C. The purpose is to determine its effect on the sulfur content and on the distribution of sulfur forms of coke at these temperatures.

#### PREPARATION AND ANALYSES OF COKE SAMPLES

Carbonization of the Coal. The bituminous coal employed to prepare the coke samples was of High Volatile A Rank from the Elkhorn No. 3 seam in Letcher County, Kentucky. It was ground to minus 10 mesh (U.S. Standard) for carbonization. Its proximate analysis was 1.0% moisture, 36.2% volatile matter, 2.6% ash, and 60.2% fixed carbon.

The coal was coked in a small laboratory movable-wall oven equipped with a calibrated ring dynamometer and Baldwin-Lima strain gauge analyzer for measuring carbonization pressure (18). A seven-pound sample of bulk density 40.4 lbs./cu.ft. was coked in 80 minutes with the oven walls heated electrically at 1100°C. The maximum force obtained was 58 lbs. which is equivalent to about 1 lb./sq.in. of the Russell oven (19). A yield of 4.4 pounds of coke was obtained.

Samples of Coke Prepared. The coke was reduced to minus 10-mesh (U.S. Standard) by successively passing it through a jaw crusher and Braun pulverizer. A 200-g. riffled sample was then further reduced to minus 60 mesh (U.S. Standard) in a Mikro-Mill pulverizer for analysis. Screening of the remaining minus 10-mesh sample produced 47% of minus 60-mesh size. This procedure allowed the separation of coke into different fractions based on their grindability characteristics. It was assumed that these fines contained more of the coke that was produced in the central portion of the coke oven charge. The fines appeared blacker in color, softer to the touch and less carbonized than the 10 x 60 portion adjacent to the coke oven walls.

The remaining 53% (10 x 60 mesh) was divided and about half was ground to minus 60 mesh. This gave two samples of the harder fraction of different mean particle size. Table I indicates the degree of carbonization of the coke according to the

dry, ash-free volatile matter content. Coke C, the softer minus 60-mesh fraction, contained 2.8% volatile matter whereas cokes A and B, representing the harder fraction of the original minus-10 sample, contained 2.0% volatile matter.

Chemical Analyses. A.S.T.M. Standard procedures for proximate analysis and total sulfur by the Eschka method were employed for the coal and coke samples (20). In the Eschka method, the sulfur is oxidized to the sulfate form and the amount of sulfur is finally calculated from the quantity of barium sulfate determined.

The pyritic form of sulfur was determined by oxidation during extraction to the sulfate form with dilute nitric acid (4). The sulfate in the final purified solution, free of iron, is converted to barium sulfate from which the pyritic sulfur is calculated. The determination of the sulfate form was made by using dilute hydrochloric acid and barium chloride to precipitate the sulfate (4). It is to be noted that the coal under study did not contain any sulfate sulfur.

Acid-volatilized inorganic sulfur was determined because hydrogen sulfide was detected during analysis of a number of cokes for pyrite (4). Previous workers also observed this and attributed this reaction to the presence of sulfides of calcium, et cetera (4,15,22). Its determination was carried out in a closed system by treating 2 g. of coal or coke with 100 ml. of dilute nitric acid, 1.3, from a dropping funnel. The hydrogen sulfide liberated was swept by air for an hour into an ammoniacal solution of cadmium chloride contained in two flasks. The solution was prepared by dissolving 3.2 g. of anhydrous cadmium chloride in 100 ml. of distilled water and adding 60 ml. of concentrated ammonium hydroxide to this solution. The yield of cadmium sulfide is determined and the percentage sulfur is accordingly calculated. The organic form of sulfur was determined by difference between the sum of the inorganic forms and the total sulfur content. The analyses of the coal and coke samples are presented in Table I.

Screen Analysis of Coke Samples. The size distribution data for cokes A, B and C are shown in Table 2. The data confirm the viewpoint on the grindability characteristics of the bulk coke sample in its reduction to minus 10 mesh. The harder and the softer coke data were calculated using the method of Hatch and Choate (23), and these data are shown on log-probability paper in Figure 1 for convenience.

The slope of the straight line portion of this curve is an indication of the ease of grinding. That is, the greater the slope, the harder it is to grind the sample. The departure from the straight line in the upper portion of the curve is caused by the limitation of the data and the deviation from the theory. This is obtained by omitting the upper limit of 10 mesh in the theory. Because of fluidization by air during grinding and sieving, the data deviate from the straight line in the lower portion of the curve in the fine particle size region. This is illustrated by the dotted line marked "theoretical" in Figure 1. The lower deviation cannot be caused by a build up of mineral matter in the fines, since there may be a slight reverse tendency as indicated by the ash values on Table 1. This might mean that the coke-mineral matter combination is slightly harder than the coke which contains less firmly bonded mineral matter.

The properties of coke vary principally because of the temperature gradient that exists during carbonization. Its non-uniformity in color and strength has been recognized (24,25). The strength of coke on grinding was found to increase with the temperature of formation of coke as opposed to a decrease in shatter index of the same coal (26). Flotation of ground coke into various fractions has shown that the black part of coke (sink fraction) contained more volatile matter and ash than the more carbonized part (float fraction) (27). The analysis of the coke samples in Table 1 and the different slopes of the straight line portion of the sieve analysis data in Figure 1 show evidence of the unhomogenous nature of coke.

#### APPARATUS AND PROCEDURE

The apparatus is schematically represented in Figure 2. The numbers refer to the corresponding numbers in Table 3 which includes a detailed design and specifications of the apparatus. The purity of the gases is also shown in Table 3. The simple design allowed a metered stream of hydrogen sulfide diluted with nitrogen. The gas

mixture was preheated before it made contact with a vertical fixed bed of coke which was maintained at the temperature of the run.

A 45-g. coke sample was introduced into the reactor through a funnel at the top and allowed to drop on to the support screen. The delivery and condenser system was then connected to the reactor. Nitrogen gas at a constant rate of 0.3 cu. ft./hr. purged the entrapped air. The reactor and the preheater were regulated to the run temperature. This required about 20 minutes. The hydrogen sulfide supply was adjusted to the desired rate, and the reaction with the hot coke proceeded for two hours. At the end of the run, after cutting off the supply of hydrogen sulfide, cold nitrogen was used to return the coke to room temperature.

The reactions were carried out with two different concentrations of hydrogen sulfide, 0.013 cu. ft./hr or mol concentration of 4.2% and 0.029 cu.ft./hr or mol concentration of 8.8% using nitrogen as carrier gas. The results of the reactions with cokes A, B and C at 800, 900, and 1000°C. are shown in Table 4.

#### DISCUSSION OF RESULTS

The analyses of the coal given in Tables 1 and 2 show 0.70% sulfur and 2.6% ash. The sulfur is 91.4% organic and 8.6% pyritic in nature. The relatively small amounts of sulfur, mineral matter and pyrite permitted the study of the reaction of hydrogen sulfide and coke, which factors would have less effect on the reactions contributing to the sulfur content of the coke. The bulk coke data indicate that almost 50% of the coal sulfur was liberated during carbonization. This agrees with in the range of values reported by other workers (2). Assuming that up to half of the pyritic sulfur contributed to the organic sulfur of coke, calculations show that the percentage of the organic sulfur liberated ranges from about 49.5 to 50. It has been reported that the amount of organic sulfur released ranges from 25 to 50% (4). No distinction in the organic sulfur content was found between the cokes A, B, and C, but these differ with the bulk sample, probably due to experimental errors.

The percentages of inorganic forms of sulfur in the cokes given in Table 1 indicate that sulfides of calcium and of other cations have been formed as based on evolution of hydrogen sulfide under acid conditions. The formation of sulfides has been reported by other workers (4,15,22). The differences in the inorganic forms in cokes A, B, and C indicate that acid volatile sulfur and pyrite decomposition are favored at more severe carbonizing conditions. However, these differences are very close to the limits of the experimental error inherent in the analysis.

The effect of the reaction of hydrogen sulfide on the sulfur content of the coke samples is shown in Figure 3. In each case the sulfur increased, but the increase varied with the concentration of hydrogen sulfide, the reaction temperature and the nature of the coke. Greater increases in sulfur occurred with the higher concentration of hydrogen sulfide, which amount reached a maximum at about 900°C. At the lower concentration optimum reactivity appeared slightly below this temperature, indicating the probable effect of concentration on the equilibrium conditions. The results indicate that the carbon-sulfur complex becomes less stable above this temperature. Ferrous sulfide and other sulfides are more stable at these temperatures (4,7).

Coke C, being the softer portion of the bulk sample, was more reactive than the harder cokes A and B. Coke A, 10 x 60 mesh, was less reactive than its counterpart Coke B, minus 60 mesh, indicating that surface area probably influences the reaction. The greater reactivity of Coke C, minus 60 mesh, over that of Coke B shows the possible effect of carbonizing conditions in the oven. These differences suggest that the reaction begins and proceeds more effectively with coke produced at some lower temperatures than that at the coke oven walls. The nature and the stability of the carbon-sulfur complex, the porosity, size and the nature of the coke as well as the mineral matter may influence the degree of the reaction and the amount of sulfur retained. These could account for the variations indicated in Figure 2.

The influence of hydrogen sulfide on the sulfur forms is given in Figures 4 and 5. In view of the scattering of the data and of the limits of experimental

error, it is apparent that concentration of hydrogen sulfide and temperature had no marked influence on the quantity of inorganic sulfur. For the most part, the amount of this sulfur was greater than that in the original coke samples because the total sulfur was higher in the reacted samples. Pyrite, being the only inorganic sulfur constituent in the coal, was probably decomposed to form ferrous sulfide under the conditions studied. The increased amount of inorganic sulfur, determined as acid extracted and volatile sulfur, points to the formation of sulfides with calcium and other cations.

Again coke C was more reactive than the harder cokes A and B as indicated by their difference in extracted sulfur content given in Table 4. Its content in coke C was highest at all reaction temperatures and concentration of hydrogen sulfide. The results suggest that the reaction is favored at lower carbonization temperatures. Under such conditions the mineral matter is probably less firmly bonded to the more porous coke which would account for the higher reactivity of coke C. Coke A was least reactive which implies that particle size and porosity are factors affecting the reactions.

The increase in total sulfur is chiefly paralleled by the increase of organic sulfur as illustrated in Figures 3 and 5. Optimum reactivity appeared around 900°C. whereat the higher concentration of hydrogen sulfide was more reactive. Table 4 shows that maximum increase of organic sulfur was about 3.4-fold while that of total sulfur was around 3.6-fold. This experimental evidence supports the view of various workers that hydrogen sulfide contributes to the organic sulfur of coke during the carbonization process (4,7,15,16,25).

The reaction of hydrogen sulfide with hot coke was deemed to involve the formation of a carbon-sulfur complex on the surface of the carbon (1). After the complex reached a sufficient concentration, the sulfur was evolved as carbon disulfide. It is generally recognized that carbon disulfide is produced at higher temperatures of carbonization (28). The decrease in organic sulfur of the coke samples at 1000°C. in this study is explained on this basis.

Hydrogen sulfide has been found to decompose homogeneously to give hydrogen and sulfur ( $S_2$ ) at 650°C. (17). Although its decomposition temperature during carbonization is unknown, it no doubt decomposes at temperatures below that at the coke oven walls. Sulfur is known to exist as polyatomic molecules at relatively low temperatures, but with increasing temperatures from the plastic state of the coal to the coke oven walls, any such molecules if formed, would tend to dissociate into smaller units. Its ability to form carbon-sulfur complexes is well known. The nature of the complex was considered to be similar to Rhead and Wheeler's carbon surface oxide complex  $C_2O$  (8). Based on this and on the fact that the outer orbital electronic configurations of sulfur and oxygen are similar, sulfur and oxygen atoms might react with carbon in an analogous manner. The initial formation of the carbon-sulfur complex via hydrogen sulfide appears to depend upon the nature of the reactive sites on carbon and upon the environment. The availability of the sites would probably be governed by the extent of the competing dehydrogenation reactions involved with free sulfur. Because of these factors and because of the secondary decomposition nature of the reaction, it is probable that the formation of the complex commences somewhere above 500°C.

The nature of the carbon appears to be important in the formation of the complex. It was suggested that only amorphous carbon forms the complex and that this is due to the high degree of unsaturation of the surface atoms of such carbon (8). From a physical point of view, the magnitude of specific surface areas of (powdered) cokes was considered to be connected with the formation of carbon sulfur complexes (7). The evidence in this study tends to support these views.

The higher reactivity of coke C over carbonized cokes A and B suggests that the reaction takes place more effectively with coke produced at temperatures below that at the coke oven walls. Such coke presumably contains more reactive sites upon which the sulfur is probably adsorbed and reacts more easily with the carbon. Although the retention of sulfur as a complex is known to depend on the temperature and the atmosphere prevailing during carbonization, it may also depend on the nature

of the complex. Figure 5 shows that the organic sulfur of coke C is considerably less stable than that of cokes A and B at 1000° under the condition studied. The temperature gradient in a byproduct oven suggests that a portion of the complex formed by reaction with hydrogen sulfide would tend to survive the carbonization process.

Physically, the formation of coke from the semicoke stage is a progressive contraction process. Recent studies show that with increased carbonization temperature a continuous decrease occurs in the diameters of the capillary constrictions associated with the internal structure of coke (29). Evidence of this was based on the decreased size of gaseous molecules necessary to penetrate into the internal structure. This implies that the diffusion of hydrogen sulfide into the capillaries would be greater with coke produced at lower temperatures. The differences in the reactivity of the coke samples tend to support this concept.

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TABLE I

PROXIMATE ANALYSIS AND SULFUR FORMS OF COAL AND COKES

Sample Basis (1)	Proximate Analysis, %					Sulfur Analyses, %			
	Moisture	V.M.	F.C.	Ash	Total	Inorganic Extract.	Vol.	Organic	
Coal	1	1.0	36.2	60.2	2.6	0.69	0.06	0.00	0.63
	2	-	36.6	60.8	2.6	.70	.06	-	.64
	3	-	37.6	62.4	-	-	-	-	.65
Coke (Bulk)	1	0.7	2.2	92.0	5.1	0.56	0.02	0.06	0.48
	2	-	2.2	92.7	5.1	.56	.02	.06	.48
	3	-	2.3	97.7	-	-	-	-	.51
Coke A (2)	1	0.6	1.9	93.1	4.4	0.56	0.01	0.05	0.50
	2	-	1.9	93.7	4.4	.56	.01	.05	.50
	3	-	2.0	98.0	-	-	-	-	.53
Coke B (2)	1	0.9	1.9	92.1	5.1	0.56	0.01	0.05	0.50
	2	-	1.9	92.9	5.2	.56	.01	.05	.50
	3	-	2.0	98.0	-	-	-	-	.53
Coke C (2)	1	1.2	2.6	90.7	5.5	0.56	0.02	0.03	0.51
	2	-	2.6	91.8	5.6	.57	.02	.03	.52
	3	-	2.8	97.2	-	-	-	-	.55

(1) 1, as received; 2, dry; 3, dry, ash-free

(2) Coke A, 10 x 60 mesh of original -10 mesh; Coke B, coke A ground to -60 mesh; Coke C, -60 mesh of original -10 mesh

TABLE 2

## SCREEN ANALYSIS OF COKE SAMPLES

U.S. Standard Mesh	Screen Opening Microns	Log <sub>10</sub> of Geometric Mean Opening Microns	Determined Wt., %			Calculated Wt., %	
			Coke A	Coke B	Coke C	Cokes A & B Cumulative	Coke C Cumulative
200	74	1.946	39.1	45.7	18.4	18.4	45.7
140 x 200	105	2.098	13.0	14.8	6.1	24.5	60.5
100 x 140	149	2.286	18.9	18.5	8.9	33.4	79.0
60 x 100	250	2.511	29.0	21.0	13.6	47.0	100.0
40 x 60	420	2.775	20.9		11.0	58.0	
20 x 45	840	3.114	39.9		21.2	79.2	
10 x 20	2000		39.2		20.8	100.0	

(1) Example:  $(74 \times 105)^{1/2} = 88$ ;  $\log_{10} 88 = 1.946$

TABLE 3

APPARATUS SPECIFICATIONS; ITEM NUMBER  
REFER TO FIGURE 2

ITEM NO:	DESCRIPTION
1	Cylinder (nitrogen gas; Matheson Co. Inc., water-pumped, standard purity)
2	Brooks rotameter, size 1-15-3, maximum capacity 0.40 cu.ft. per hr. at 25°C., 1 atm.
3	"Drierite" drying towel and copper wool deoxygenifier with furnace at 450°C.
4	Cylinder (hydrogen sulfide; Matheson Co. Inc., 99.9% pure)
5	Fischer rotameter, No. 08-150 D.W.G.-S-21654-3, maximum capacity 0.05 cu.ft. per hour at 25°C., 1 atm.
6	Mixing tee
7	Preheater, Hevi Duty furnace, type 70, 1-inch ID and preheater tube packed with porcelain rods; temperature maintained at 500°C. with variac type 116
8	Mullite Coors reactor tube, 24" long and 1-inch ID, 29/42 ♀ female joints at ends, with preheater zone packed with silica rods 1/4 inch OD and 12 inches long, support screen, nickel-iron alloy, 60-mesh and 1-inch dia. as shown in the enlarged view in Figure 2. Chromel-Alumel thermocouple, encased in Vycor glass well at base of reactor tube, and attached to Hoskins thermoelectric pyrometer type AH
9	Reactor furnace, Hoskins, type FH 303A equipped with a 15-volt 37-ampere output transformer controlled by variac type 116
10	Liebeg condenser, 20 inches long, with 150-ml condensate trap and fines trap; 24/40 ♀ joints
11	Hydrogen sulfide absorption trap with fritted glass filter, corning extra course, absorption medium 10% aqueous monoethanolamine
12	Sargent Wet Test Meter, maximum capacity 100 cu.ft.

TABLE 4

EFFECT OF HYDROGEN SULFIDE ON THE SULFUR CONTENT OF COKE FOR TWO-HOUR RUNS AT 800, 900, and 1000°C.

Analyses Before Reaction, % Sulfur

<u>Sample</u>	<u>Inorganic Sulfur Extracted</u>	<u>Sulfur Volatile</u>	<u>Organic<sup>(1)</sup> Sulfur</u>	<u>Total Sulfur</u>
Original Coal	.06	.00	.63	.69
Bulk Coke	.02	.06	.48	.56
Coke A, Hard, 10x60 mesh	.01	.05	.50	.56
Coke B, Hard, minus 60 mesh	.01	.05	.50	.56
Coke C, Soft, minus 60 mesh	.02	.03	.51	.56

Analyses After Reaction, % Sulfur

Flow rate of Hydrogen Sulfide: 0.013 cu.ft./hr.(0.015 mols/hr.)(Mol conc.4.2%)

Temp., °C.

800 Coke A, Hard, 10x60 mesh	.08	.00	.72	.80
Coke B, Hard, minus 60 mesh	.14	.04	1.06	1.24
Coke C, Soft, minus 60 mesh	.34	.02	1.36	1.72
900 Coke A, Hard, 10x60 mesh	.01	.01	.66	.68
Coke B, Hard, minus 60 mesh	.04	.02	.72	.78
Coke C, Soft, minus 60 mesh	.22	.02	1.39	1.63
1000 Coke A, Hard, 10x60 mesh	.02	.00	.66	.68
Coke B, Hard, minus 60 mesh	.07	.03	.78	.88
Coke C, Soft, minus 60 mesh	.24	.04	.54	.82

Flow rate of Hydrogen Sulfide: 0.029 cu.ft./hr.(0.034 mols/hr)(Mol conc.8.8%)

800 Coke A, Hard, 10x60 mesh	.07	.01	.81	.89
Coke B, Hard, minus 60 mesh	.12	.05	.96	1.13
Coke C, Soft, minus 60 mesh	.28	.00	1.68	1.96
900 Coke A, Hard, 10x60 mesh	.04	.03	.98	1.05
Coke B, Hard, minus 60 mesh	.12	.03	1.08	1.23
Coke C, Soft, minus 60 mesh	.27	.01	1.74	2.02
1000 Coke A, Hard, 10x60 mesh	.01	.01	.79	.81
Coke B, Hard, minus 60 mesh	.13	.02	1.10	1.25
Coke C, Soft, minus 60 mesh	.32	.52(2)	1.20	2.04

(1) Organic sulfur is all sulfur other than inorganic (extracted and volatile)

(2) Believed to be in error

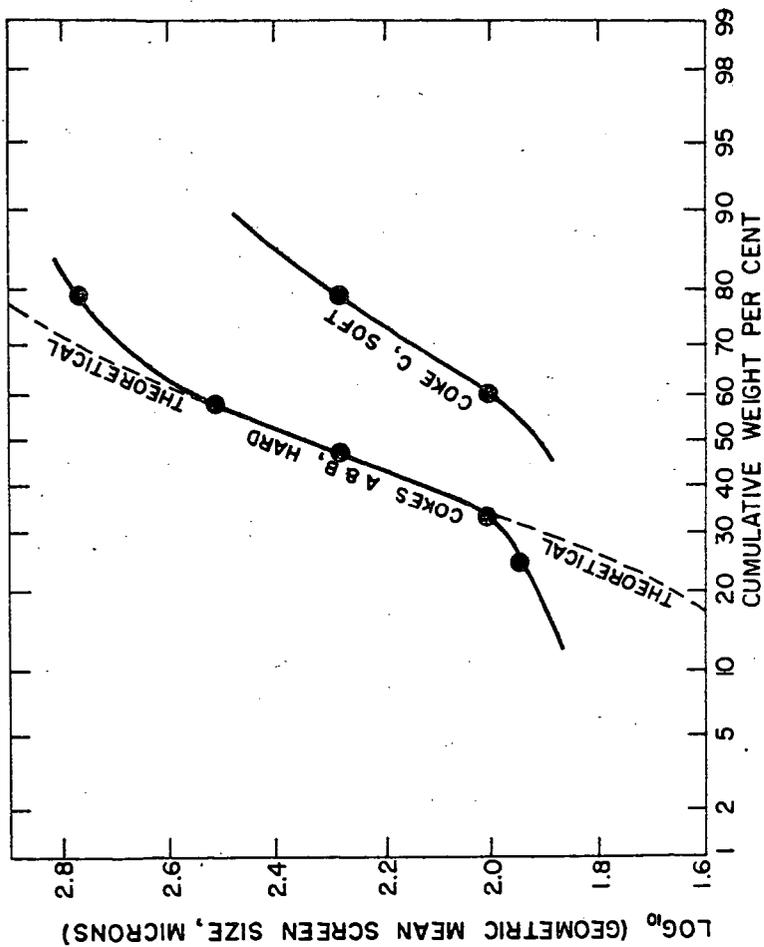


FIGURE 1 - GRINDABILITY PROPERTIES OF COKE SAMPLES

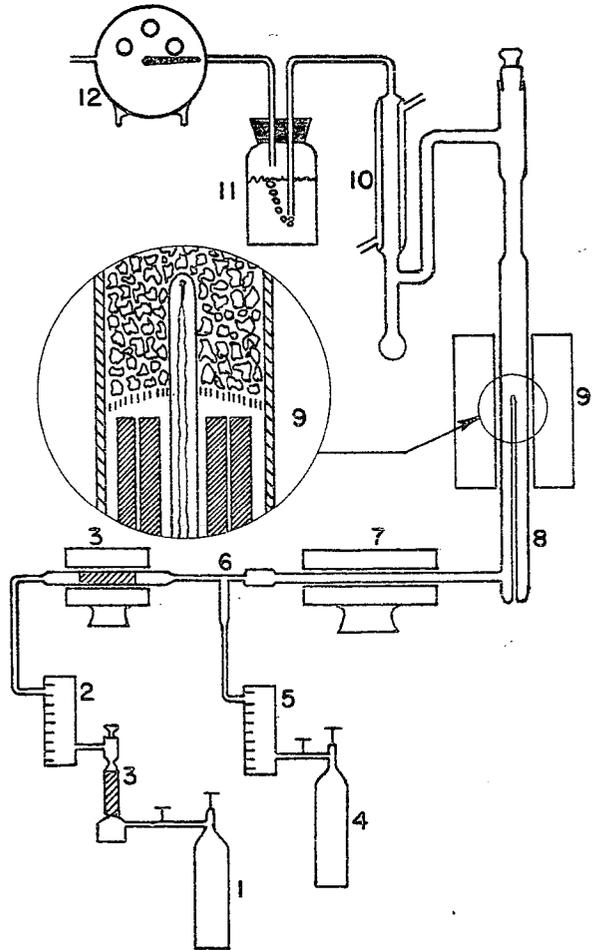


FIGURE 2 - EXPERIMENTAL APPARATUS  
(REFER TO TABLE 3 FOR  
SPECIFICATIONS)

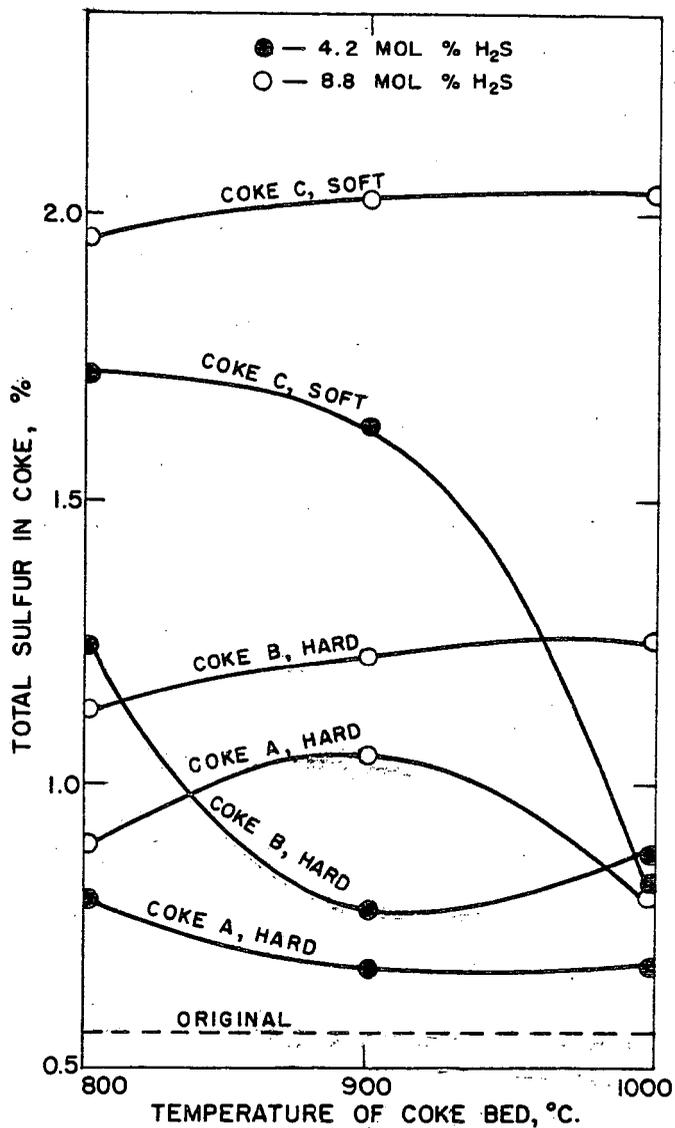


FIGURE 3 - EFFECT OF HYDROGEN SULFIDE ON TOTAL SULFUR CONTENT OF COKE

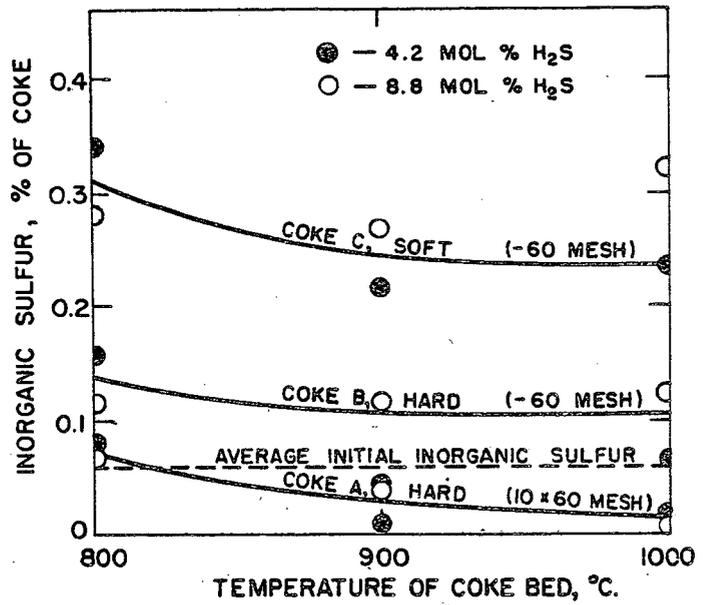


FIGURE 4 - EFFECT OF HYDROGEN SULFIDE ON THE INORGANIC SULFUR CONTENT OF COKE

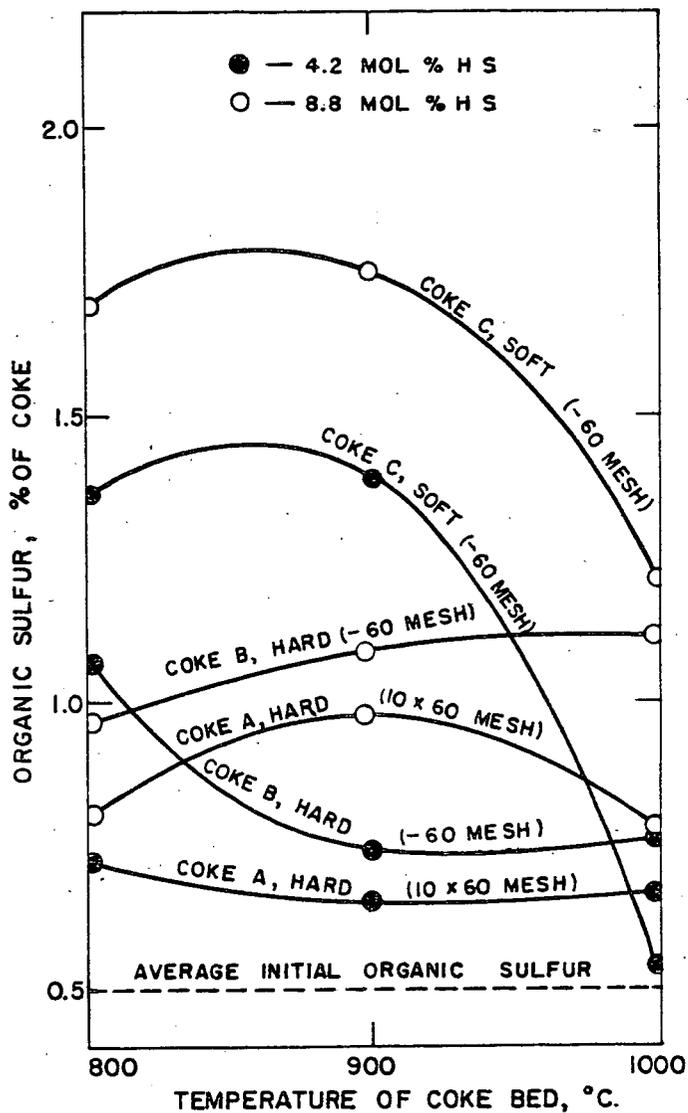


FIGURE 5 - EFFECT OF HYDROGEN SULFIDE ON THE ORGANIC SULFUR CONTENT OF COKE