CHAPTER IV

PRESENTATION OF RESULTS AND DISCUSSIONS

4.1 Quality of Data Obtained and Measurement of D1

The quality of data obtained is shown in figures 4.1 (a), (b),(c) for three different situations. The response curves were averaged and sampled at various time intervals depending on length of experiment. Three problems were found one was that for some experiments steady-state was very long and it was sometimes difficult to determine the highest concentration, the second problem was that for some experiments the noise level was high and it was necessary to average the values, and the third problem was that in some cases the experimental values of the curves decreased after reaching a maximum because of the support zone effect and took a long time to reach a final concentration. However all three types of experiments could be optimized. Figure 4.2 shows the results of an optimization for the case where the experimental curve reaches a maximum and then decreases.

4.2 Determination of D2

The system used consists of an agitated column where turbulence is described by D1 and a support zone where turbulence is described by D2. In the support zone it is believed that turbulence is much smaller than in the column because of two reasons, first of all the cross sectional area of the support zone is 170.8 square centimeters whereas the cross sectional area of the largest column used is 78.54 square centimeters. Thus if a pulsation Af in cm/s is applied to the largest column then the resulting pulsation in the support zone is Af x 78.54/170.8. Actually in the range of pulsating velocities used Af in the support section varies between 0.22 to 0.27 cm/s or at an average of 0.245 cm/s. Secondly the support section is devoid of disks and rings and turbulence is thus reduced as a result.

However the value of D2 does influence the measurement of D1 and an average value of D2 corresponding to a pulsating velocity of around 0.24 cm/s was estimated as follows. Tracer experiment as described in the previous chapter were conducted on the largest column using the largest distance between disks and rings of 6.25 cm and using three pulsating velocities in the column (0.47, 0.53, 0.59 cm/s) resulting in 9 experiments. D2 was estimated and D1 optimized from the experimental curves and the most likely value of D2 was chosen as shown in figure 4.3.

A set of data was made with the largest column but devoid of disks and rings. The results indicate that in such a situation mixing between nitric acid and tracer solution and water is not very good due to lack of micromixing in the early stages of contact and the experimental data had problems of repeatability. Thus this set of data was discarded. It was then decided to make use of the largest column with the largest distance between the disks and rings in order to estimate D2.

A sensitivity analysis on D1 indicates the following results. Variations of D2 of 0.75 between 0.50 and 1.0 results in variations in the determination of D1. For one set of data when D2 is set at 0.75 cm^2/s a value D1 = 2.2 cm^2/s is obtained, the sensitivity analysis shows that the value of D1 varies only -5.6 percent to 6.8 percent from D1 = 2.2 cm^2/s when D2 is varied between 0.50 to 1.0 cm^2/s. For another set of data when D2 is set a 0.75 a value of D1 = 10.35 cm^2/s is obtained, the sensitivity analysis shows that the value of D1 varies between -1.2 percent to 6.3 percent from D1 = 10.35 cm^2/s when D2 varies between 0.50 to 1.0 cm^2/s. For a third set of data when D2 is set at 0.75 cm^2/s a value of D1 = 17.5 cm^2/s is obtained, the sensitivity analysis shows that the value of D1 varies between 0 percent to 4.0 percent from D1 = 17.5 cm^2/s. Sensitivity analyses were made for a total of 18 runs and similar deviations from the D1 value obtained base on D2 = 0.75 cm^2/s ranged from zero to a maximum of 6.9 percent. We concluded therefore that error in the determination of D1 based on a single value of D2 (i.e. D2 = 0.75 cm^2/s) were not significant.

4.3 Presentation of the main data

A set of D1 experiments was conducted for the determination of the axial dispersion coefficient D1 in the test columns for the following conditions.

Column L : 10 cm diameter, A1 = 78.54 cm^2
pulsation velocity Af cm/s, varying between 0.47 and 0.59

Column M : 7.5 cm diameter, A1 = 44.18 cm^2
pulsation velocity Af cm/s, varying between 0.87

and 1.05

Column S : 4.5 cm diameter, A1 = 15.90 cm^2

pulsation velocity Af cm/s, varying between 2.42 and 2.91

Two other variables are h or the distance between disk and ring which were set at 6.25 cm, 3.75 cm, 2.50 cm and the presure of suspended solid polystyrene beads between 0 - 2.50 percent.

The experiments are presented in table 4.1

4.4 Discussion of the Influence of Solid in the System.

In actual leaching columns there will be substantial solids present, thus two third of these experiments were conducted with suspended solids present at concentrations up to 2.5 percent. The data for solids present is also included in table 4.1. The 27 experiments conducted in the absence of solid were compared to 54 experiments conducted. What was done during the experiments was to start with an empty column and proceed with the measurement of the axial dispersion coefficient D1. A small amount of solids, less than 1 percent of total volume would then be added to the system and we would proceed with another experiment to measure D1 with the other parameters remaining identical. Then we would add a greater amount of solids, greater than 1 percent, and we would proceed again with another experiment to measure D1. Therefore each experiment with no solids will have 2 additional experiments with two concentrations of solids present (both lower than 2.50 percent of total volume).

A quick analysis of the 27 sets of experiments as mentioned above indicates the following. In some sets of 3 experiments (15 sets of experiments) D1 increases as solids are added, in some of the experiments (7 sets of experiments) the addition of solids causes an increase in D1 but the addition of further solids results in a decrease in D1 or vice-versa. Finally in some of the experiments (5 sets of experiments) the addition of solids causes a decrease in D1.

It is difficult to say whether the variations are within experimental error or whether there exists a definite trend. It was thus decided to present a generalized correlation for three cases : a correlation based on the data with no solids, a correlation based on the data with solids (up to a holdup of 2.5 percent), and a correlation based on all the 81 data points which assumes a negligible influence of the pressure of solids on the system.

4.5 Presentation of Results as a Generalized Empirical Relation

Having concluded that the presence of solids up to a holdup of 2.5 percent does not affect the measurement of the axial dispersion in the column section the results were presented in a generalized empirical relation presented as follows.

The generalized empirical relation used was

$$D1 = a(Af)^{b}(Al)^{c}(h)^{d} \qquad (4.1)$$

The estimation of constants b, c, d, a was obtained by rearranging equation 4.1 as

$$\ln D1 = b \ln(Af) + \ln[a(A1)^c(h)^d] \qquad (4.2)$$

$$\ln D1 = c \ln(A1) + \ln[a(Af)^b(h)^d] \qquad (4.3)$$

$$\ln D1 = d \ln(h) + \ln[a(Af)^b(A1)^c] \qquad (4.4)$$

$$\ln D1 = \ln a + \ln[(Af)b(A1)^c(h)^d] \qquad (4.5)$$

and identifying coefficients b, c, d by plotting ln D1 against ln (Af), ln(A1), ln(h) respectively and measuring the slopes b, c, d using a least square method presented in the annex, then by plotting ln D1 against $\ln[(Af)^b(A1)^c(h)^d]$ to obtain ln a as intercept.

The results of the least square calculations indicate the following results

- Case of no solids : $b = 0.5910367$; $\ln [a(A1)^c(h)^d] = -0.6345595$
  (27 data points) $c = -0.5961291$; $\ln [a(Af)^b(h)^d] = 4.39069$
  $d = 0.0792938$; $\ln [a(Af)^b(A1)^c] = 1.256944$
  $a = 34.9716$
- Case of presence of solids : $b = 0.6219066$; $\ln [a(A1)^c(h)^d] = -0.7261941$
  (54 data points) $c = -.06077505$; $\ln [a(Af)^d(h)^d] = 4.442399$
  $d = 0.0865654$; $\ln [a(Af)^d(A1)^c] = 1.242499$
  $a = 36.31347$
- General case both with and without solids : $b = 0.6250168$; $\ln [a(A1)^c(h)^d] = -0.7225142$
  (81 data points) $c = -0.6112552$; $\ln [a(Af)^b(h)^d] = 4.439412$
  $d = 0.08244621$; $\ln [a(Af)^b(A1)^c] = 1.248362$
  $a = 36.37274$

On figure 4.4 a, b, c are plotted ln D1 against ln (Af), ln (A1) and ln (h). On figure 4.5 a, b, c are plotted ln D1 against ln $[(Af)^b(A1)^c(h)^d]$ for 3 cases.

Finally figure 4.6 represents the entire set of data including the cases of no solids and with solids in terms of ln D1 against ln $[(Af)^b(A1)^c(h)^d]$.

4.6 Discussions of the Generalized Relation

The generalized relation represents all the data obtained combined into a single figure. It must be noted before the relation is used that the limitations of the relation are limitations in the ranges of parameters as previously introduced.

One weakness of this study was that the range of pulsation velocity was restricted by the pulsing equipment improvised as no proper pulsers with greater pulsation velocities could be found.

Figure 4.1 Response curves

(a) 7.5 cm column, h = 2.5 cm, Δf = 1.05 cm/s, 1.74 % solid holdup, chart paper speed 2 cm/min

(b) 10.0 cm column, h = 2.5 cm, Δf = 0.53 cm/s, 2.5 % solid holdup, chart paper speed 2 cm/min
(this curve was reduced in size)

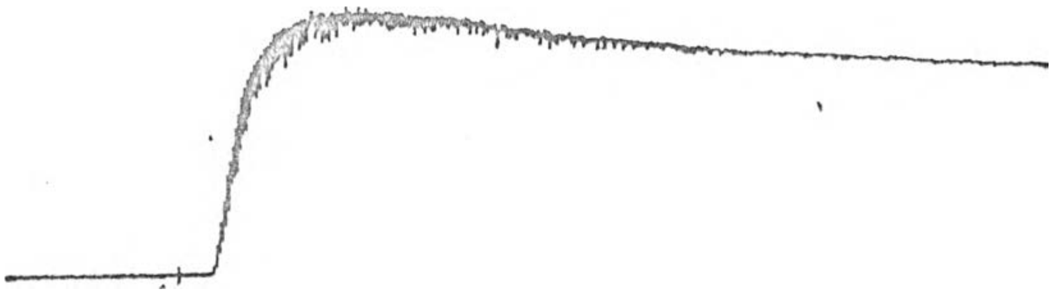

Figure 4.1 Response curves

(c) 4.5 cm column, h = 3.75 cm, Af = 2.42 cm/s, 0 % solid holdup, chart paper speed 2 cm/min

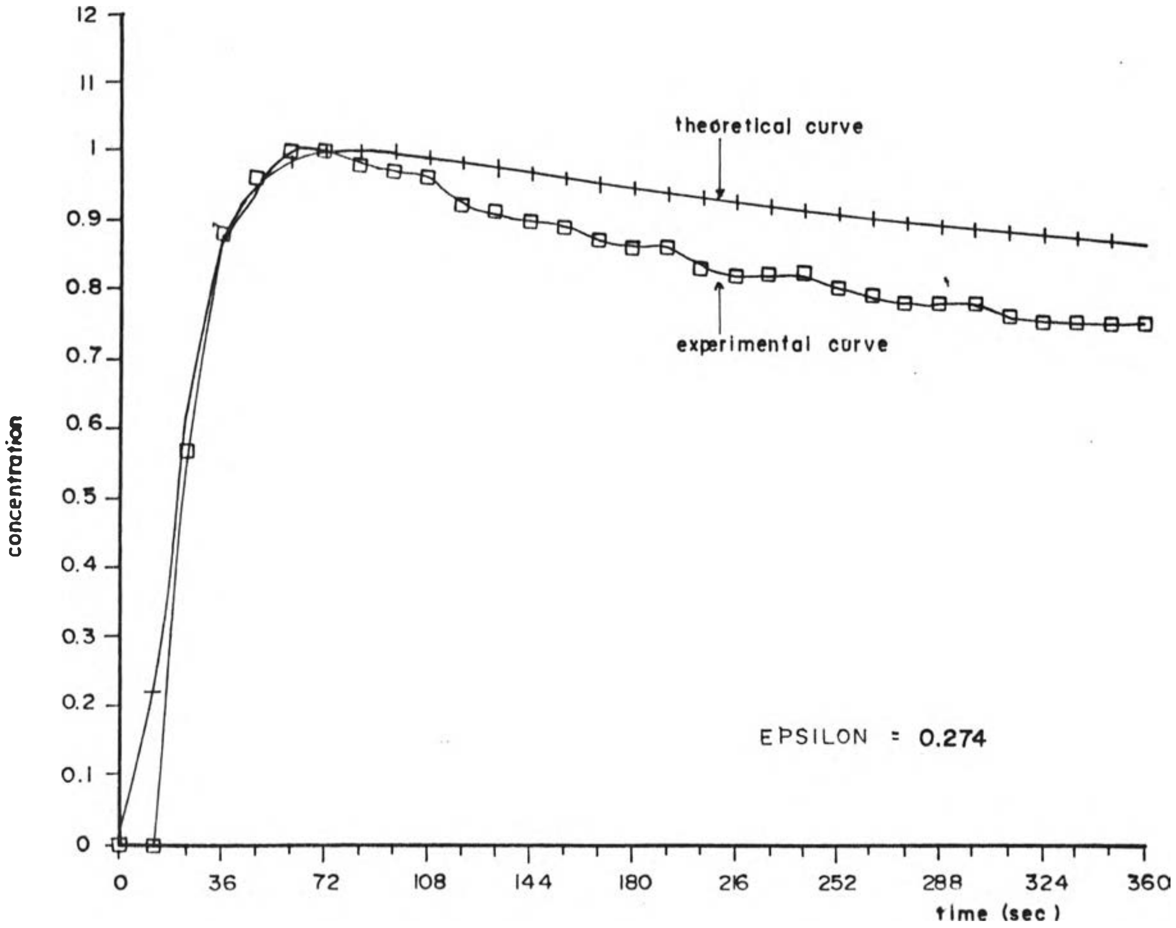

Fig.4.2 - Result of an optimization betwen an experimental curve and a theoretical curve.

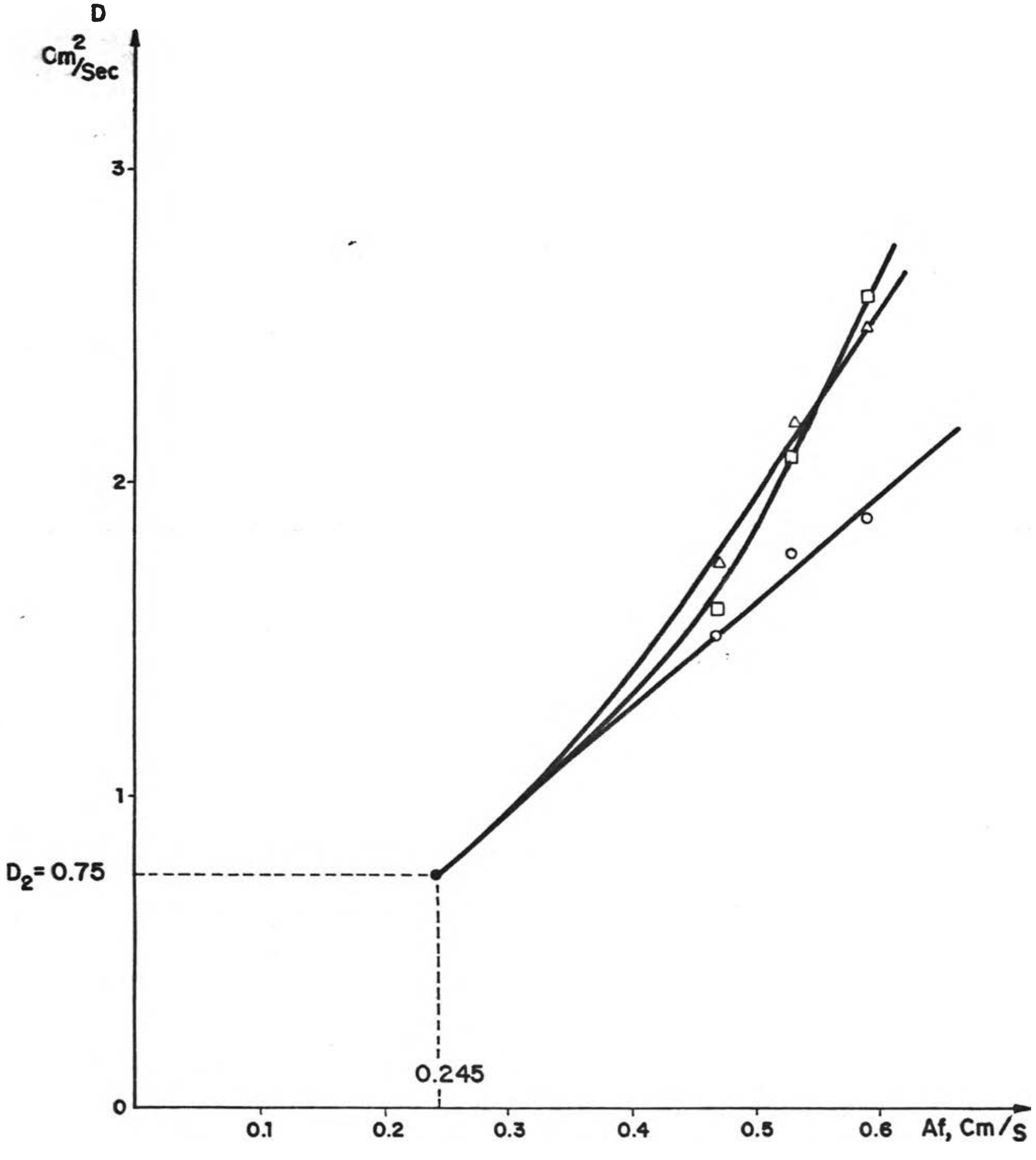

Fig. 4.3 – Determination of D_2 based on extrapolations of D_1

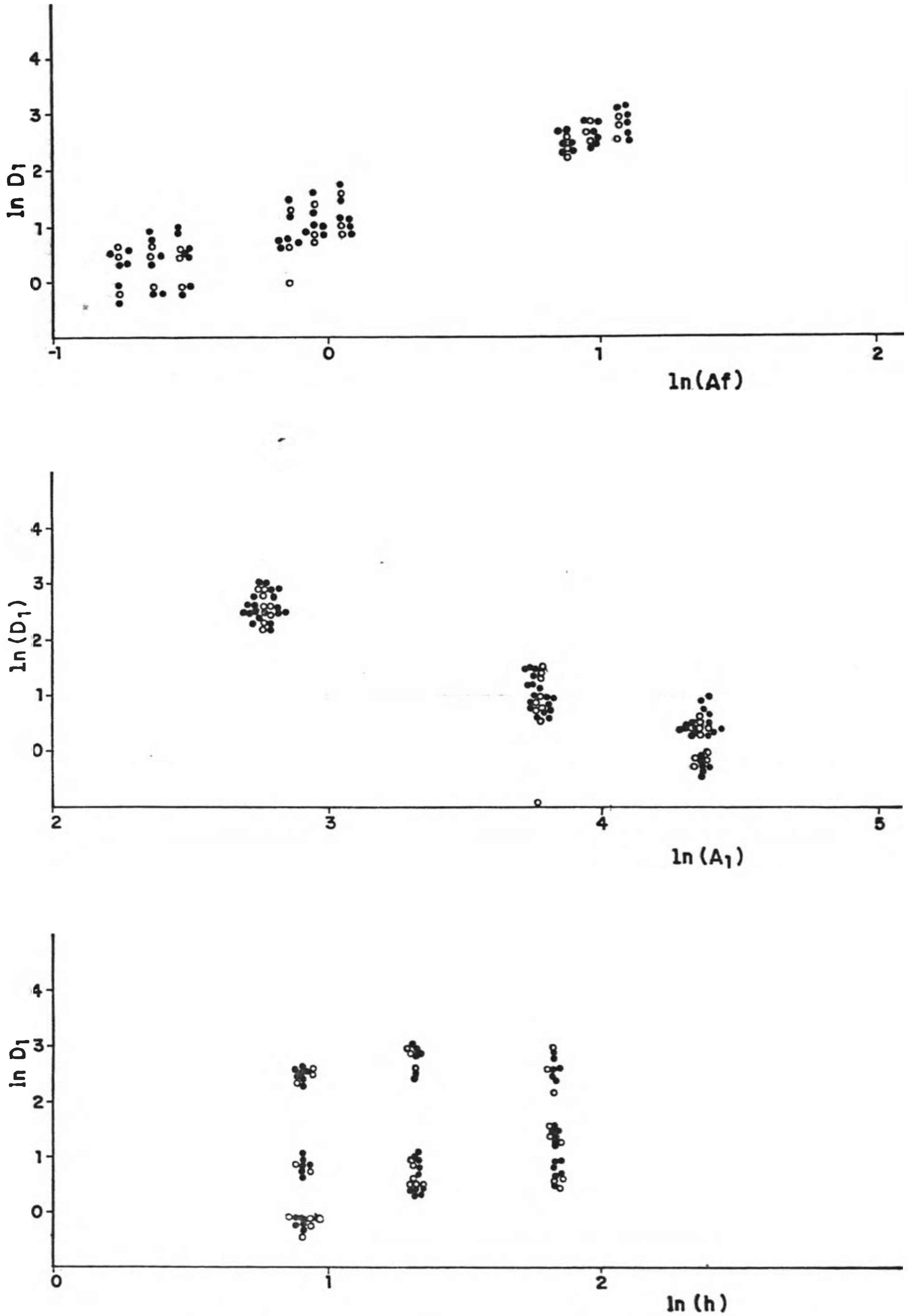

Fig. 4.4 – Plots of ln D_1 against ln(Af), ln(A_1), ln(h).

○ system with no solid

● system with solid

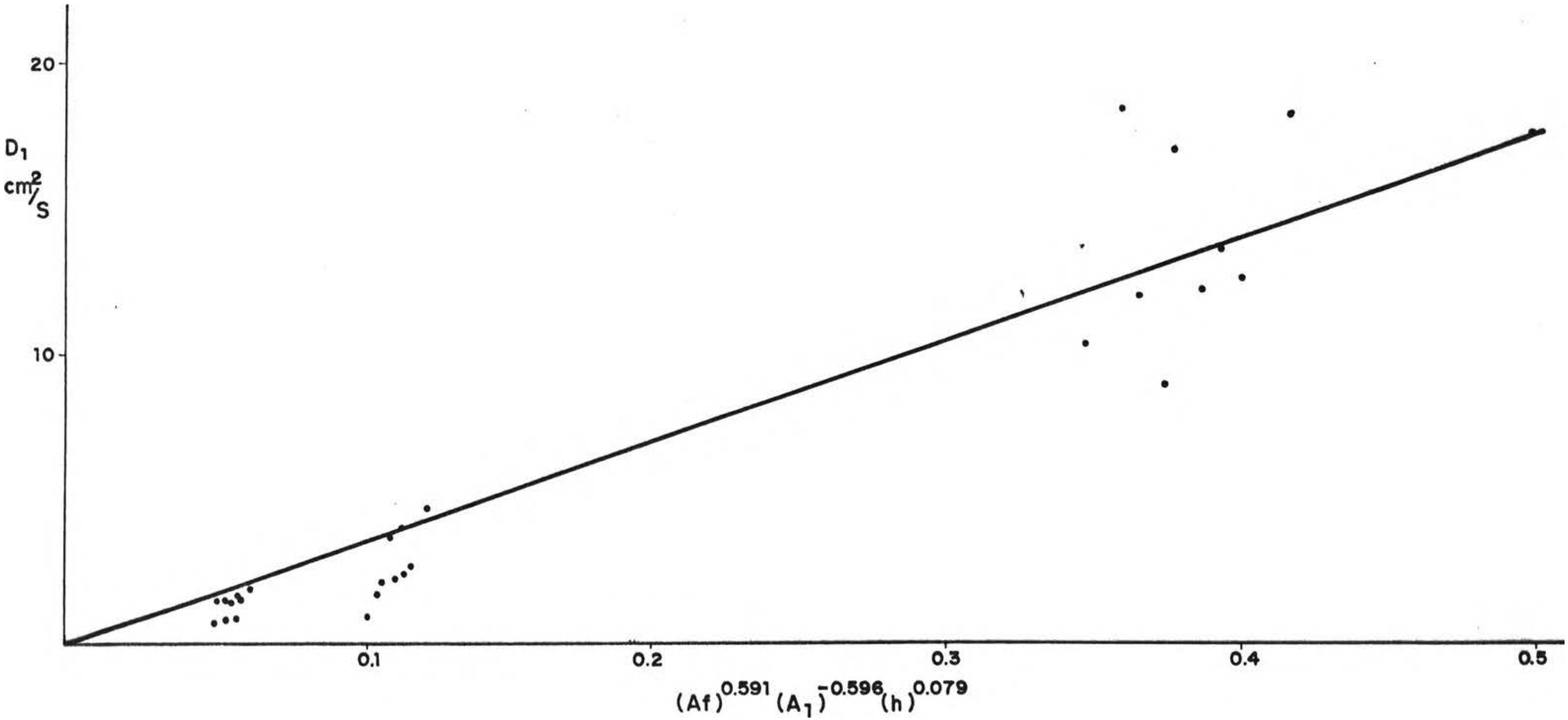

Fig. 4.5 (a) - Relation for Data based on experiments with no solids present. The slope of the least-square line shown is a= 34.97.

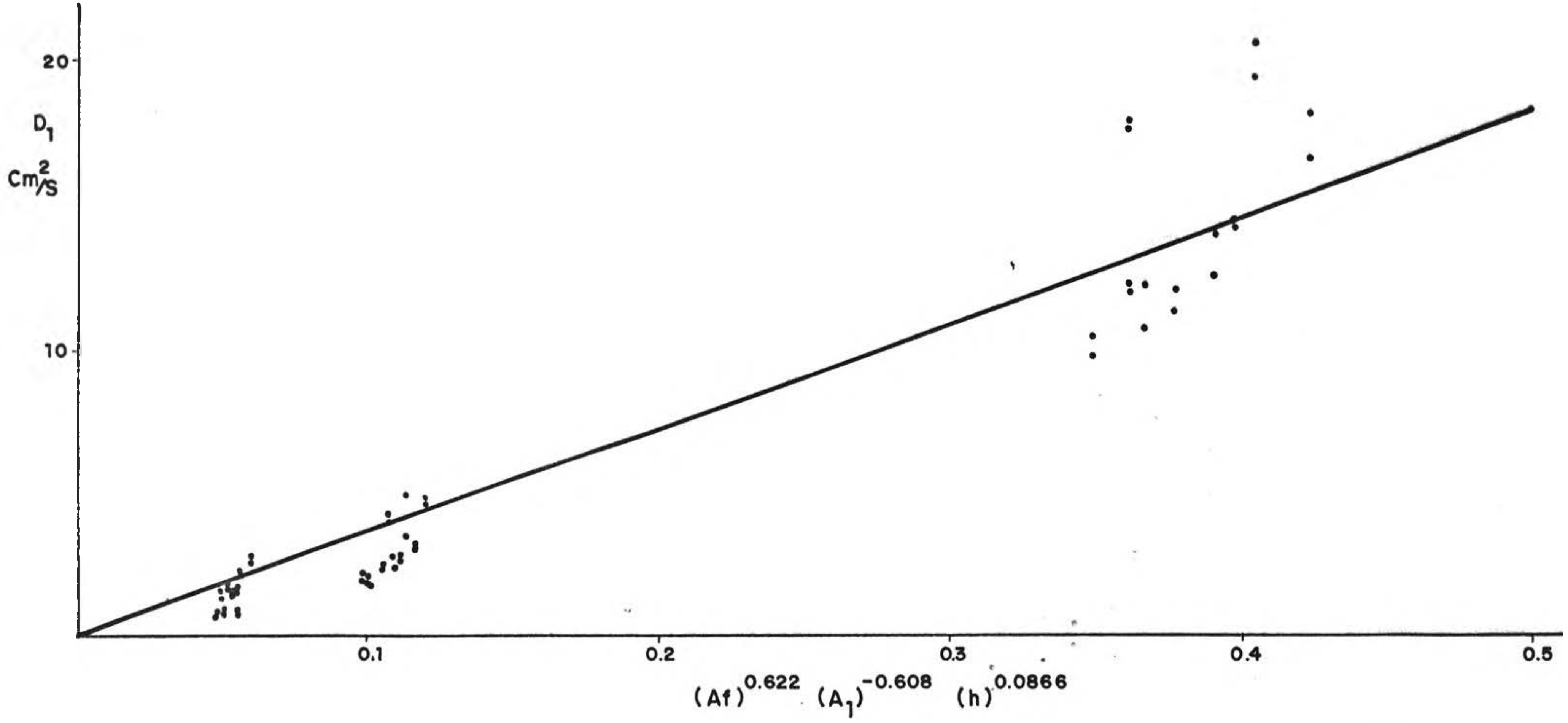

Fig. 4.5 (b) – Relation for Data based on experiments with solids present. The slope of the least-square line shown is $a = 36.31$.

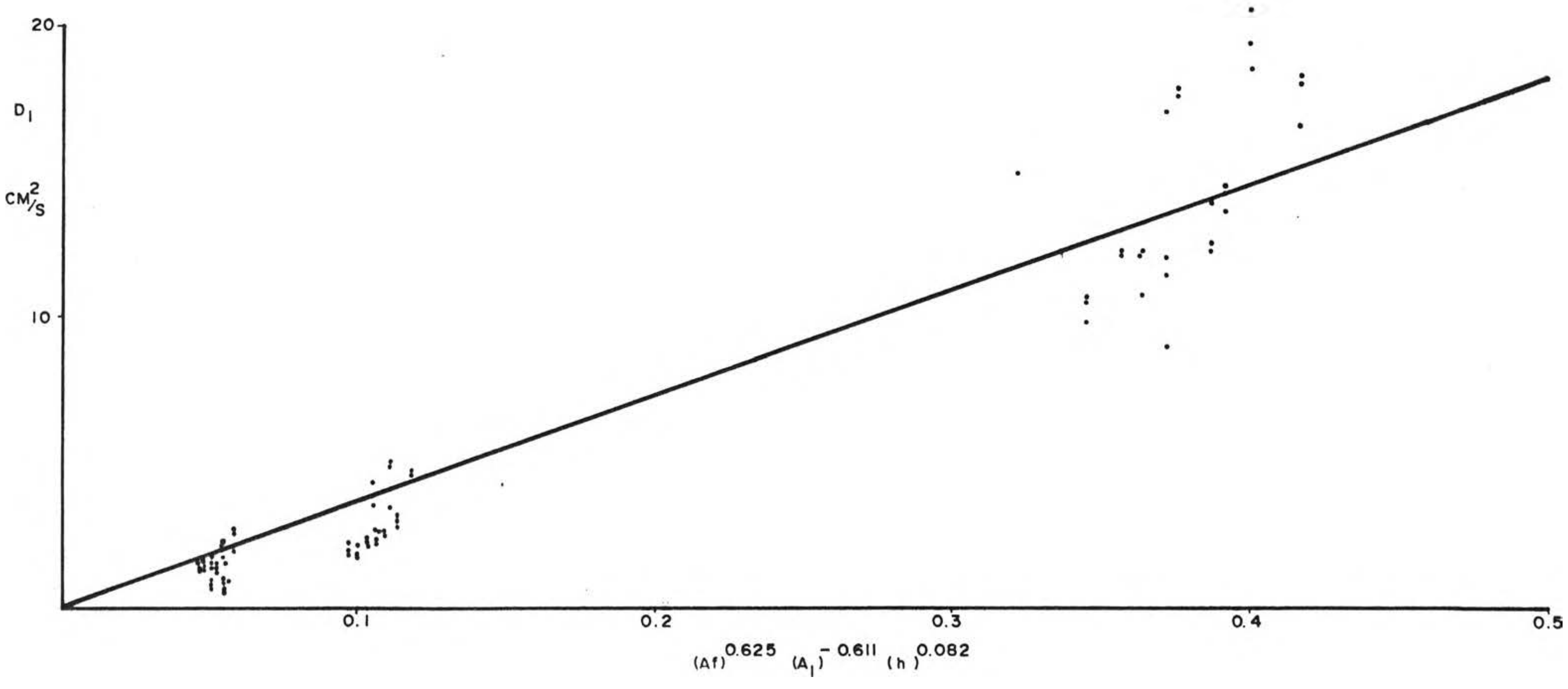

Fig. 4.5 (c) - Relation for data based on experiments with and without solids present. The slope of the least square line shown is a = 36.37.

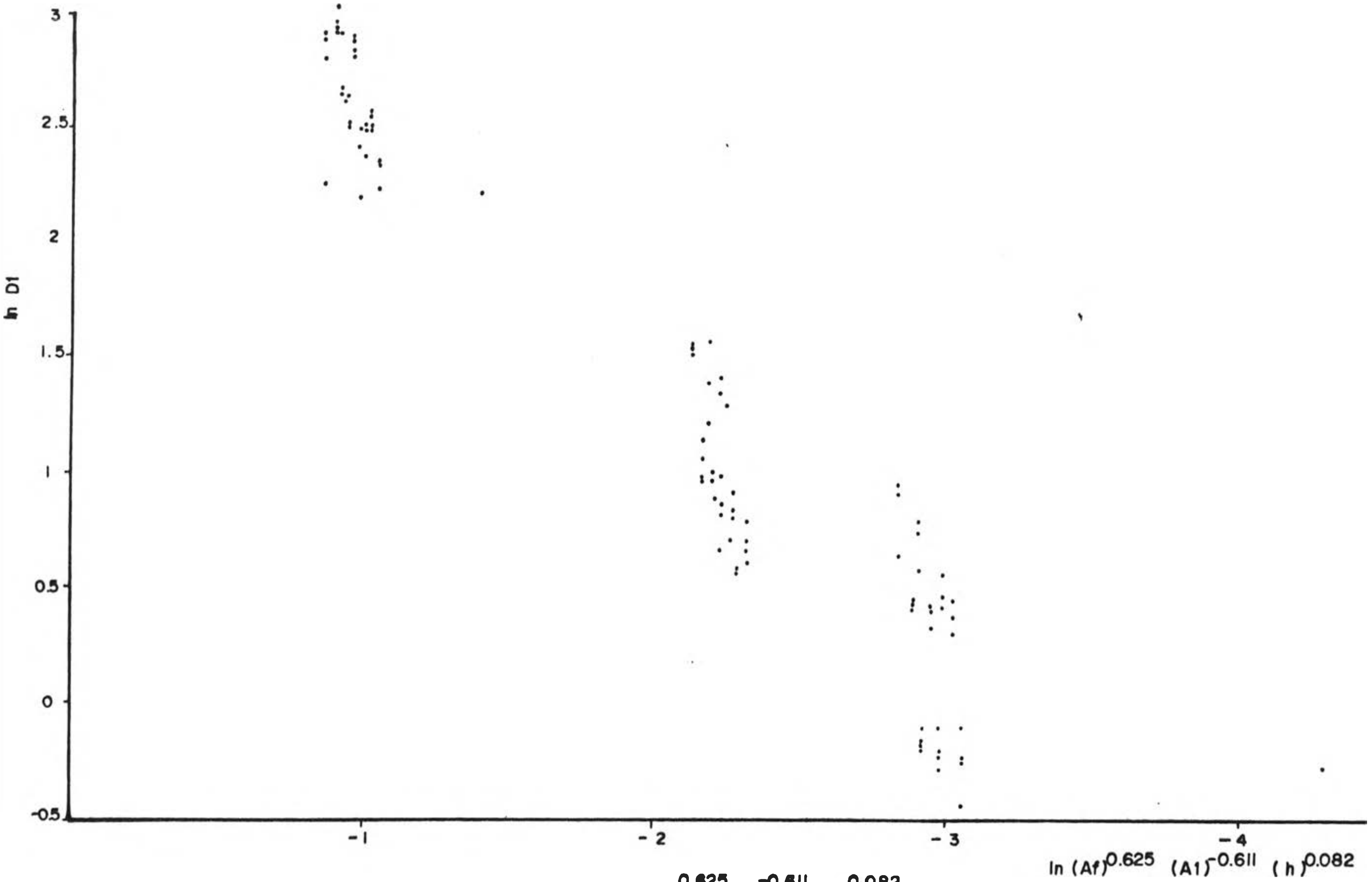

Figure 4.6 Plots of ln DI against ln $(Af)^{0.625} (A_l)^{-0.611} (h)^{0.082}$

Table 4.1 Experimental results for the determination of D1

	large column	medium column	small column
diameter(cm)	10.00	7.50	4.50
area (cm2)	78.54	44.18	15.90

	h = 6.25 cm								
	large column			medium column			small column		
Af(cm/s)	0.47			0.87			2.42		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.52	1.75	1.60	3.65	4.12	3.82	8.9	12.0	10.5
epsilon	.030	.025	.034	.089	.164	.109	.055	.045	.026
Af(cm/s)	0.53			0.95			2.63		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.78	2.20	2.10	4.02	4.82	3.40	13.6	14.4	14.2
epsilon	.022	.045	.026	.143	.173	.078	.026	.062	.028
Af(cm/s)	0.59			1.05			2.91		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.90	2.50	2.60	4.80	4.62	4.52	18.2	16.5	18.0
epsilon	.091	.046	.171	.148	.210	.078	.022	.034	.011

	large column	medium column	small column
diameter(cm)	10.00	7.50	4.50
area (cm2)	78.54	44.18	15.90

h = 3.75 cm									
	large column			medium column			small column		
Af(cm/s)	0.47			0.87			2.42		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.57	1.35	1.45	1.75	2.10	1.80	13.0	12.2	12.0
epsilon	.029	.023	.024	.076	.149	.030	.274	.095	.220
Af(cm/s)	0.53			0.95			2.63		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.50	1.38	1.53	2.24	2.67	2.27	17.0	17.5	17.8
epsilon	.045	.024	.024	.147	.176	.126	.150	.135	.145
Af(cm/s)	0.59			1.05			2.91		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	1.55	1.50	1.53	2.70	2.92	3.14	18.4	19.3	20.5
epsilon	.025	.032	.020	.142	.218	.300	.174	.084	.088

	large column	medium column	small column
diameter(cm)	10.00	7.50	4.50
area (cm2)	78.54	44.18	15.90

h = 2.50 cm									
	large column			medium column			small column		
Af(cm/s)	0.47			0.87			2.42		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	0.77	0.80	0.64	1.95	1.84	2.02	10.4	9.7	10.5
epsilon	.149	.301	.145	.082	.063	.094	.168	.036	.043
Af(cm/s)	0.53			0.95			2.63		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	0.90	0.79	0.75	2.19	2.23	2.32	12.0	12.2	10.7
epsilon	.071	.127	.062	.238	.220	.109	.106	.088	.030
Af(cm/s)	0.59			1.05			2.91		
solid(%)	0	0.50	2.50	0	0.35	1.74	0	0.20	1.02
D1(cm2/s)	0.82	0.90	0.83	2.45	2.74	2.62	12.2	13.9	12.5
epsilon	.180	.154	.064	.319	.095	.173	.079	.075	.035