DOE/PC/89781--3

DE92 016167

Quarterly Technical Progress Report
April 1, 1990 - June 30, 1990

Title:A NOVEL COAL FEEDER FOR PRODUCTION OF LOW SULFUR FUEL

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During the past three months, the coal feeding system has been tested and currently undergoing evaluation at the University of Cincinnati. The system consists primarily of an auger feed tube which is used to both convey and provide desulfurization of a high sulfur coal feedstock. The coal is conveyed at temperatures ranging from 350 to 550 °C and under normal atmospheric pressure. Under these mild processing conditions, the coal partially pyrolizes and emits sulfur in the form of hydrogen sulfide while maintaining a relatively high heating value in the char product. The evolved gases are evacuated from the reactor (the feed tube) to another absorbing bed where H_2S reacts with the sorbent, usually lime or limestone. The resultant sorbent utilization is substantially higher than the values found in current dry scrubbing system and the produced low-sulfur char may then be used in a conventional steam boiler.

PRELIMINARY RESULTS AND DISCUSSION

The results of a limited number of tests on an Ohio No. 8 coal are given in Table 1 including those reported in the previous report. The data in Table 1 represents results for pyrolysis temperatures between 375 °C and 450 °C for 3.3 mm-diameter pellets. The data in Table 2 represents preliminary results for pyrolysis for temperatures of 375 °C and 450 °C for 0.9 mm-diameter particles. The values of the total mass of coal tested (M_i) and recovered (M_f) as well as percent sulfur in the product char are given for the various coal residence times. The percent devolatilization and desulfurization are calculated by the following formulas;

$$DeV = (M_i - M_f)/M_i \tag{1}$$

$$DeS = (M_iS_i - M_fS_f)/M_iS_i \tag{2}$$

where,

DeV is the fractional devolatilization
DeS is the fractional desulfurization
M and S are mass of coal and fraction of sulfur, respectively
the subscripts i and f represent initial and final conditions.

Both the fractional devolatilization and desulfurization values appear to be approaching an asymptotic upper limit. This upper limit is assumed to represent the available amount of volatiles and sulfur capable of being evolved at the reaction temperature at infinite reaction time.

The kinetics of desulfurization and devolatilization are assumed to be proportional to the amount of "escapable" sulfur or volatiles remaining in the char at any time. Thus, a modified form of linear rate form may be written as

$$-\frac{dS}{dt} = k_S(S - S_\infty) \tag{3}$$

$$-\frac{dM}{dt} = k_V(M - M_\infty) \tag{4}$$

where,

t is the reaction time

k_s and k_v are the desulfurization rate constant and the devolatilization rate constant, respectively, and the subscript ∞ represents the total escapable amount of sulfur or volatile at infinite reaction time.

Integration of Equations 3 and 4 gives the progress of desulfurization and devolatilization with time, or

$$\frac{DeS}{DeS_\infty} = 1 - e^{-k_s t} \tag{5}$$

$$\frac{DeV}{DeV_\infty} = 1 - e^{-k_V t} \tag{6}$$

where, the subscript ∞ indicates the fractional desulfurization or devolatilization at infinite time at the reaction temperature. The values of DeS_∞ and DeV_∞ are obtained by maximizing the regression coefficient when fitting the experimental data to the linear forms of Equations 5 and 6. The rate constants, k_s and k_v, are then obtained from the slope of the linear fit.

A comparison of the data with Equation 5 for desulfurization (Figure 1) and with Equation 6 for devolatilization (Figure 2) indicates a reasonable agreement between theory and measurements. The values of DeS_∞ and DeV_∞ are listed in Table 1.

It is not known at this time if the sulfur loss can be solely attributed to organic sulfur loss, or from some other mechanism such as the decomposition of ferric sulfide (pyrite) to ferrous sulfide (troilite) in the inorganic sulfur fraction.

Figure 3 shows the Arrhenius plot of the rate constants. From the slope of each curve, activation energies for desulfurization and devolatilization are calculated. These are 7,583 cal/mol for desulfurization and 23,665 cal/mol for devolatilization. These values indicate more temperature dependency for devolatilization. We will revise these values as more experimental values are obtained.

Preliminary pyrolysis tests were also performed for Ohio #8 coal using smaller particles (+16, -30 U.S. mesh, about 0.9 mm diameter). The tests were conducted under two different temperatures of 375 °F and 450 °F with differing residence times as shown in Table 2 and Figures 4-7. The results indicate that devolatilization is more particle size dependent than desulfurization in terms of both the rate constant and the ultimate value. The process seemed to be less influenced by particle size at higher temperatures than at lower temperatures. These phenomenon may be explained by two facts: the first fact that the particles are not in a dispersed condition inside the feed tube at higher temperatures since they are swollen and stick to each other when heated. The higher the temperature, the more coagulation the particles would undergo and hence, the less influence of the particle size on the process. The second fact is that the process may be controlled by the heat transfer limitation at higher temperature, thus the reaction rates would be less influenced by the particle size. It would take more fundamental studies to find out actual details of these mechanisms.

Works to be performed

1. Reaction rates between H_2S from pyrolyzed gas and CaO particles will be measured using a packed bed reactor.
2. The BTU values of the initial coal and the product char will be measured.
3. The fabrication of double screw feeder will be nearly completed and mechanical testing will begin.
4. Devolatilization and desulfurization studies will be continued.

Table 1. Desulfurization and devolatilization of Ohio No. 8 Coal
(Particle size = 3.3 mm)

Temp.	time(min)	DeS	DeV	Max DeS	Max DeV
375 C	0.00	0.00	0.00	34.35	14.00
	1.00	15.67	1.13		
	1.84	21.07	1.33		
	3.30	22.00	2.00		
	5.30	27.00	3.00		
	7.75	32.00	5.00		
400 C	0.00	0.00	0.00	37.00	24.00
	1.00	8.13	3.14		
	1.25	11.34	3.12		
	1.84	32.07	3.37		
	2.50	33.17	8.49		
	3.30	35.00	12.45		
	7.70	35.29	17.55		
	10.00	35.60	17.63		
425 C	0.00	0.00	0.00	42.10	27.00
	1.00	23.58	6.87		
	1.25	29.99	13.75		
	2.00	40.19	18.66		
	7.70	39.93	22.05		
450 C	0.00	0.00	0.00	53.00	36.00
	0.67	12.59	20.00		
	1.17	27.74	10.00		
	1.40	32.65	14.00		
	1.87	37.33	15.00		
	2.55	44.56	22.00		
	3.30	45.10			

Table 2. Desulfurization and devolatilization of Ohio No. 8 coal (Particle size = 0.9 mm)

Temp	Time(min)	DeS	DeV
375 C	0.00	0.00	0.00
	1.13	20.33	4.28
	1.80	25.72	5.77
	4.60	26.76	7.08
	7.00	29.90	7.62
450 C	0.00	0.00	0.00
	1.10	31.78	18.33
	1.80	46.84	46.84
	4.70	50.76	50.76

Figure 1. Desulfurization of Ohio #8 Coal

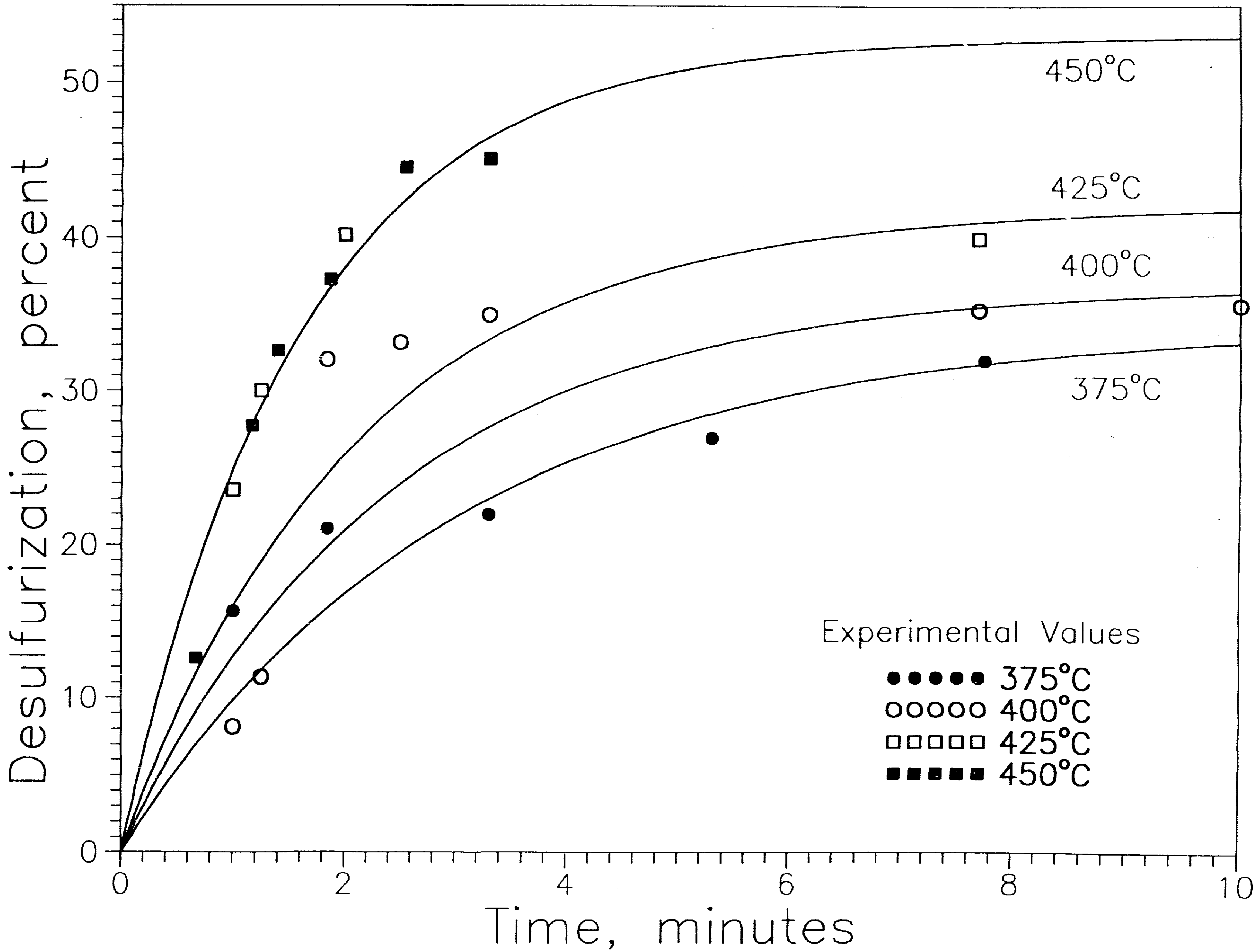


Figure 2. Devolatilization of Ohio #8 Coal

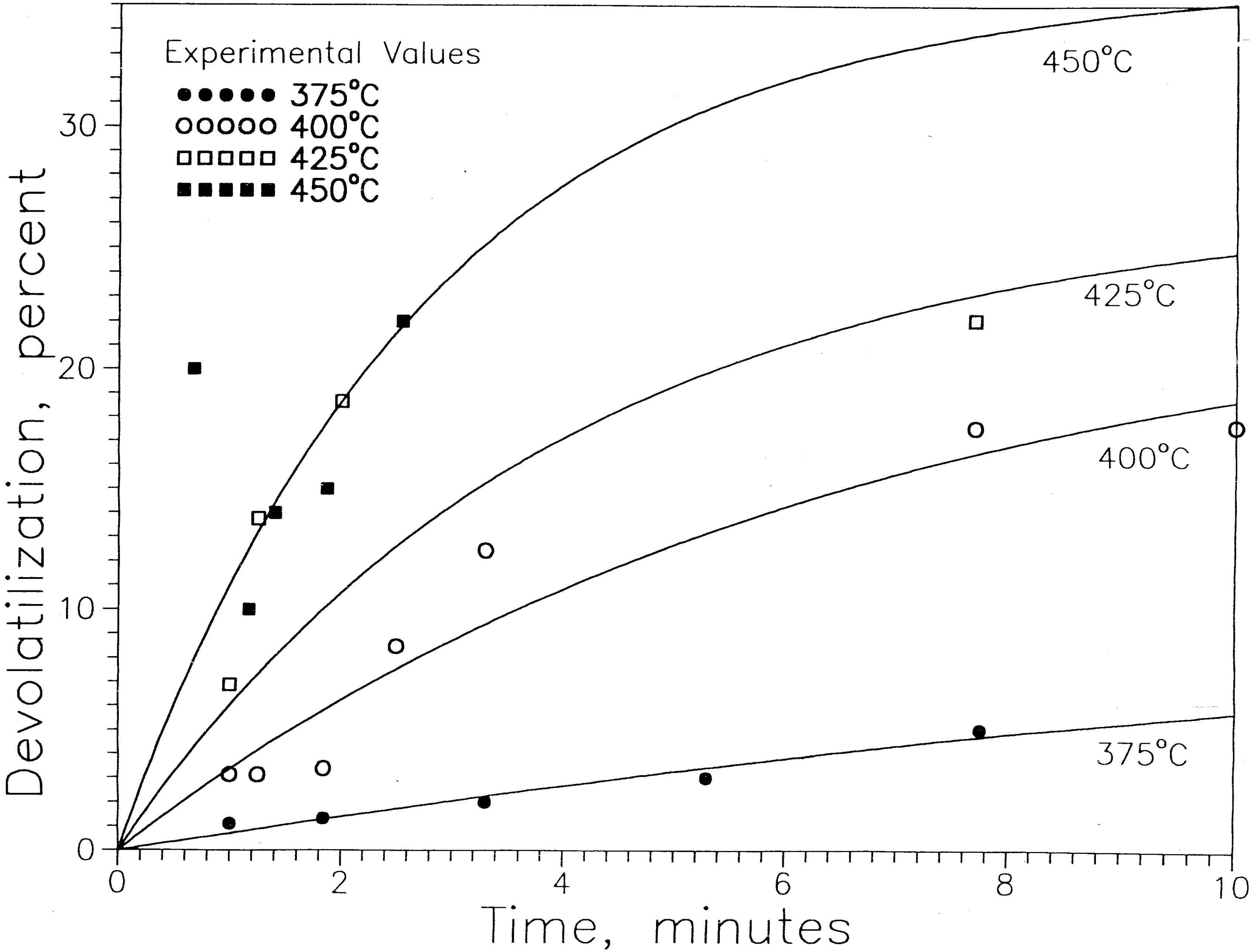
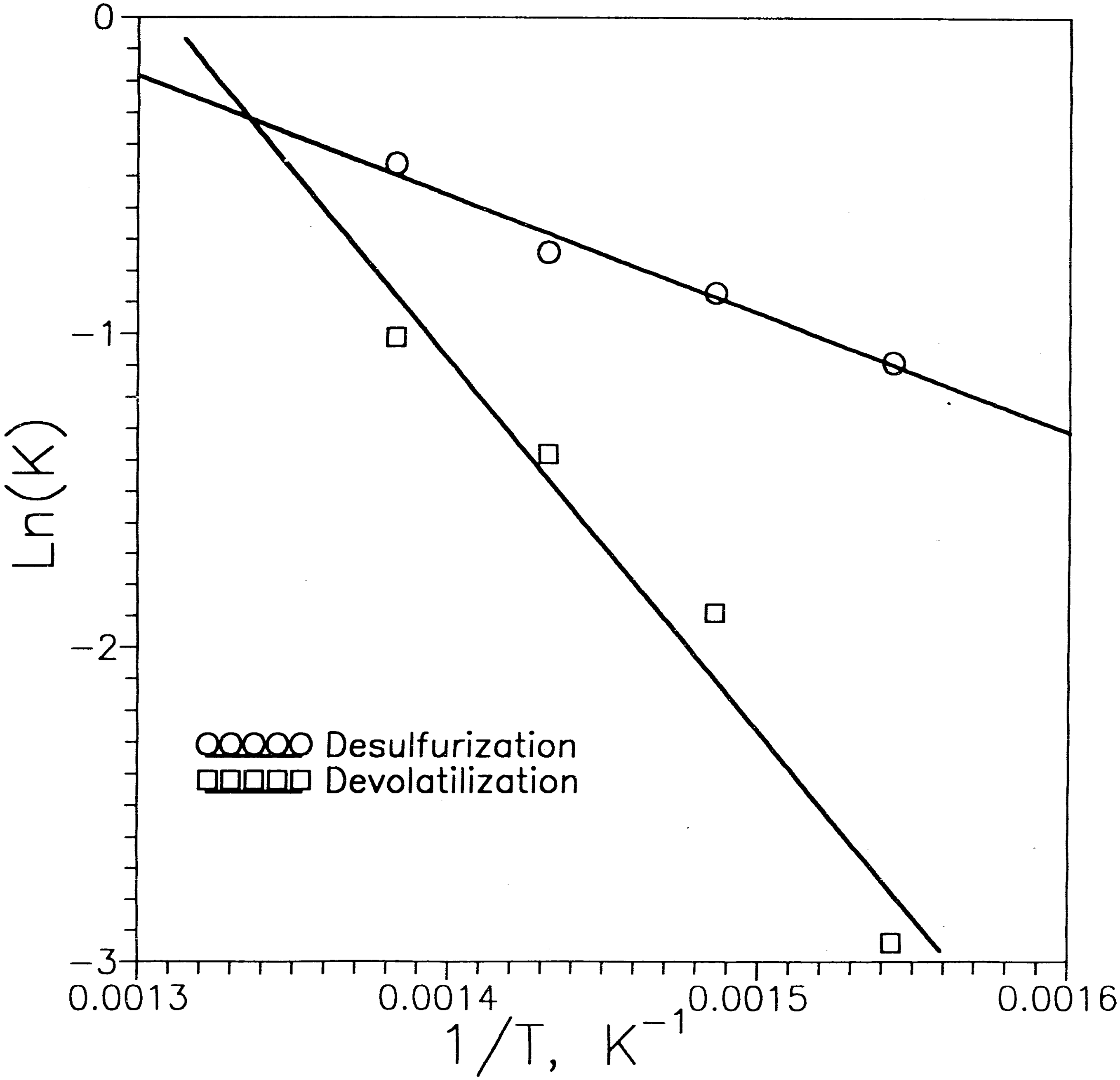


Figure 3. Arrhenius Plot for Reaction Rates



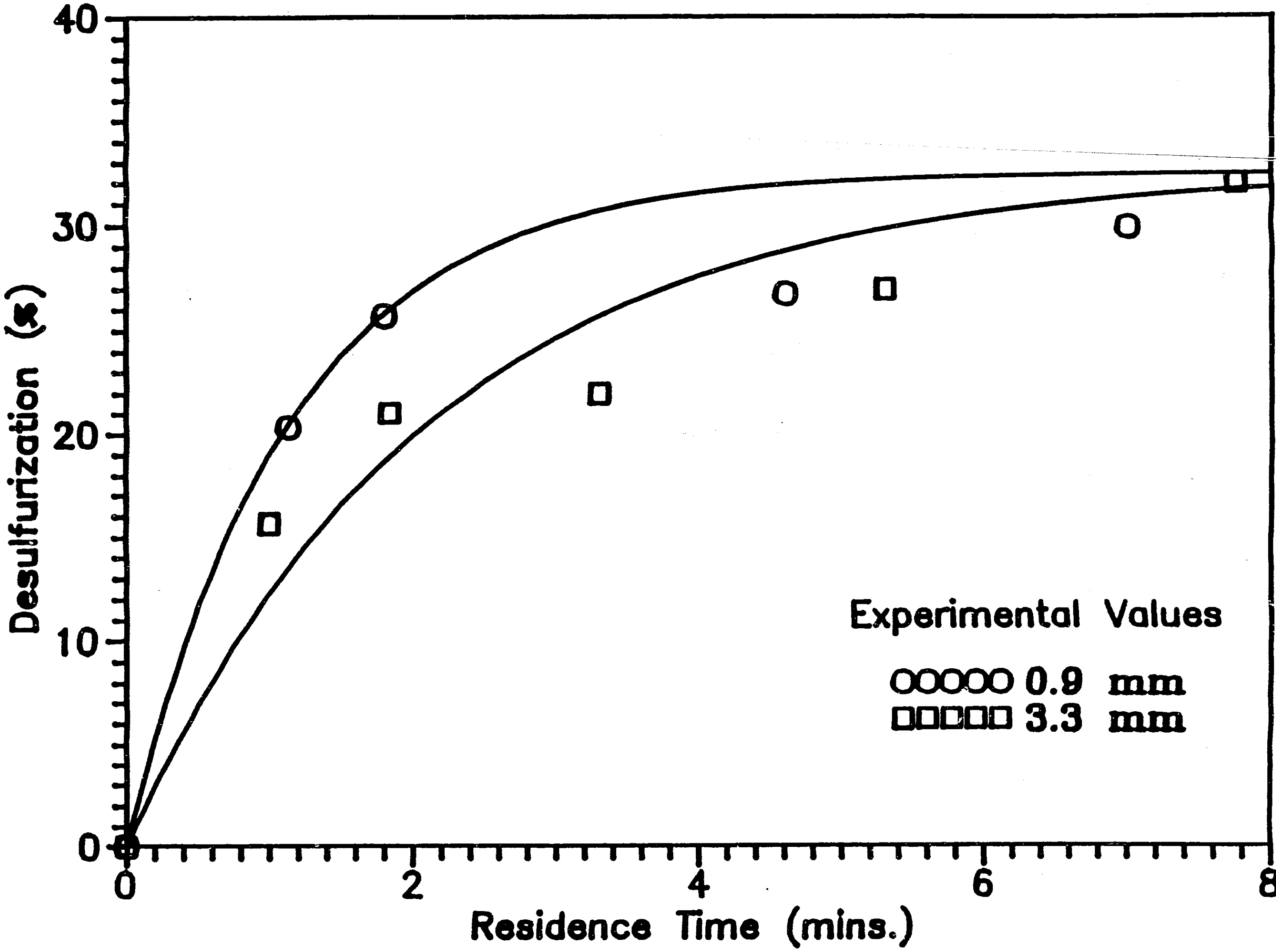


Fig. 4 Desulfurization of Ohio No.8 Coal

Temperature: 375°C

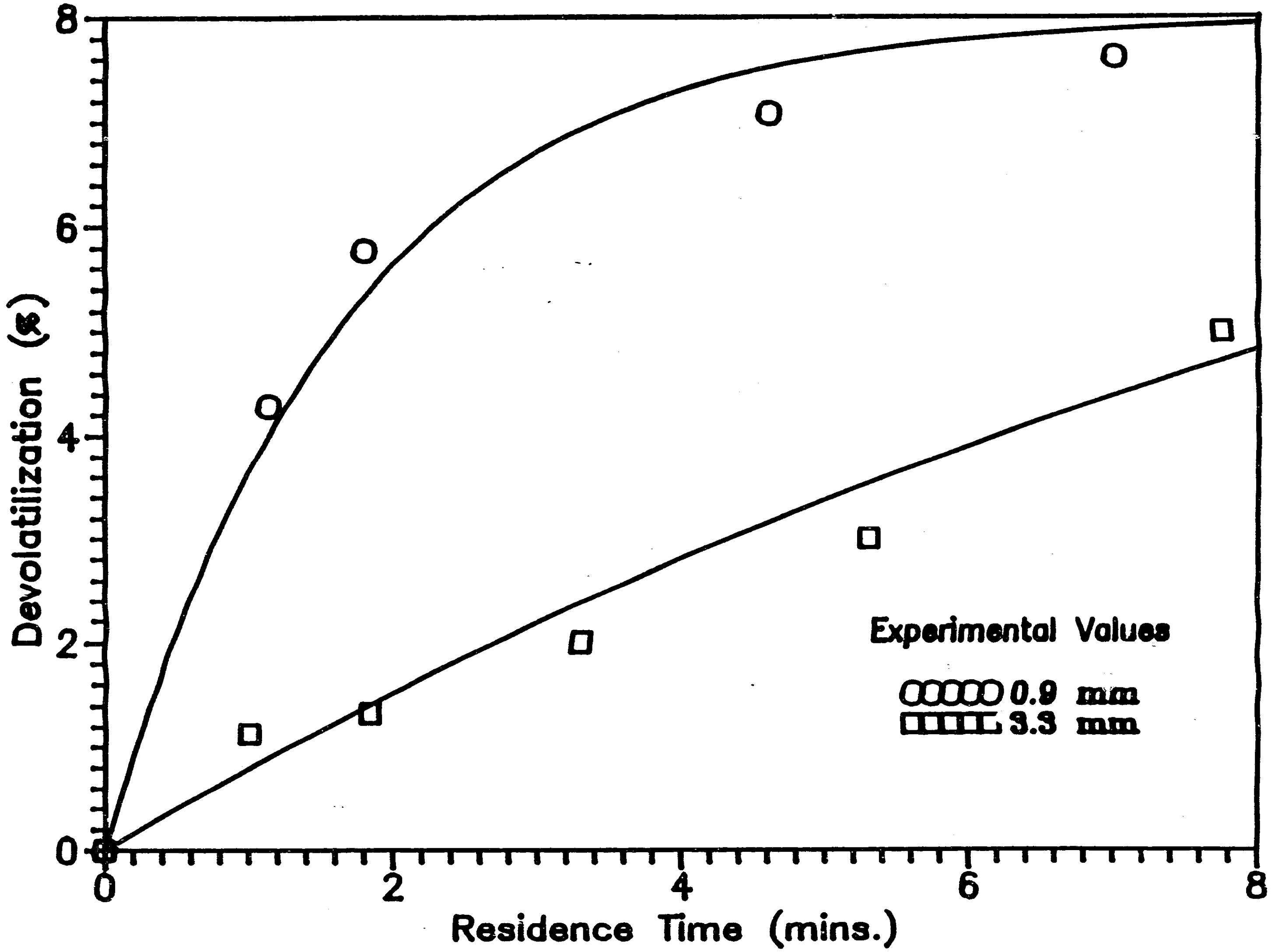


Fig. 5 Devolatilization of Ohio No.8 Coal

Temperature: 375°C

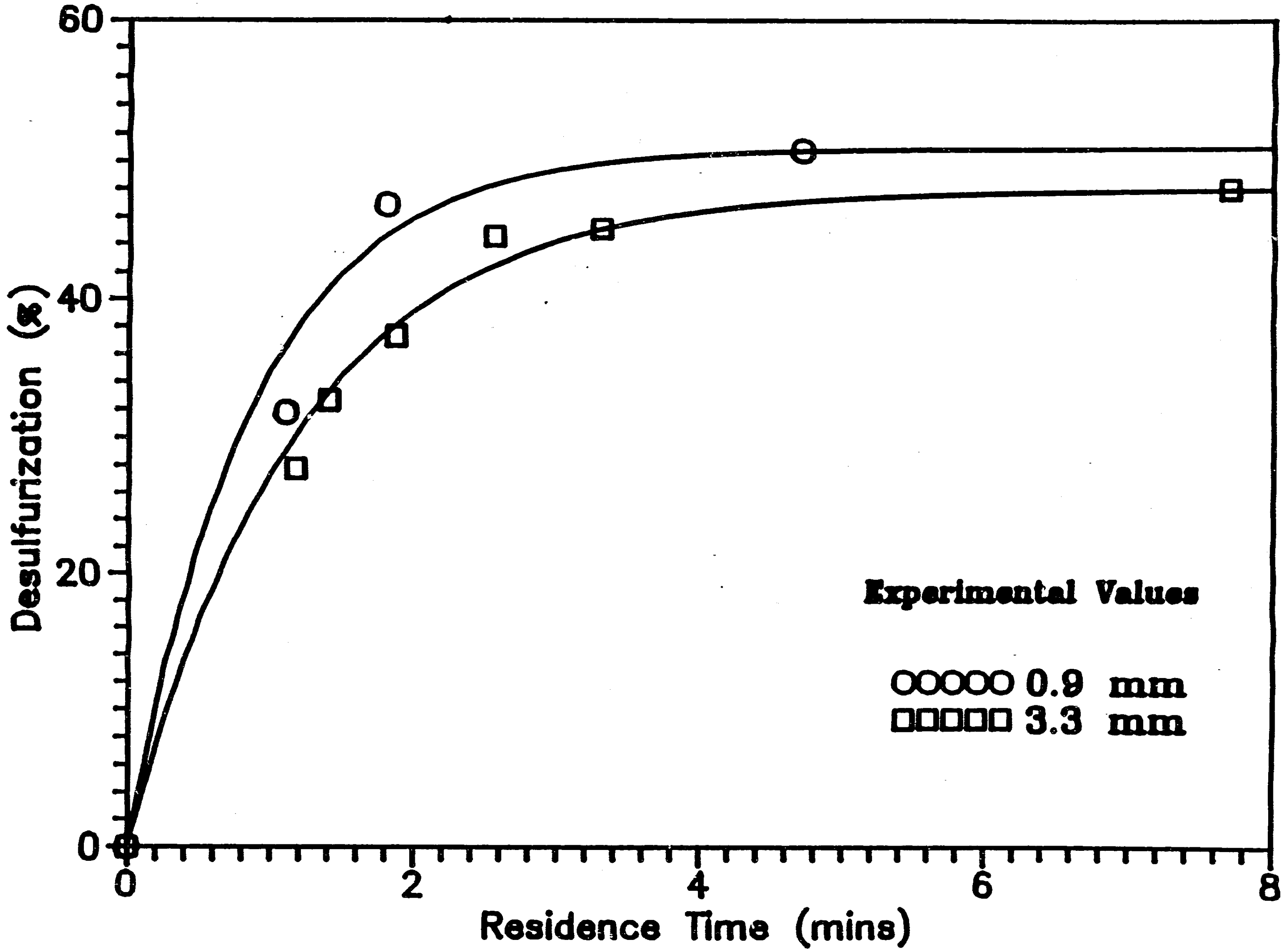


Fig. 6 Desulfurization of Ohio No.8 Coal

Temperature: 450°C

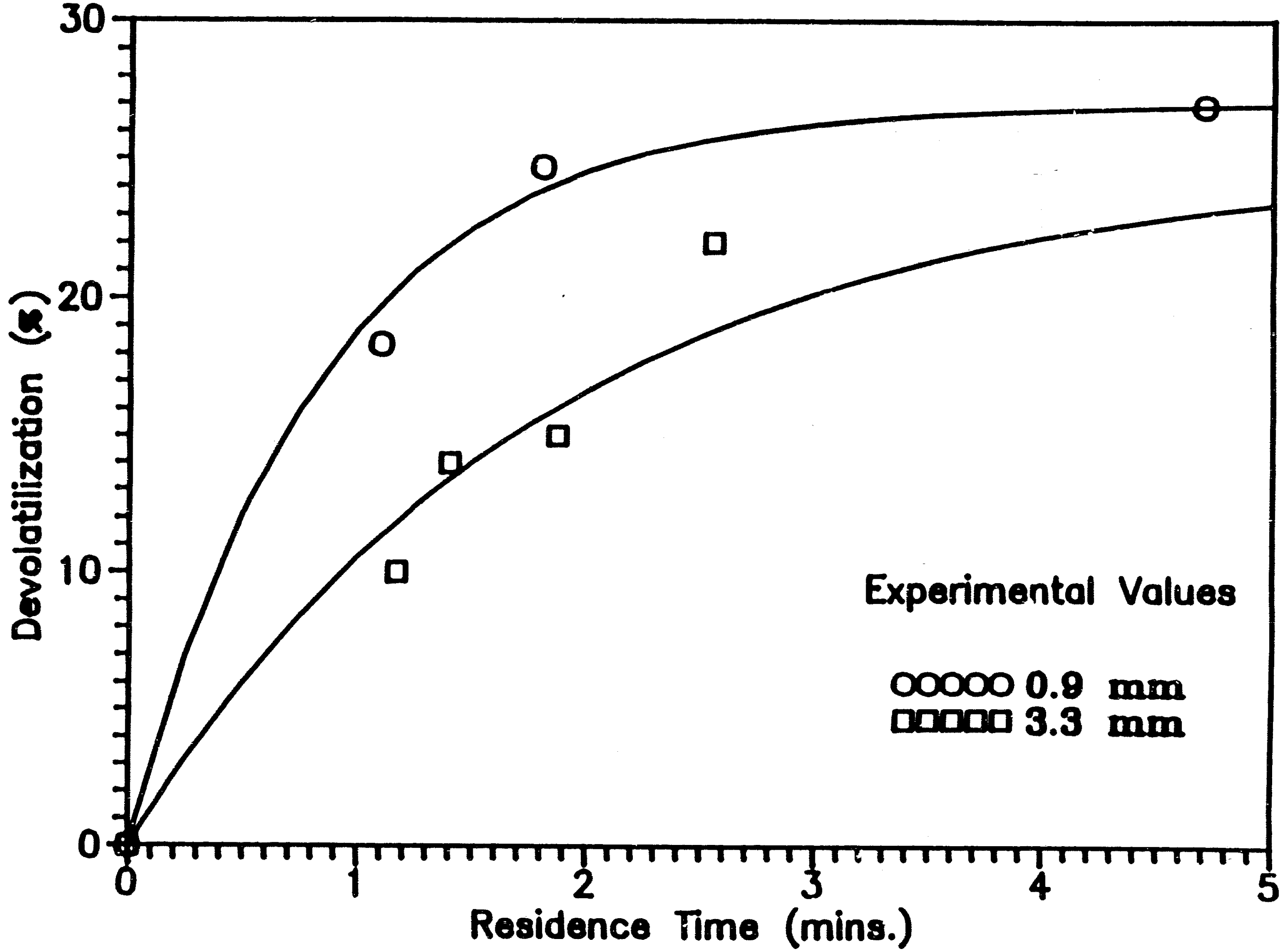


Fig. 7 Devolatilization of Ohio No.8 Coal

Temperature: 450°C

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