The Influence of Mineral Matter on The Rate of Coal Char Combustion

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Introduction

The rate of coal combustion can, in some instances, influence the design of boilers. The intrinsic rate of char combustion is, however, poorly known. Figure 1 shows that estimated intrinsic rate of char combustion can vary by a factor of 10^4 (1). The largest uncertainties are (2):

Property	Factor of Uncertainity
Surface Area	100
Effectiveness Factor	50
Catalysis	100
Crystal Structure	30

Other uncertainities account for less than a factor of four in the estimated intrinsic rate of coal char combustion.

Changes in the apparent rate of char combustion by a factor of 10 can influence the predicted performance of boilers. An example of these changes for a 660 MWe boiler is shown in Table 1. These figures were calculated using a well tested model of boiler performance (3). Increasing the accepted apparent rate constant by a factor of 10 predicts slightly improved performance, but decreasing the accepted rate constant by a factor 10 predicts severely degraded and unacceptable boiler performance.

This paper assesses one of the major uncertainity in estimating intrinsic rate constants, the influence of catalysis of the combustion rate of coal char.

Mineral Matter

Mineral matter contained in the coal could influence the rate of char combustion by blocking part of the coal surface or by catalytically increasing the rate of combustion. Figure 2 shows that the measured rate of combustion of purified nonporous graphics is uncertain by less than a factor of 3. This is a small difference compared to the spread in the overall rate data and suggests that some of the scatter in the measured rates of coal combustion are caused by the mineral matter in the coal.

Blocking of the surface area of coal by ash is unlikely to significantly change the rate of char reaction. Calculations for a coal with 25 percent ash indicate that, except at high levels of burnout, much less that 1 percent of the surface area of char will be blocked with ash particles.

Experiments have shown that small amounts of certain metals can accelerate the rate of char combustion (4,5,6,7,8,9). A number of anions and cations have been shown to accelerate the combustion of carbons at concentrations of 10 to 1000 ppm. Table 2 shows the relative influence on the combustion rate of various salts added as solutions to purified graphite. Relatively small amounts of metals can accelerate the rate of combustion by many orders of magnitude. Metals which appear in coal in significant concentrations which will accelerate the combustion of coal are 1) sodium and 2) calcium. Sodium can be present in coal in concentrations of 100-6000 ppm and calcium at concentrations of 50-12,000 ppm. The in-

fluence of relatively minor levels of sodium on the combustion rate of graphite is shown in Figure 3. Addition of sodium to a concentration of 15 ppm accelerates the reaction by one to two orders of magnitude; higher levels of sodium accelerate the reaction at a lower rate. Calculations show that the sodium must be distributed on nearly the molecular level to be effective. In addition, the influence of catalysis will be less pronounced at the higher temperatures of combustion where noncatalytic combustion proceeds much faster. No data exists at these higher temperatures. The available data indicates that combustion of carbon is accelerated by up to two orders of magnitude by levels of sodium normally present in coals at temperatures only slightly lower than combustion temperatures.

Summary

Minerals present in coal can accelerate the rate of char combustion by as much as a factor of 100. Molecularly attached Sodium and Calcium Compounds are likely to increase the char combustion substantially at low temperatures. However, information is not available and work should be undertaken to assess the acceleration of char combustion by minerals at the temperatures of combustion.

References

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TABLE I INFLUENCE OF COMBUSTION RATE ON POWER PLANT PERFORMANCE FOR A 660 MW_e COAL-FIRED BOILER

Kinetic Constant, g/cm's Atmosphere	Furnace Efficiences (%)	Mean Furnace Exit Temp °F	Mean Net Heat Flux Btu/ft^{2}hr	Maximum Net Heat Flux Btu/ft^{2}hr	Position of Maximum Heat Flux (ft)	Maximum Flame Temp (°F)	Percent Unburned Fixed Carbon	Percent Combustibles In Ash (%)
$40e^{-21,450/RT}$ [a]	43.1	2190	39,000	61,500	116	2650	0.66	5.97
$400e^{-21,450/RT}$	44.2	2160	40,300	62,800	102	2670	0.04	0.38
$4e^{-21,450/RT}$	33.6	2200	26,000	64,700	224[b]	2350	32.17	69.03

[a]Normal Value

[b]Boiler Exit Plane

TABLE 2 INFLUENCE OF METALS ON THE RATE OF GRAPHITE COMBUSTION(9)

Metal	ppm	Relative Reactivity
Be	120	1
B	80	1
Al	70	3
Ca	120	4
mg	120	6
Sr	120	8
Ni	150	32
Cd	120	90
Ba	120	100
Na	120	230
Au	120	240
V	120	340
Cu	120	500
Ag	120	1,340
Cs	120	64,000
Mn	80	86,000
Pb	130	470,000

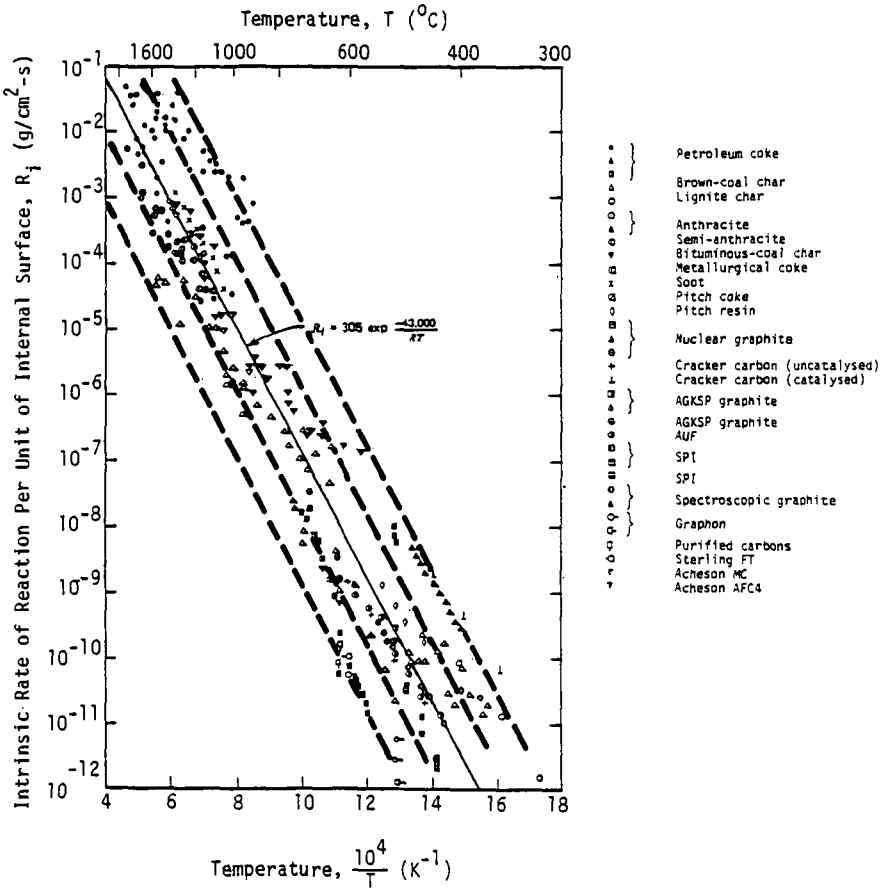

Figure 1. Intrinsic Rate of Reaction of Chars (1)

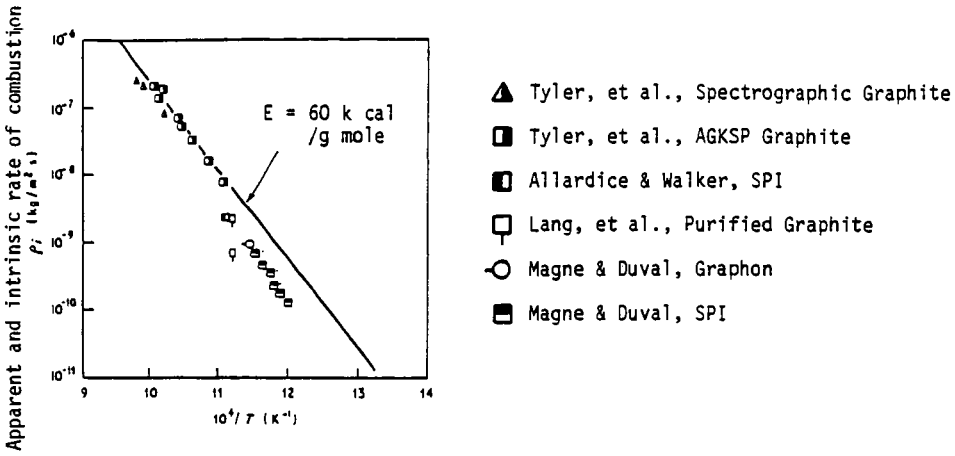

Figure 2. Combustion Rates of Highly Purified Graphite (4)

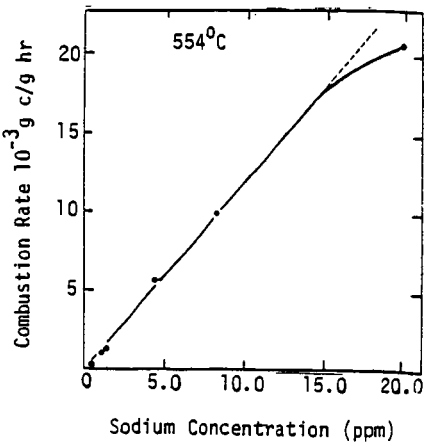

Figure 3. Catalysis of Graphite Combustion by Sodium (9)