statoil

SPECIAL CORE ANALYSIS REPORT
1/9-3A

FILE: PL 044 ALF 1/9-3 P5.12.04

STATOIL PRODUCTION LABORATORY

DEC. 1979

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INTRODUTIONS

The main purpose of this work on 1/9-3A was to run a quality check on Geco's routine core measurements, and also to compare Statoil Lab. data with log data. 40 horizontal plugs were chosen.

Formation factor was measured for all plugs. This was done to get Rw cross-plots of porosity versus formation factor, at atmospheric conditions. We could then define "m" and "a" values in the relation $F = a\emptyset^{-m}$ for Ekofisk and Tor formations.

LITHOLOGY

The carbonate reservoir has been divided into two zones, the Ekofisk Formation and Tor Formation. The top of the reservoir is at 3087 m. The lithology is white - light grey chalk. It is hard, homogeneous and interbedded with white - light grey, soft - hard limestone.

The interval 3119.5 - 3157 m is tight and contains several stringers of shale and marl.
Below 3157, chalk and limestone is interbedded with an increase in limestone with depth.

Experimental procedures

Well shaped 1 inch cylindrical plugs were cleaned in toluene and methanol, and dried at 60°C. Air permeability for 3 different upstream pressures were found, and hence empirical liquid (KLLB) were obtained by plotting $\frac{1}{Pm}$ vs Kair. Statoil measured helium porosities (PHE) were found using matrix cup / Boyle's Law helium injection method. As an independant check on porsity, Ø saturation (PSAT) was measured gravimetrically using kerosene as the saturation fluid.
Porosity reduction is measured using helium injeciton method, measuring reduction in pore volume by increasing overburden pressure. It's to be noted that the start point (first set point of overburden pressure) is 200 psi. The porosity reduction from atmospheric pressure and up to 200 psi is taken to be approx. .1 P.U. (porosity units)

Evacuation and saturation (under 1000 psi pressure) with 55000 ppm degassed sodium chloride solution followed, measuring Ro and Rw, the resistivity of 100 % saturated plug, and the resistivity of the saturating brine. Temperature was held constant close to room temperature. (21.5°C)

The plugs were salt extracted using methanol dried at 60°C, and then the process repeated at 97000 ppm and 117000 ppm and Ro and Rw measured. Before storing the plugs were cleaned by methanol.

RESULTS DISCUSSION

Table 1 gives a listing of measured data with associated plug numbers and core depth.

Cross-plot of PHE vs PSAT (fig 1), where two independant techniques for porosity measurement are used show good agreement.

Consultant (Geco) routine core analysis quality checks.

Poor agreement of PHE vs PHEC (Geco lab. porosity) is shown in (fig 2), for low porosity measurements, .6 P.U. (porosity units) to high for 10.0 P.U., but fairly good agreement for high porosity measurements.

Plot KLLB vs KLCO shows poor agreement. This could be due to air permeability measured at different inflow pressure. To control this both Geco and Statoil have to measure Kair at the same inflow prssure, both having atmospheric pressure at the outlet.

Ø - K plot

Fig 4 and fig 5 are a plot of PHEVS KLLB to define representative sections of the reservoir, in this case Ekofisk and Tor formations.

Porosity reduction at NCP

Fig 6, the cross-plot of P1500 (net confining pressure) vs PSAT (lab cond.) shows neglible reduction of the porosity with overburden pressure. For this specific case, the reduction in porosity is 1.5 % or .4 P.U. at 30 P.U. Lab porosity.

Comparison Labdata - Logdata

Fig 7, P1500 vs PELG shows a plot of effective log porosity after shaliness and hydrocarbon corrections have been performed, versus helium porosity at net confining pressure. Poor agreement could be due to inexact depth matching.

Fig 8, RB1500 vs P1500 describe a limestone line with matrix density 2.70 g/cc.
We define :

$$RBLB = \frac{(Vb - Vg) \rho mf + W}{Vb}$$

For 1/9-3A, temperature = 255°F
P 483 bar
Rmf = .045 m at 124°C

and accroding to Schlumberger L.I.P. fig 8.5 we read ρmf = 1.01 g/cc
When PHE = 0 , RBLB = 2.70 g/cc, so this graph is a check on porosity quality control.

Fig. 9, RBLG (Formation Density log reading) vs RB1500 shows poor agreement, also when eliminating depth mismatched points. RBLG shows much higher reading than RB1500

Porosity versus Formation factor plots.

Fig 10 - 18 plot Co, conductivity of 100 % . saturated plug versus Cw, conductivity of saturating brine. The points plot a line through the origion as expected indicating constant F values independent of salinity. Poor fitted lines could be due to "Clay effect", where clay ions become involved in the Ro mesurement.

Fig. I9, and fig.20, PSAT versus Formation Factor for both Ekofisk and Tor Formation gives the relation

$F= I.I\ \emptyset^{-2.I}$ (Ekofisk) Deleted data points: IO,II, I8,I9.

$F= I.3\ \emptyset^{-I.8}$ (Tor) Deleted data points: 25

On reviewing F-Ø plot at atmospheric pressure, and assuming a=I the relation

$F= a\emptyset^{-m}$ is given by

$F= \emptyset^{-2.I5}$ for Ekofisk Formation Fig. 2I

$F= \emptyset^{-2.0}$ for Tor Formation Fig. 22

CONCLUSIONS

Poor agreement for helium porosity between Geco and Statoil with Geco reading high of .6 (P.U.) for low porosity(IO%) and good agreement for high porosity, Geco high of about .2 (P.U.) for 30%. Emperical liquid permeabilities correlations are poor.

Poor agreement on the plot P1500 versus PELG.
F -Ø plot gives the relation assuming a=I

$F= \emptyset^{-2.I5}$ Ekofisk

$F = \emptyset^{-2.0}$ Tor

Nomenclature

a = coefficient in F - Ø relaiton

A = gradient coefficient in Y = Ax+B computer linear regression curve fit.

B = constant in Y = Ax+B computer linear regression curve fit.

Co = specific conductance of rock 100% saturated in aqueous soulution (mho·cm^{-1})

Cw = specific conductance of aqueous solution (mho cm^{-1})

C_2 = correlation coefficient in Y = Ax+B computer linear regresssion curve fit.

Data = computer number given to plug in sequence

Depth = driller's depth of core (m)

FLB = average formation factor measured with 3 different brine solutions

KLCO = consultant (Geco) empirical liquid perm. (mD)

KLLB = Statoil empirical liquid perm (mD)

Pm = $\frac{P_1 + P_2}{2}$

P_1 = upstream pressure

P_2 = downstream pressure

m = porosity exponent/lithology factor (cementation factor)

P = approx. reservoir fluid pressure

P1500 = Statoil lab. porosity in situ

PELG = efffective Statoil log porostiy after shaliness and hydrocarbon corrections performed

PHE = Statoil helium porosity

PHEC = consultant helium porosity (Geco)

PLUG = plug noumber associated with depth

PSAT = Statoil kerosene stauration porosity

RB1500 = Statoil lab. bulk density in situ (g/ml)

RBLG = log bulk density reading (g/ml)

RMAC = consultant matrix density (g/ml) (Geco)

RMALB = Statoil matrix density (g/ml)

Ro	=	specific resistance of rock (ohm-m) at lab. temperature and pressure
Rw	=	specific resistance of aqueous solution (ohm-m) at lab. temperature and pressure
Rmf	=	invaded zoned " mud filtrated resistivity (ohm-m)
ρmf	=	density of mud filtrate in situ pressure (g/ml)
Vb	=	bulk volume (ml) (mercury displacement method)
Vg	=	grain volume (ml)
W	=	dry weight of plug (g)

[redacted] NOTE [redacted] . [redacted] 1 [redacted]ANS [redacted] NO [redacted] KLLB MEASURED [redacted]

. 01 MEANS NO PSAT MEASURED

TABELL : I.

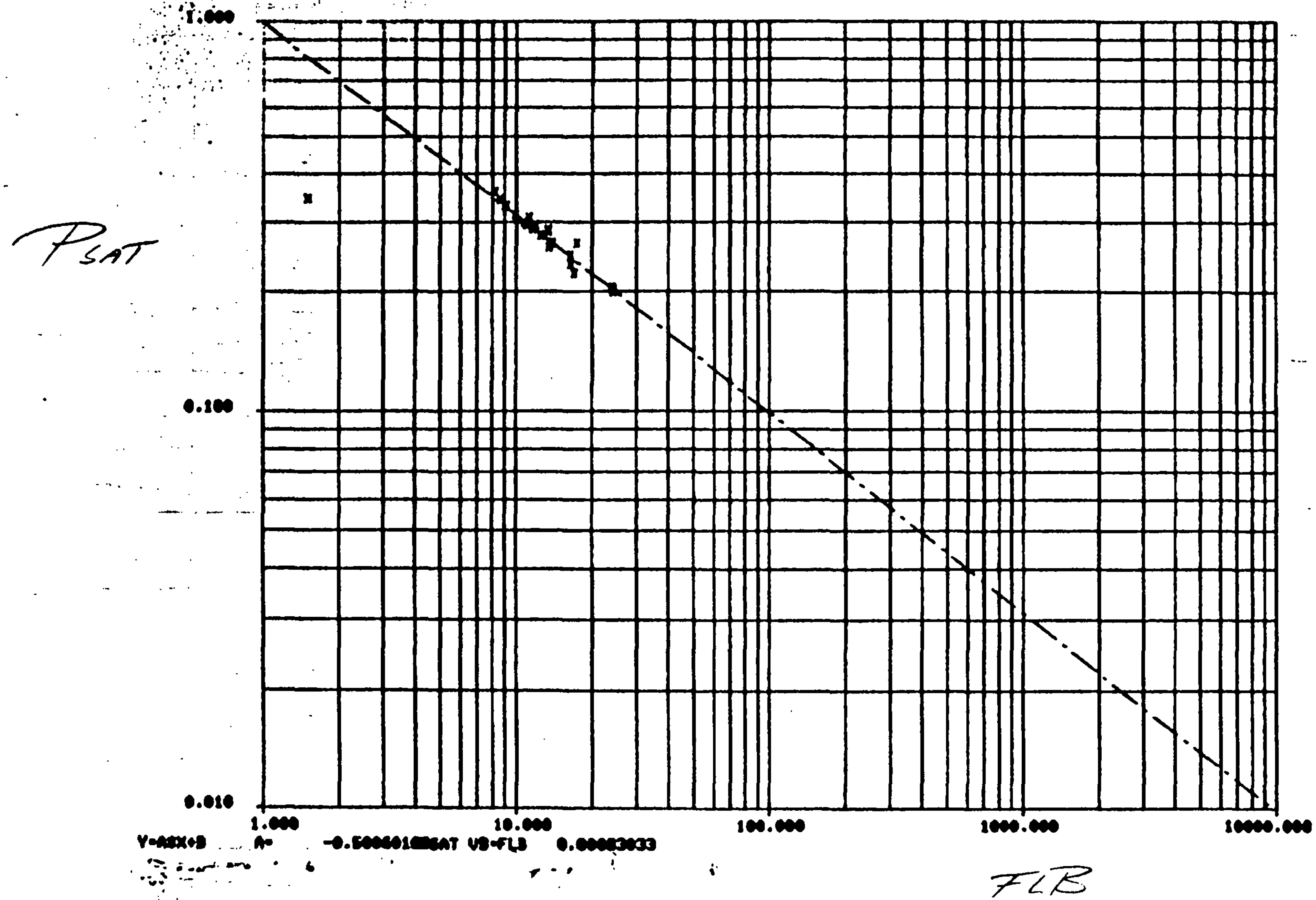
1.50 MEANS NO FORMATION FACTOR MEASURED

DATA NO.	DEPTH M	KLLB MD	KLCO MD	PHE %	PHEC %	P1500 %	PELG %	PSAT %	FLB	RMALB gm/cc	RMAC gm/cc	RB1500 gm/cc	RBLG gm/cc
1	3105.70	.001	1.40	.389	.391	.384	.330	.390	7.97	2.71	2.70	2.06	2.14
2.	3107.35	1.15	1.40	.382	.380	.377	.345	.383	8.24	2.70	2.69	2.07	2.11
3.	3108.70	1.00	1.20	.365	.365	.360	.315	.365	9.06	2.70	2.69	2.10	2.20
4.	3109.35	0.95	1.60	.367	.366	.362	.317	.367	8.84	2.70	2.70	2.09	2.17
5.	3110.35	0.80	1.30	.373	.374	.368	.312	.375	8.52	2.70	2.70	2.08	2.17
6.	3112.00	0.80	1.10	.363	.365	.358	.310	.364	8.87	2.70	2.71	2.10	2.16
7.	3112.70	0.85	1.30	.392	.395	.387	.335	.393	8.04	2.70	2.71	2.05	2.09
8.	114.00	0.75	1.00	.365	.367	.360	.290	.366	9.03	2.70	2.71	2.10	2.20
9.	3116.35	0.15	0.26	.296	.299	.292	.275	.295	15.25	2.70	2.71	2.21	2.17
10.	3116.70	0.45	0.61	.341	.341	.336	.260	.340	14.78	2.70	2.70	2.14	2.22
11.	3117.00	0.36	0.46	.324	.329	.319	.255	.324	13.78	2.70	2.70	2.16	2.30
12.	3117.70	0.10	0.19	.271	.278	.267	.235	.272	15.53	2.69	2.70	2.24	2.28
13.	3118.00	0.25	0.20	.282	.290	.278	.230	.284	13.75	2.69	2.70	2.23	2.30
14.	3118.35	.001	0.15	.254	.258	.250	.225	.001	18.46	2.70	2.70	2.28	2.32
15.	3119.00	0.11	0.13	.241	.246	.237	.220	.242	19.62	2.70	2.71	2.30	2.31
16.	3119.70	0.07	0.09	.212	.219	.208	.170	.213	23.51	2.69	2.71	2.34	2.40
17.	3120.70	0.06	0.10	.202	.208	.198	.225	.201	29.62	2.70	2.70	2.37	2.41
18.	3121.00	.001	0.03	.138	.141	.135	.230	.128	50.13	2.70	2.71	2.47	2.40
19.	3121.70	.001	0.03	.141	.145	.138	.230	.138	51.88	2.71	2.71	2.48	2.41
20.	3165.40	1.05	1.30	.288	.286	.284	.240	.288	11.63	2.71	2.70	2.23	2.39
21.	3165.75	0.95	1.10	.299	.297	.295	.235	.300	10.76	2.71	2.70	2.21	2.38
22.	3167.00	0.65	0.74	.264	.263	.260	.225	.265	13.74	2.70	2.70	2.26	2.35
23.	3168.00	0.55	0.64	.233	.234	.229	.225	.235	16.35	2.70	2.71	2.32	2.37
24.	3175.35	1.07	1.40	.293	.294	.289	.300	.294	11.01	2.71	2.71	2.22	2.28
25.	3187.80	.001	3.70	.346	.351	.341	.330	.346	1.50	2.70	2.71	2.13	2.22

TABELL 1

DATA NO.	DEPTH M	KLLB MD	KLCO MD	PHE %	PHEC %	P1500 %	PELG %	PSAT %	FLB	RMALB gm/cc	RMAC gm/cc	RB1500 gm/cc	RBLG gm/cc
26.	3189.00	3.45	3.60	.356	.361	.351	.340	.359	8.22	2.70	2.72	2.11	2.22
27.	3189.90	2.30	2.30	.328	.334	.323	.340	.331	9.06	2.70	2.72	2.16	2.23
28.	3190.30	2.10	2.90	.344	.349	.339	.340	.345	8.59	2.71	2.72	2.14	2.21
29.	3191.50	1.70	2.50	.329	.335	.324	.340	.330	9.09	2.71	2.72	2.16	2.22
30.	3192.30	1.40	1.60	.305	.311	.301	.300	.308	11.19	2.71	2.72	2.20	2.23
31.	3193.40	1.80	2.20	.311	.319	.306	.270	.313	9.94	2.71	2.72	2.19	2.27
32.	3195.70	0.90	1.00	.282	.289	.278	.255	.283	13.40	2.70	2.72	2.23	2.35
33.	3196.40	1.70	2.10	.286	.290	.282	.250	.287	13.31	2.70	2.71	2.23	2.35
34.	3197.60	1.40	1.30	.264	.271	.260	.235	.266	17.29	2.70	2.72	2.26	2.34
35.	3210.95	0.40	0.80	.243	.249	.239	.230	.247	16.34	2.70	2.72	2.30	2.40
36.	3223.20	.001	1.60	.277	.284	.273	.250	.277	12.49	2.71	2.72	2.25	2.37
37.	3224.35	1.00	1.60	.292	.292	.288	.265	.294	11.88	2.70	2.70	2.22	2.40
38.	3225.40	1.10	1.50	.258	.263	.254	.250	.260	13.46	2.70	2.71	2.27	2.48
39.	3226.10	0.45	0.59	.222	.225	.218	.215	.223	16.98	2.70	2.71	2.33	2.48
40.	3226.45	0.60	0.41	.198	.202	.194	.215	.199	23.90	2.71	2.71	2.38	2.48

FIG 22. SHOWS THE SAME PLOT AS FIG. 19, (PSAT) VERSUS (FLB) WITH a = 1, TOR FORMATION. DELETED DATA POINT (25).



PLOTTED BY: ILP

FIG. 21 Shows the same plot as Fig. 19, (PSAT) versus (FLB), with a = 1, Ekofisk Formation. Deleted data points 14, 18, 19 (No Porosity, Low Porosity).

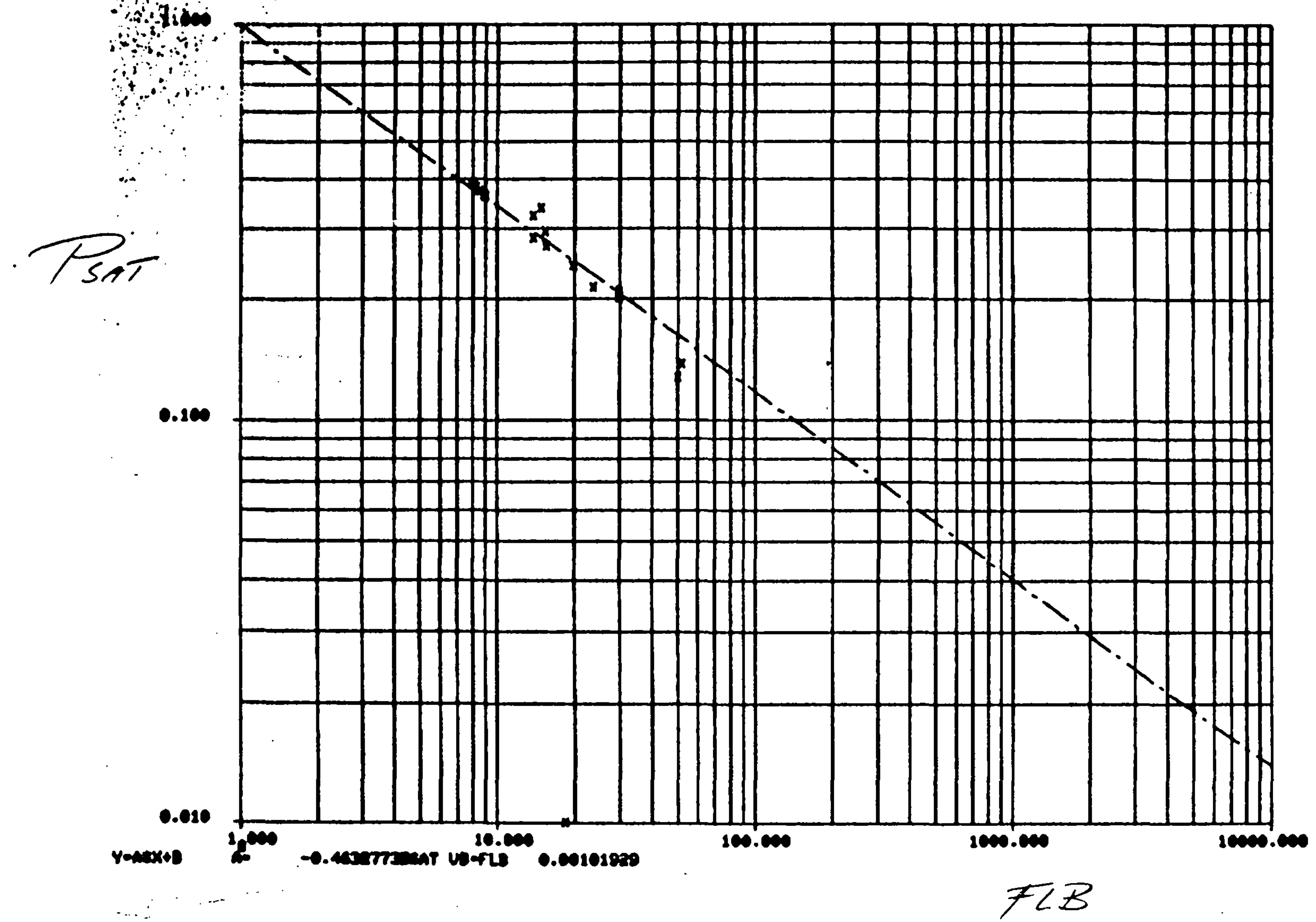
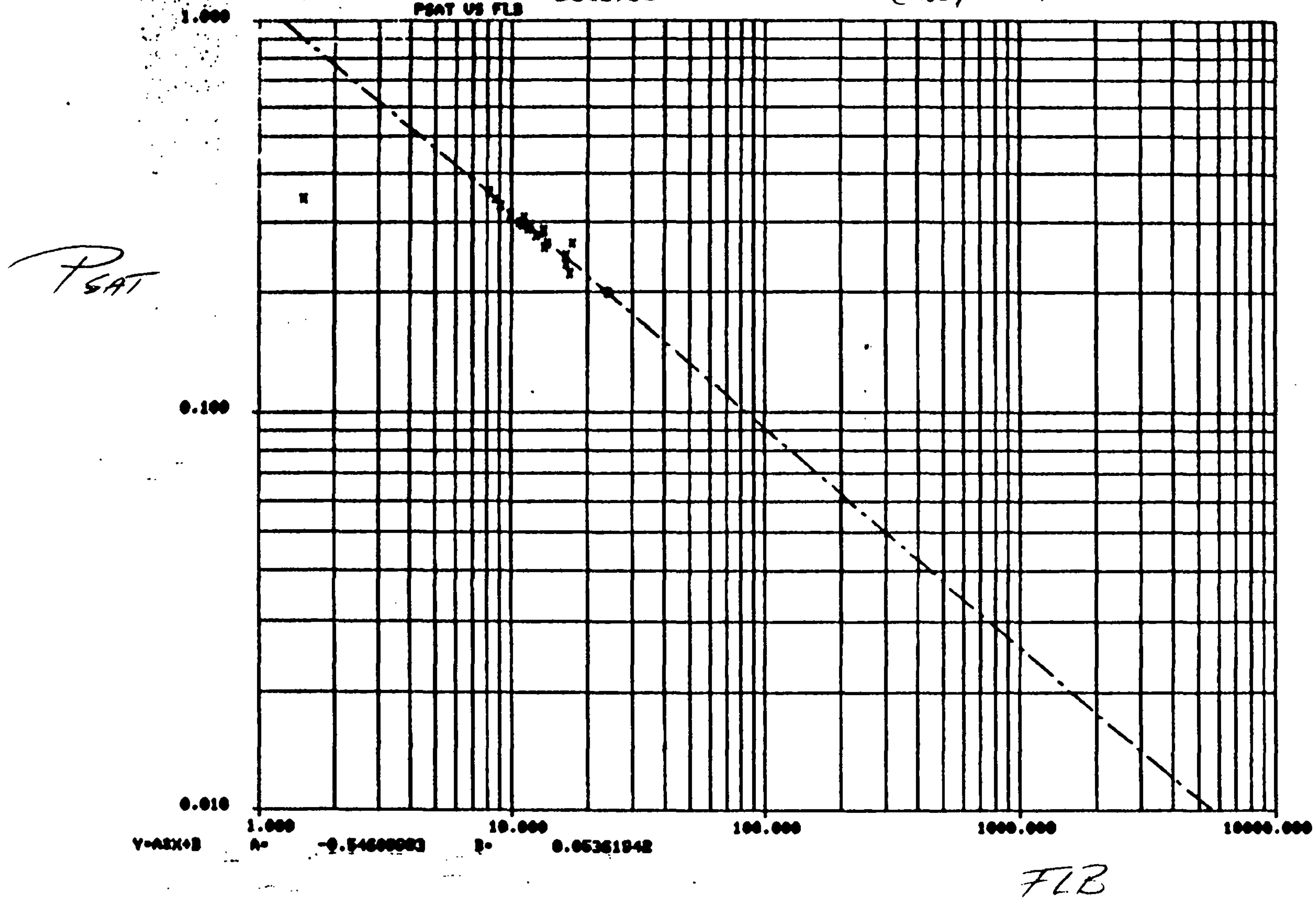


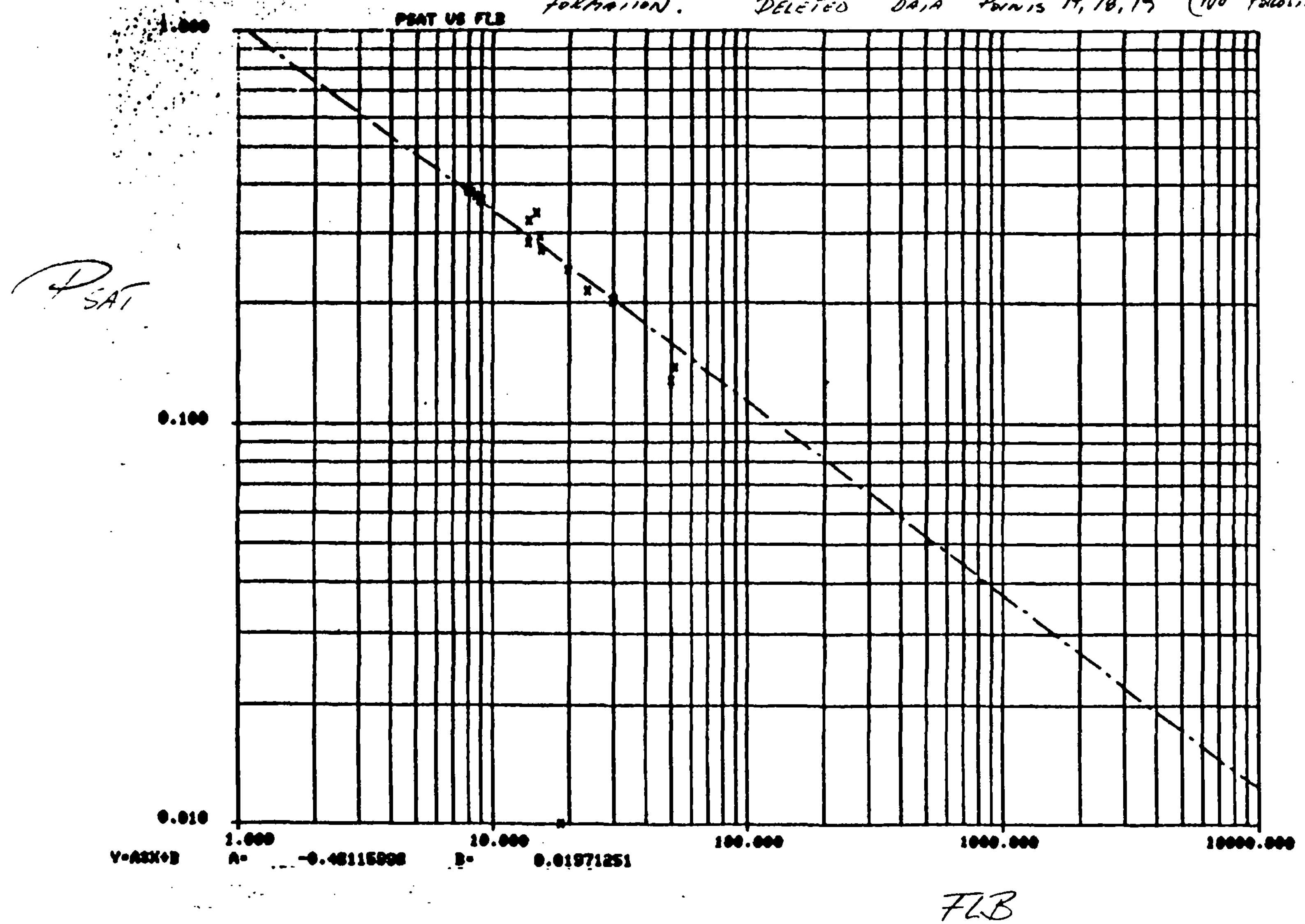
FIG. 20 SHOWS THE RELATION BETWEEN POROSITY (PSAT) VERSUS AVERAGE FORMATION FACTOR FOR 3 DIFFERENT BRINE SOLUTIONS. (FLB) FOR TOR FORMATION.

DELETED DATA POINTS (25) NO FORMATION FACTOR MEASUREMENT



PLOTTED BY: ILP

FIG. 19 SHOWS THE RELATION BETWEEN SATURATION POROSITY (PSAT), VERSUS AVERAGE FORMATION FACTOR FOR 3 DIFFERENT BRINE SOLUTIONS. (FLB). FOR EKOFISK FORMATION. DELETED DATA POINTS 14, 18, 19 (NO POROSITY, LOW POROSITY)



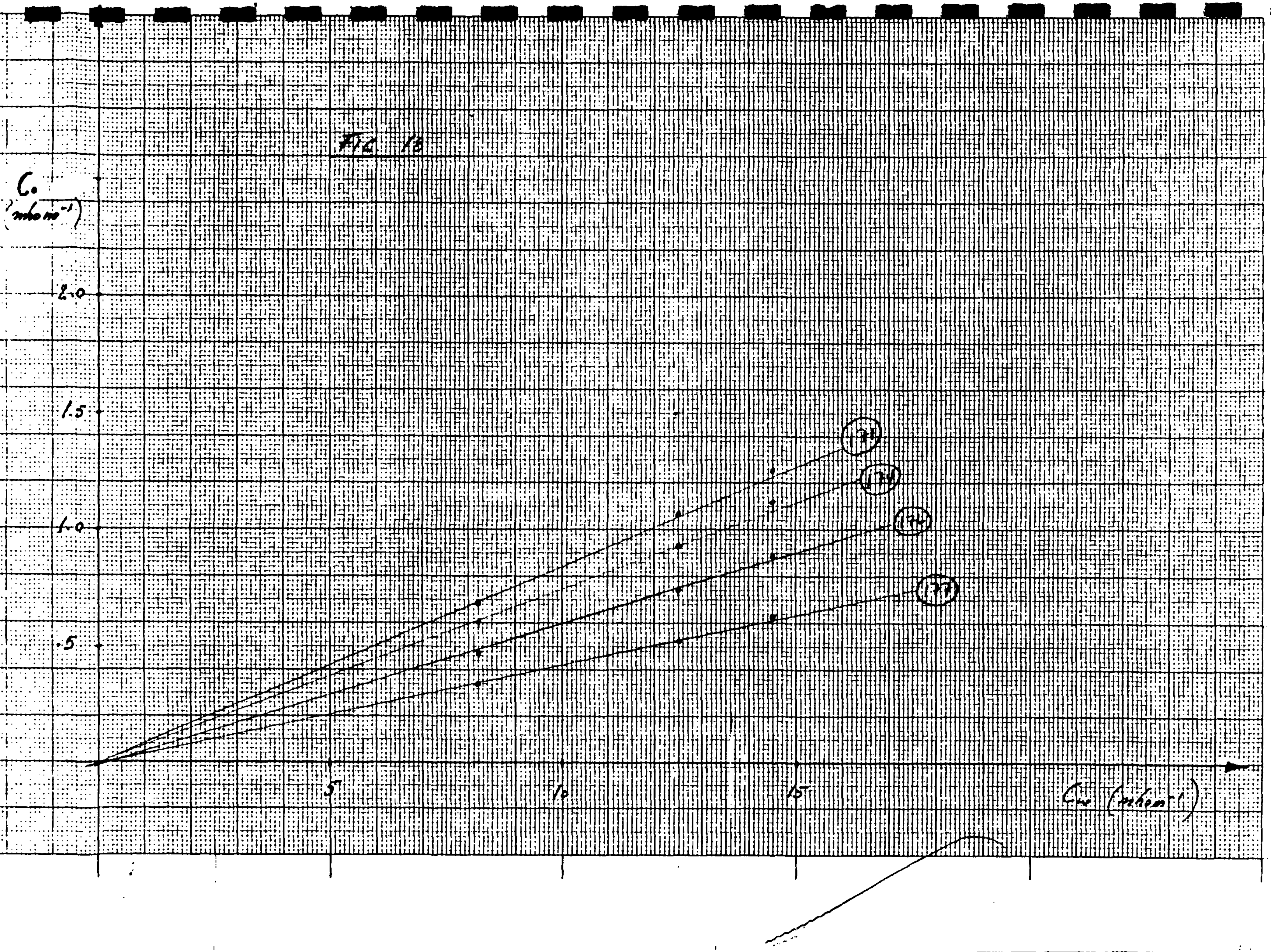


FIG 13

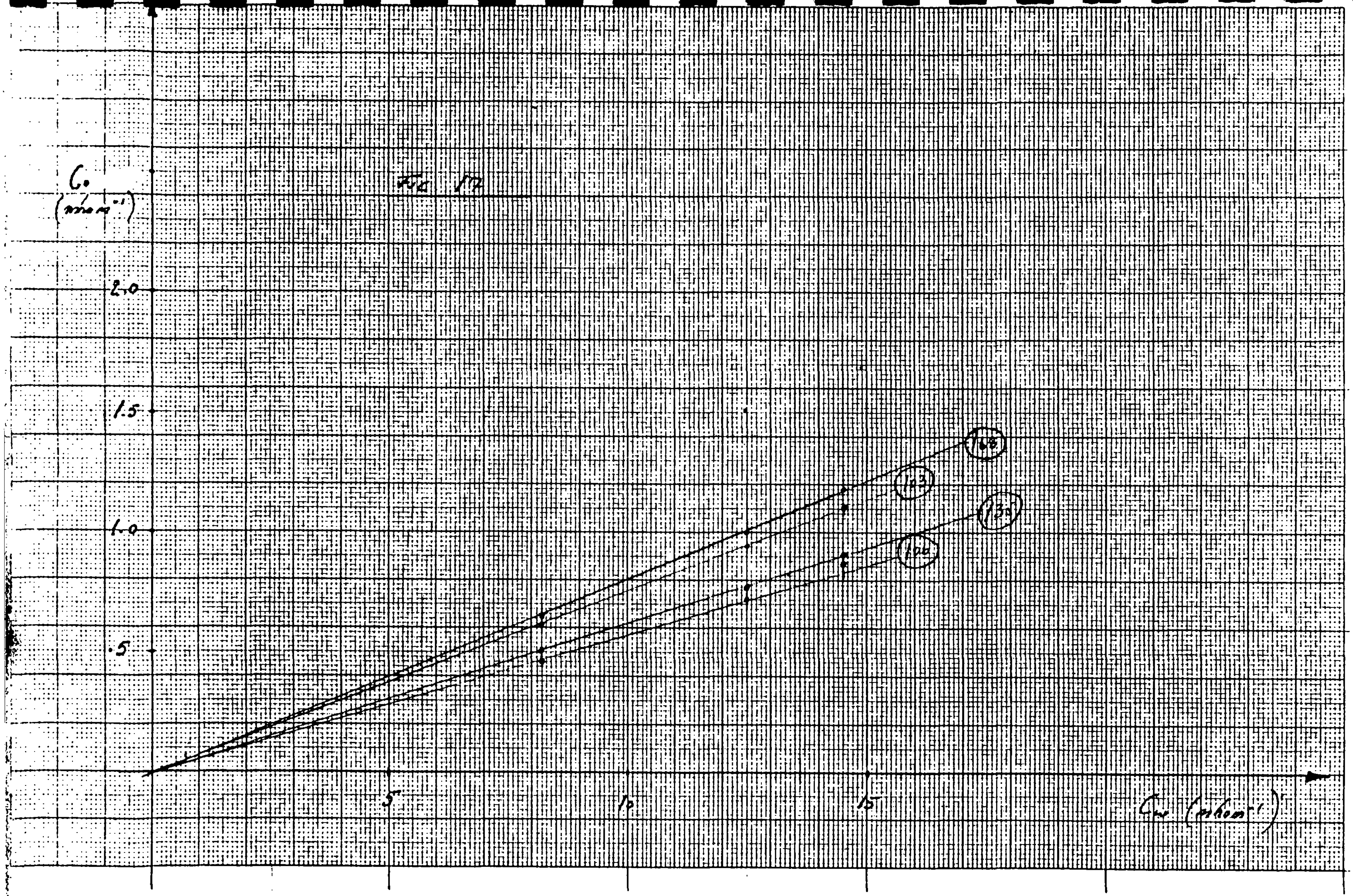


Fig 17
C₀ (mhom⁻¹)
2.0
1.5
1.0
.5
5
10
15
Cw (mhom⁻¹)

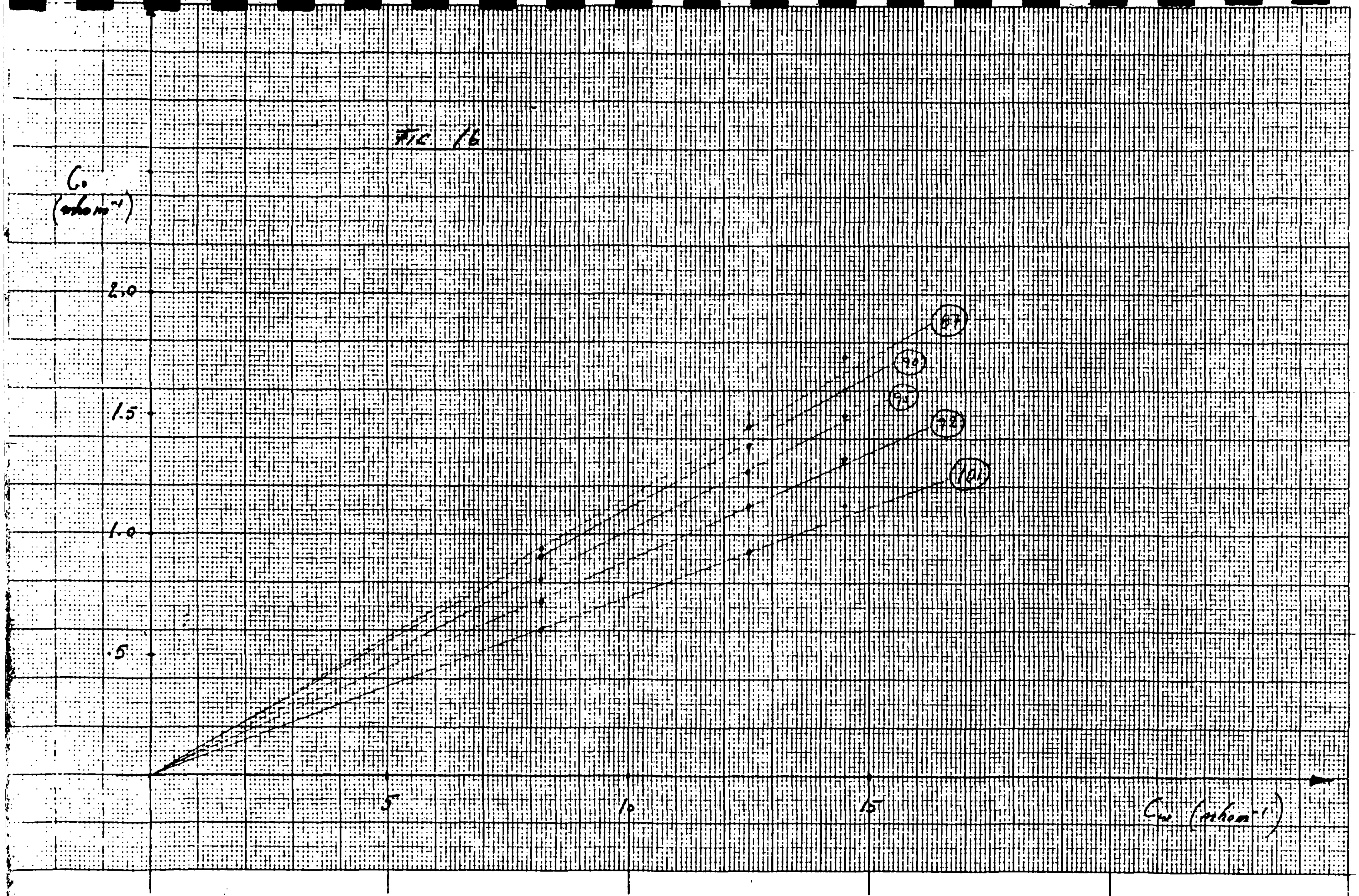


FIG 16

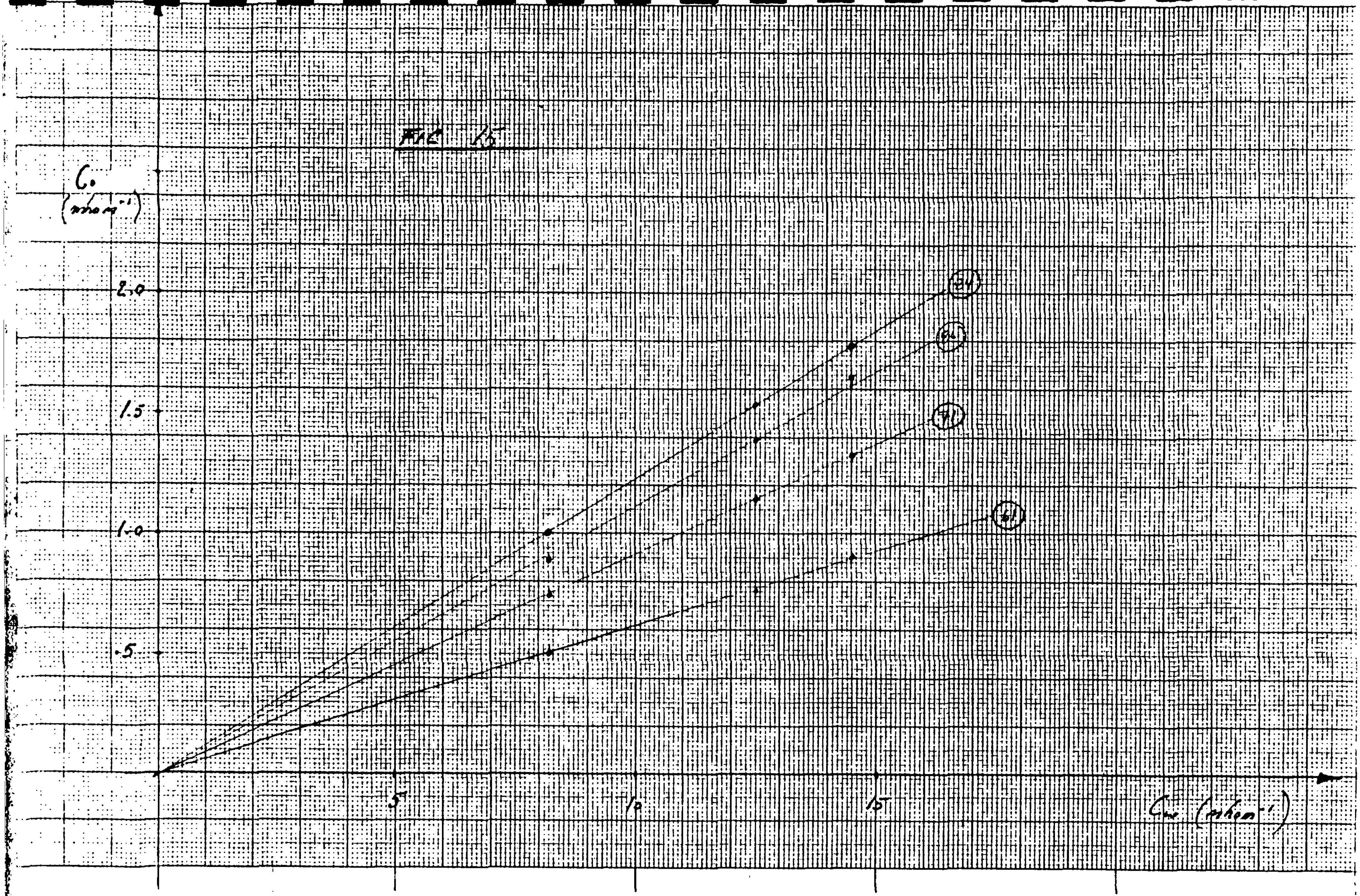
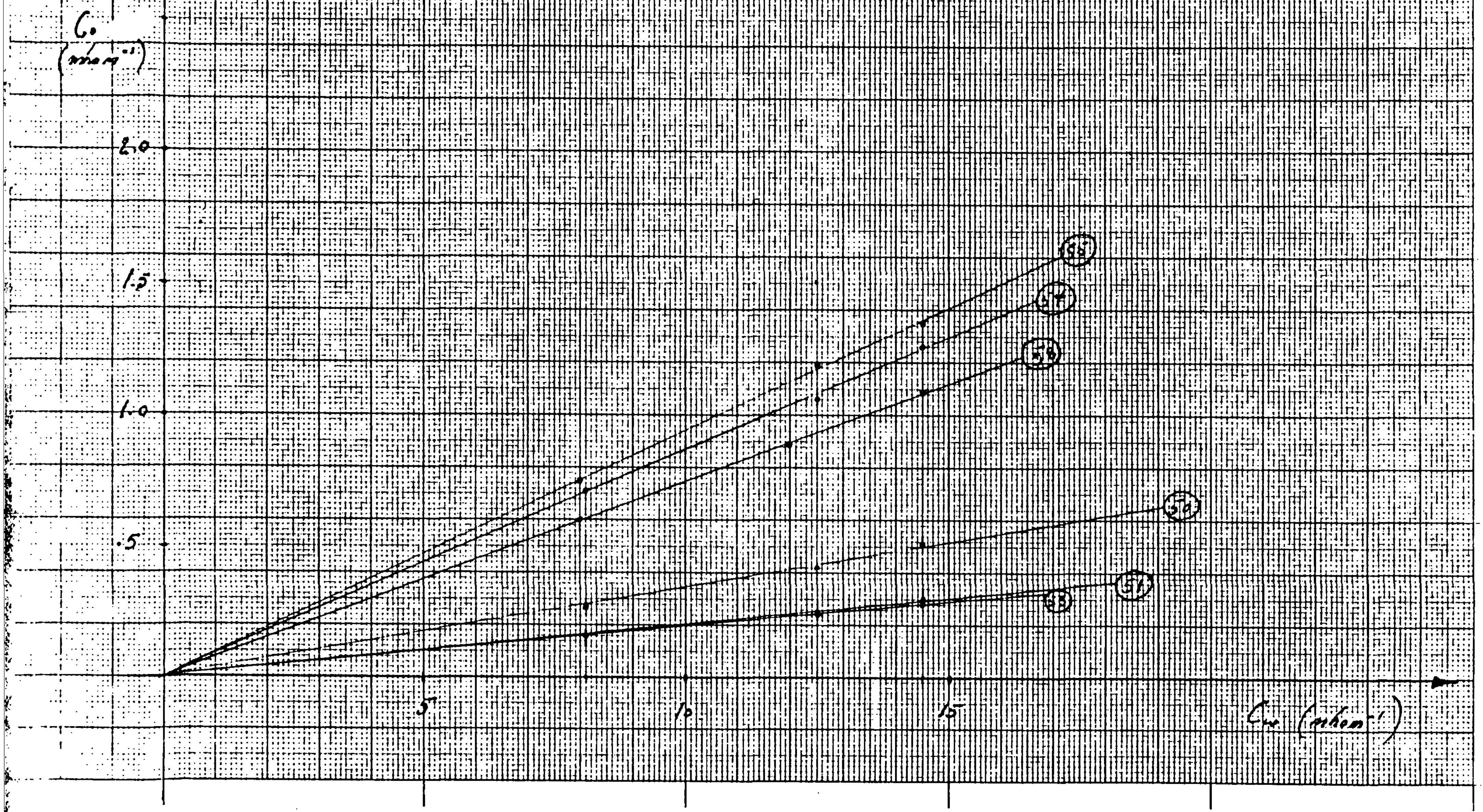


FIG 15

FIG 14



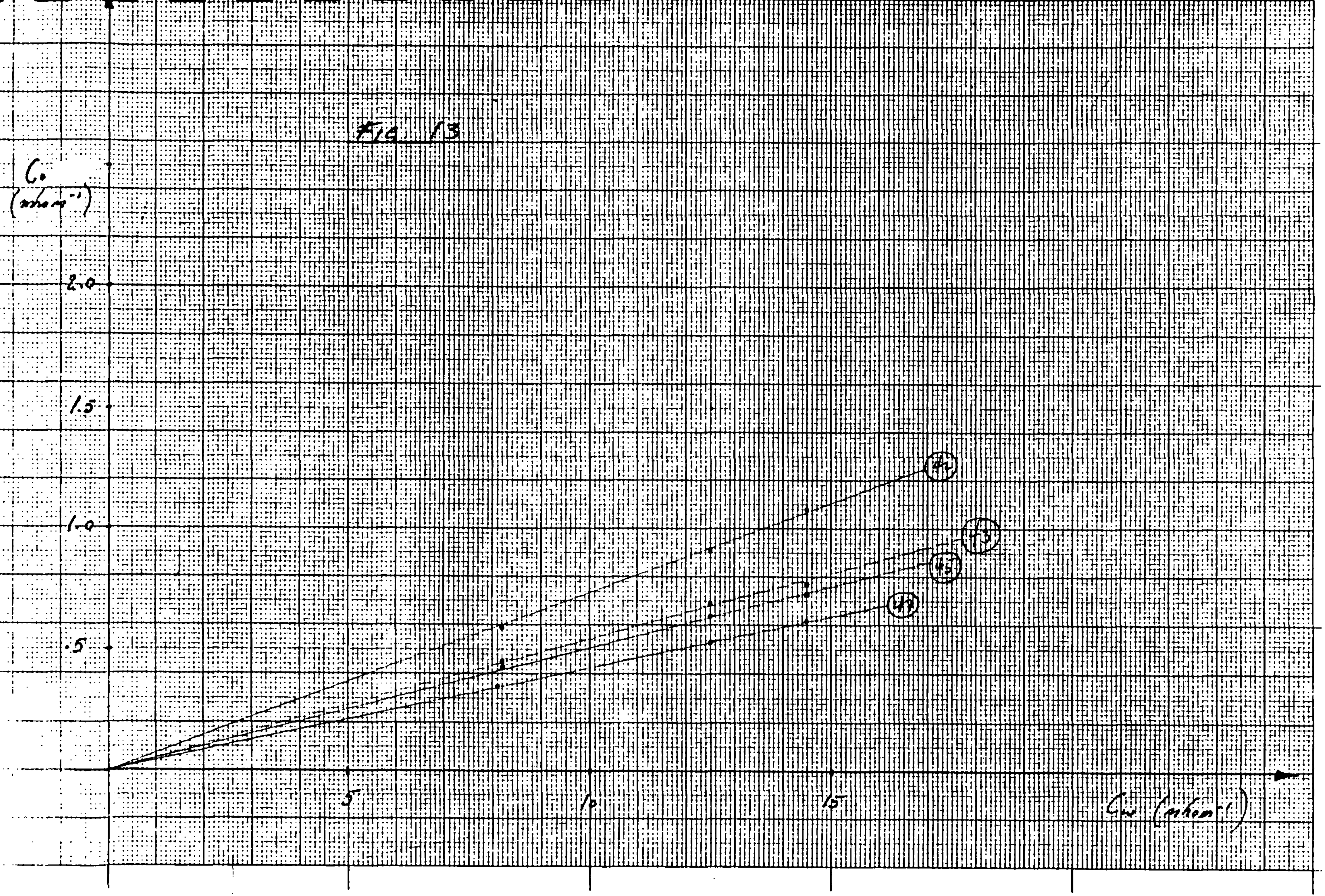
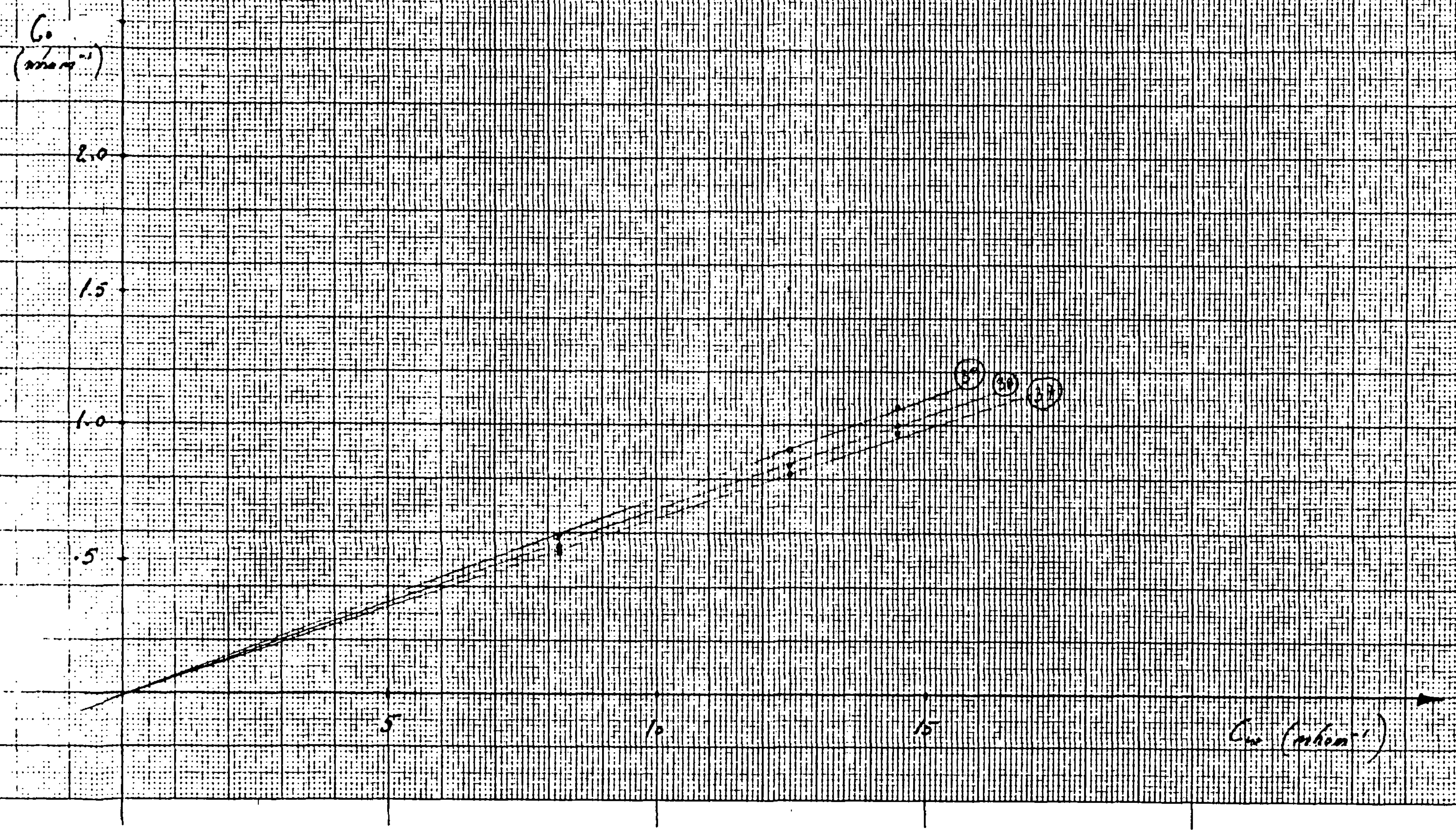


FIG 13

FIG 12



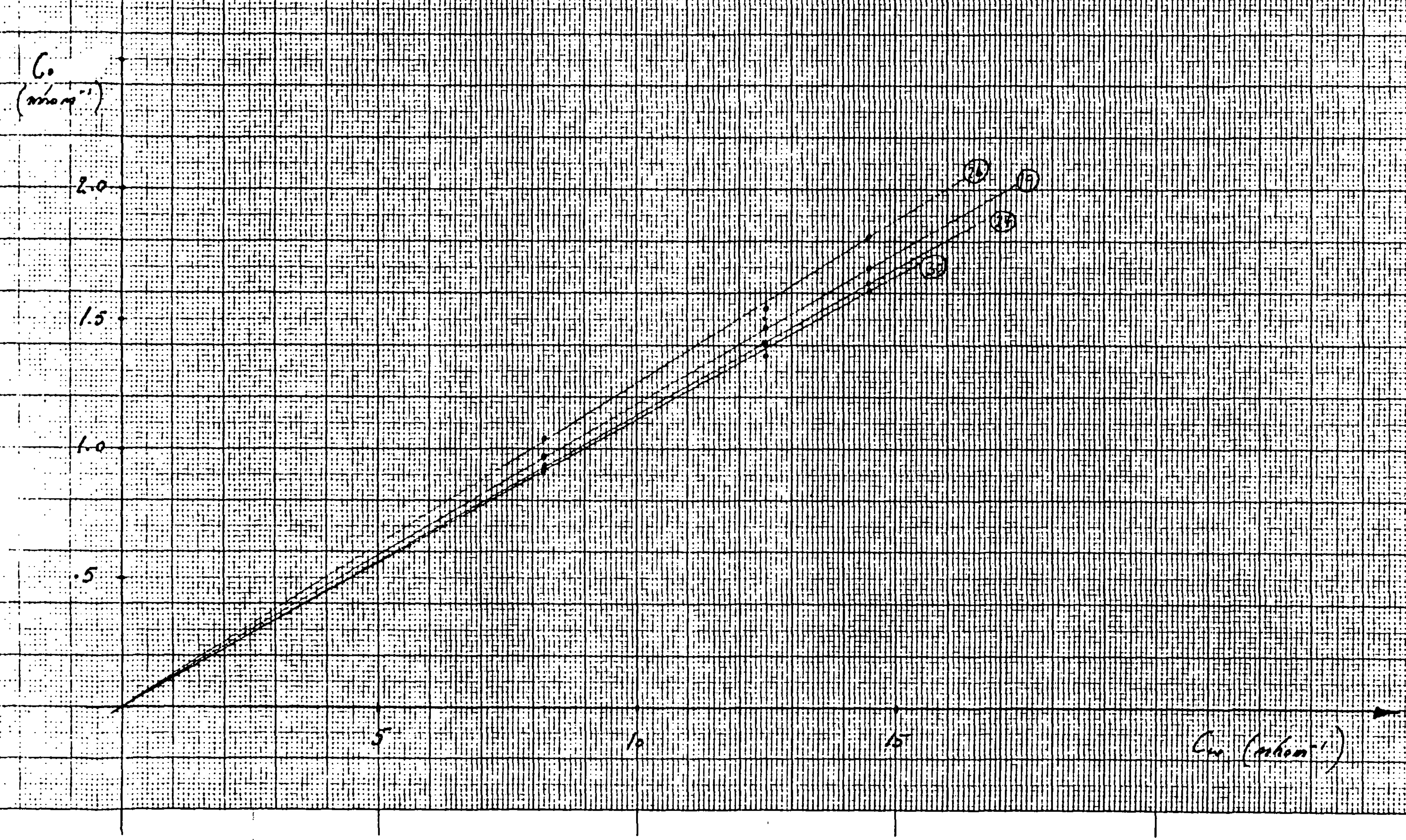


FIG 11

FIG. 10 SHOWS THE PLOT OF CONDUCTIVITY OF 100% SATURATED PLUG (C_o) VERSUS CONDUCTIVITY OF SATURATING BRINE (C_w)

THE SAME PLOT FROM FIG. 10 - FIG. 18.

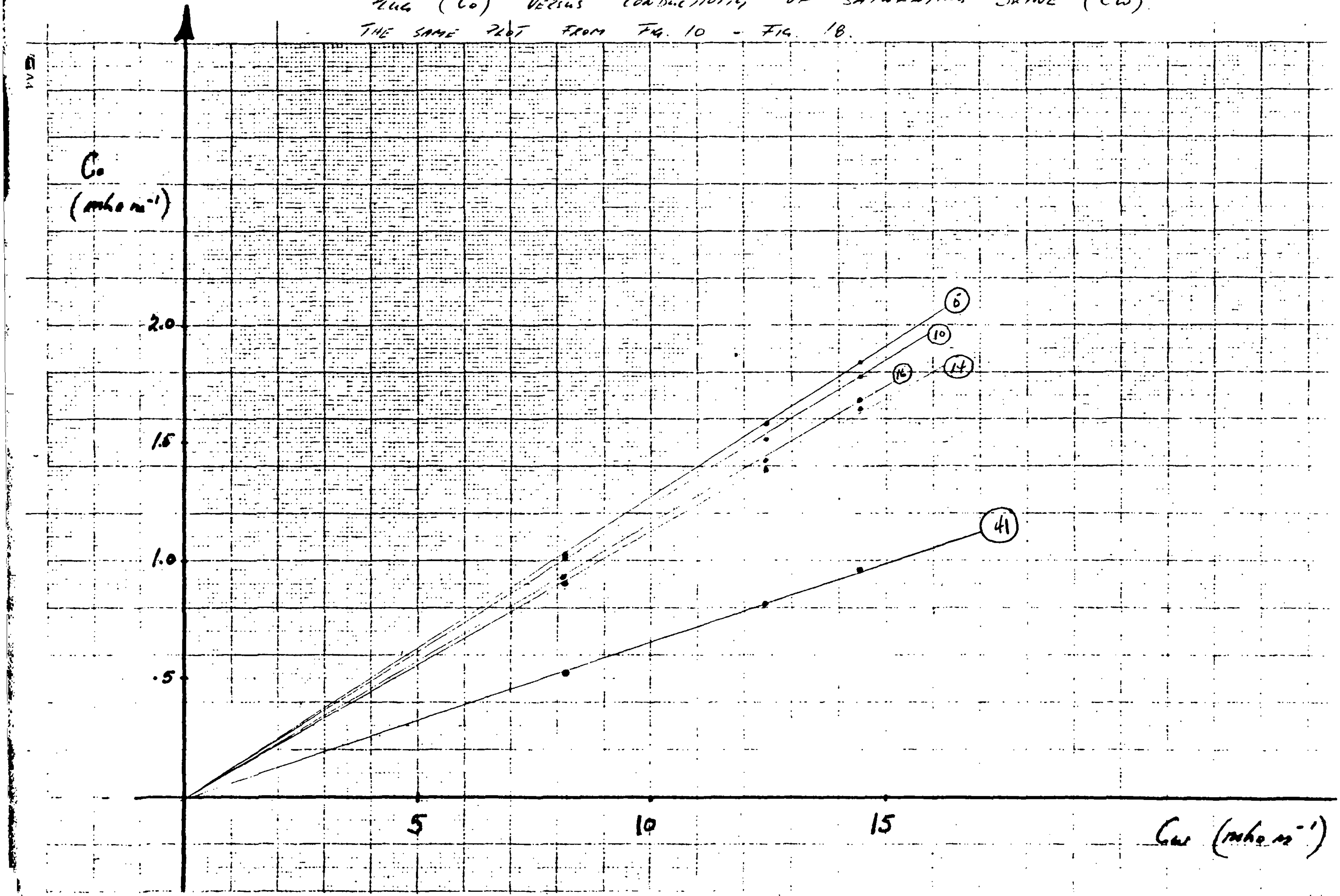


FIG. 9 SHOWS THE RELATION BETWEEN LOG BULK DENSITY (RBLG), AND THE STATOIL LAB. BULK DENSITY IN SITU (RB 1500).

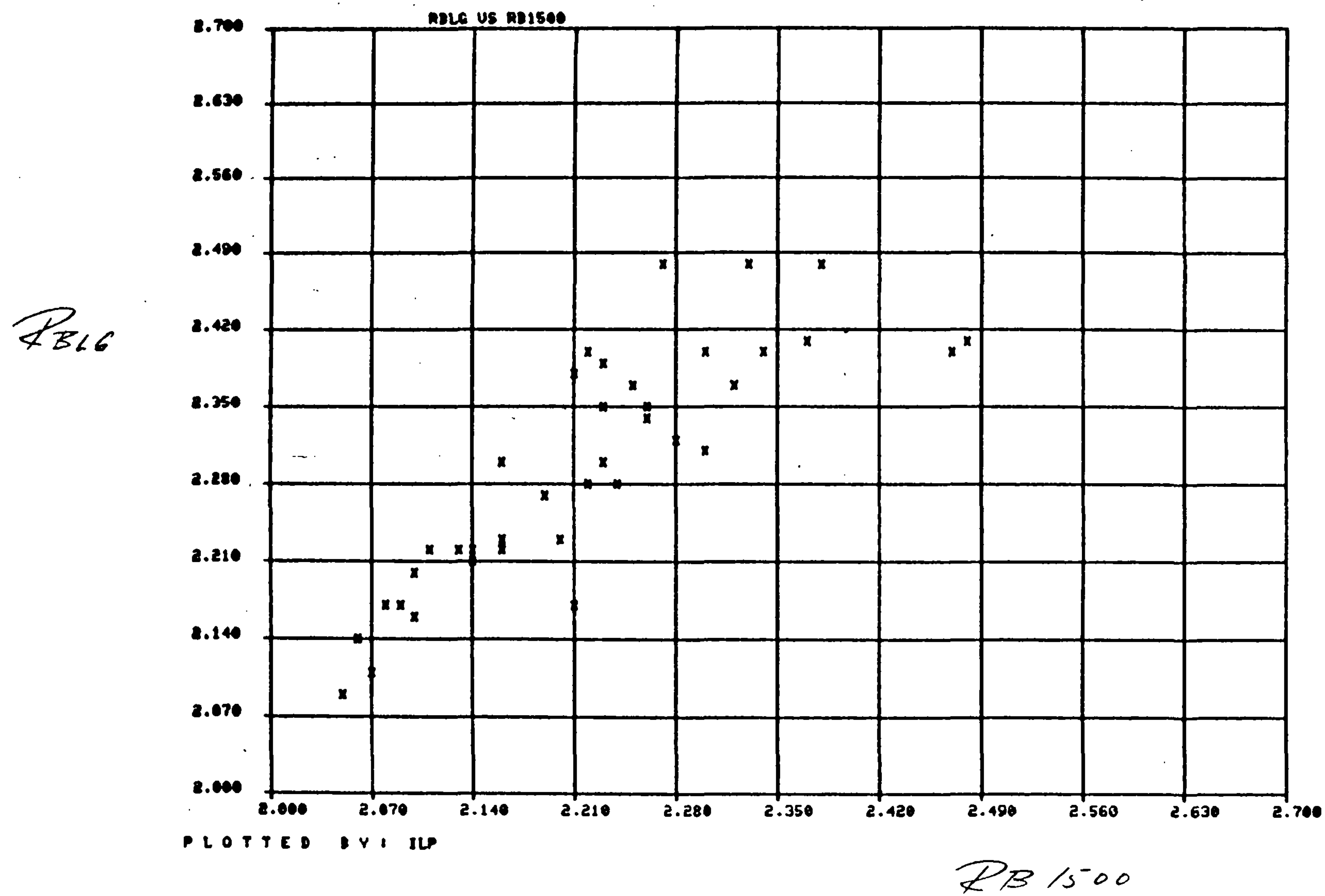


FIG. 8 Shows the relation between Statoil lab bulk density in situ (RB1500), and porosity at net confining pressure (P1500).

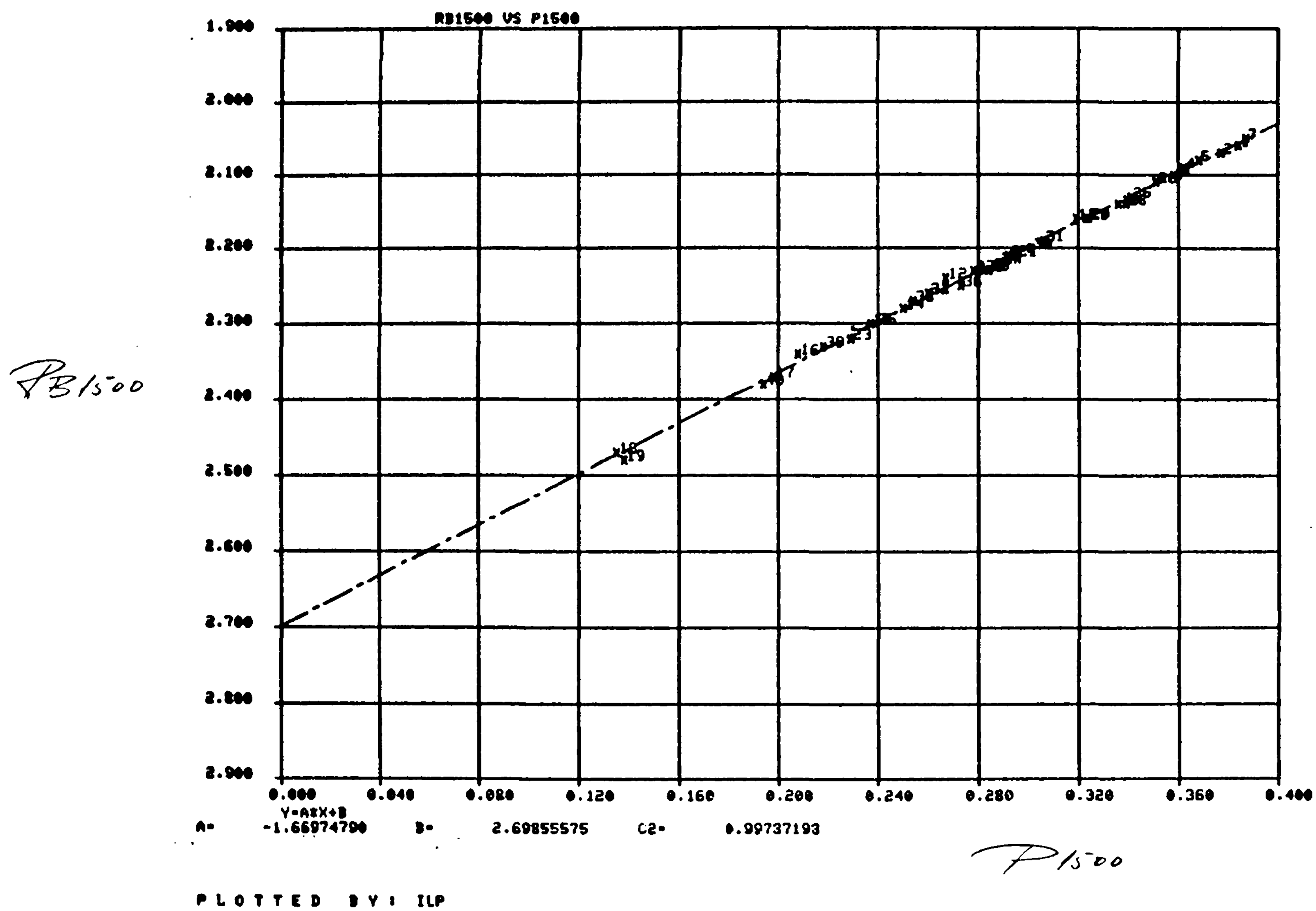


FIG. 7

SHOWS THE RELATION BETWEEN POROSITY AT NET CONFINING PRESSURE (P1500), AND THE POROSITY FROM THE LOG (PELG)

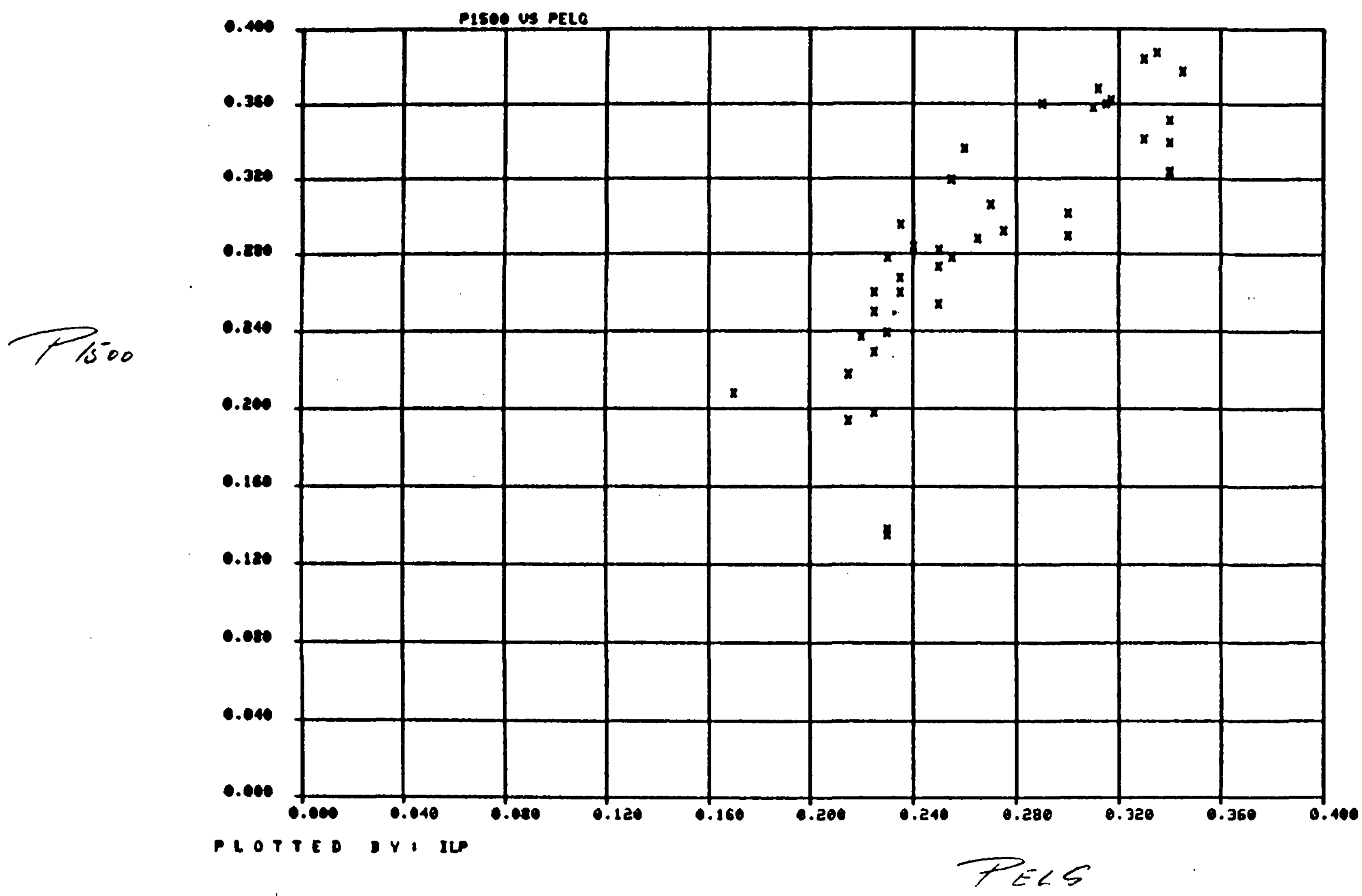
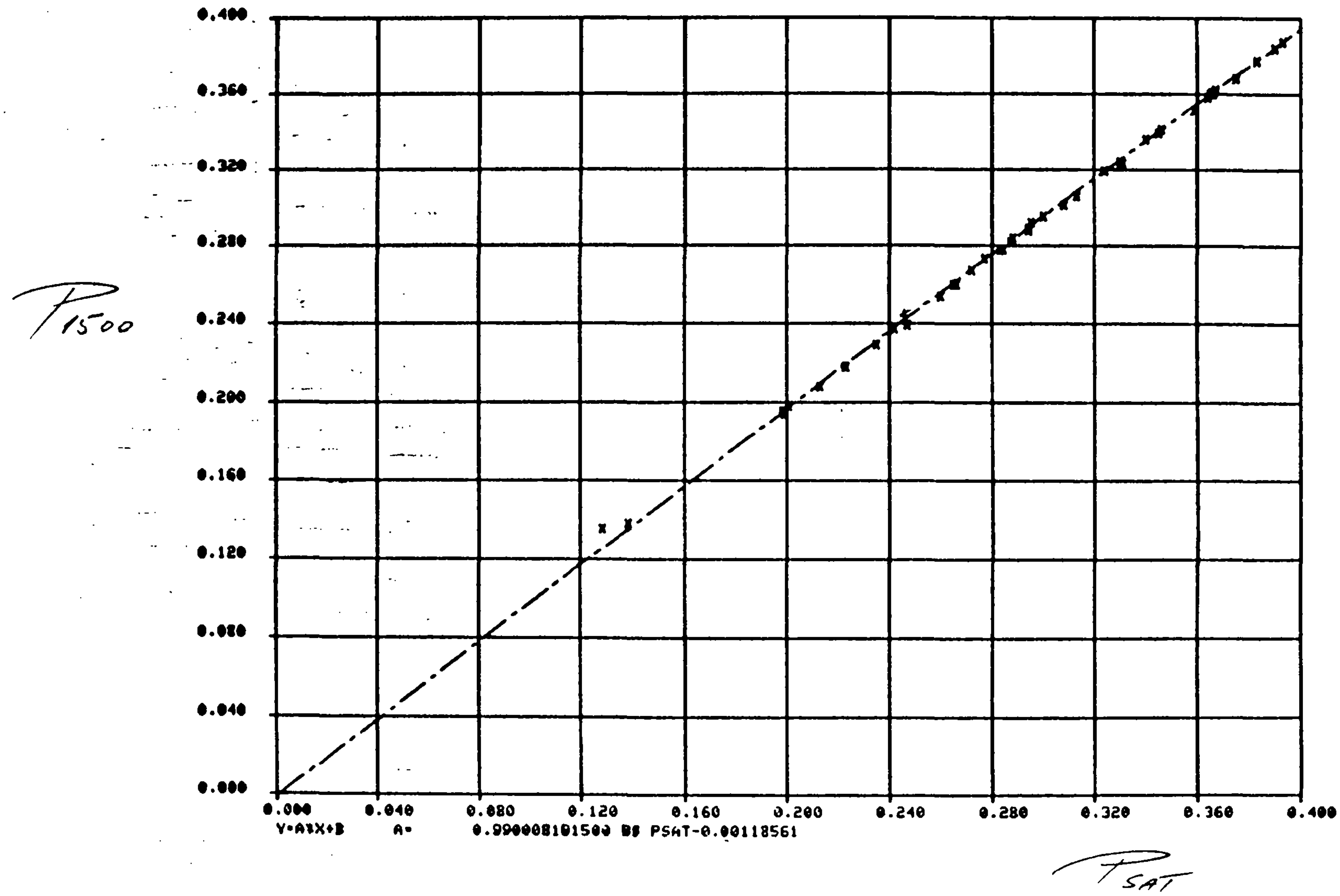


FIG. 6 SHOWS THE RELATION BETWEEN POROSITY AT NET CONFINING PRESSURE, (P1500) AND THE POROSITY MEASURED BY SATURATION METHOD (PSAT)



PLOTTED BY: ILP

FIG. 5 Shows the relation between Statoil measured helium porosity (PHE), and Statoil emperical liquid permeability (KLLB). This plot is for Tor formation

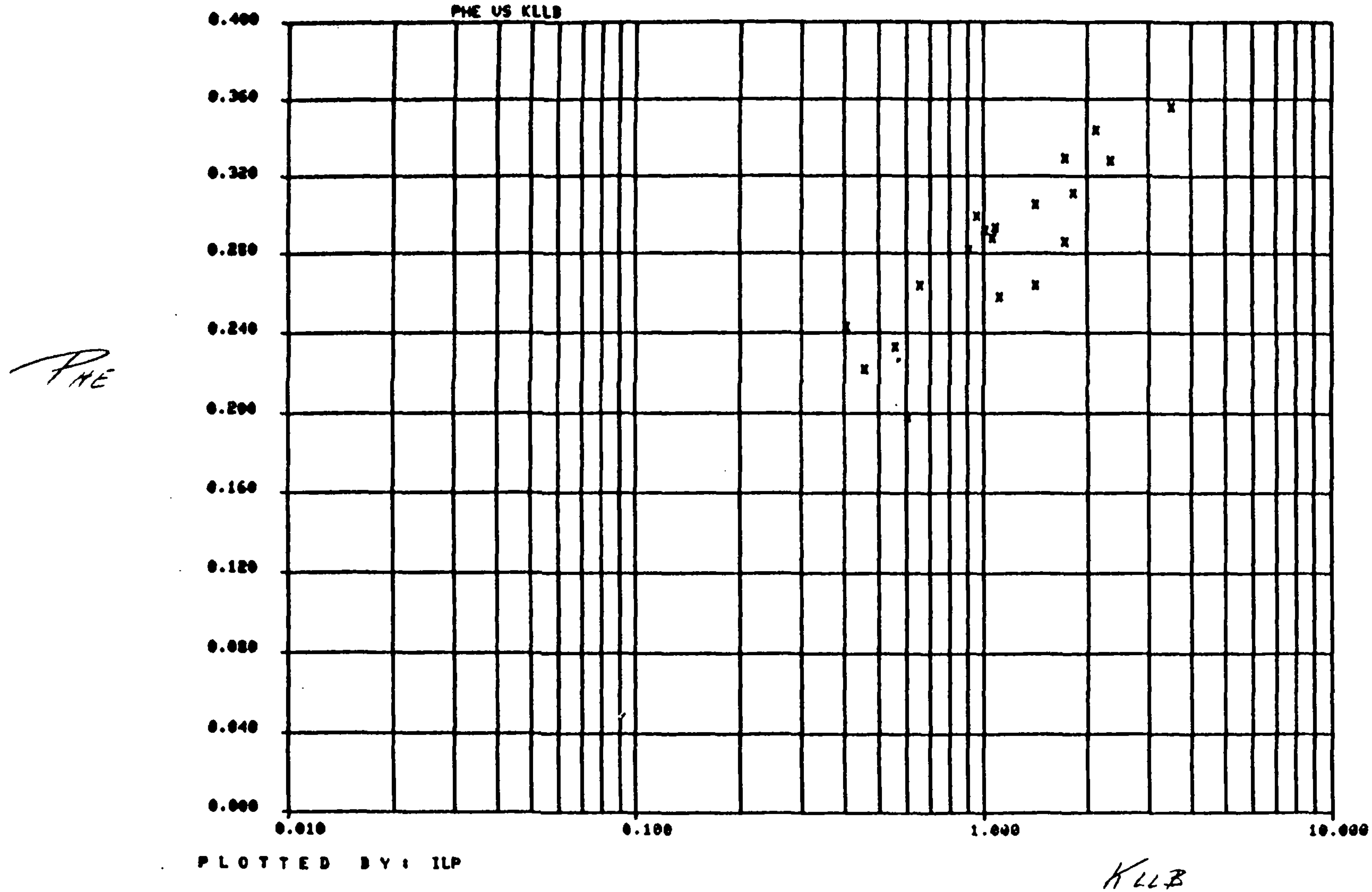
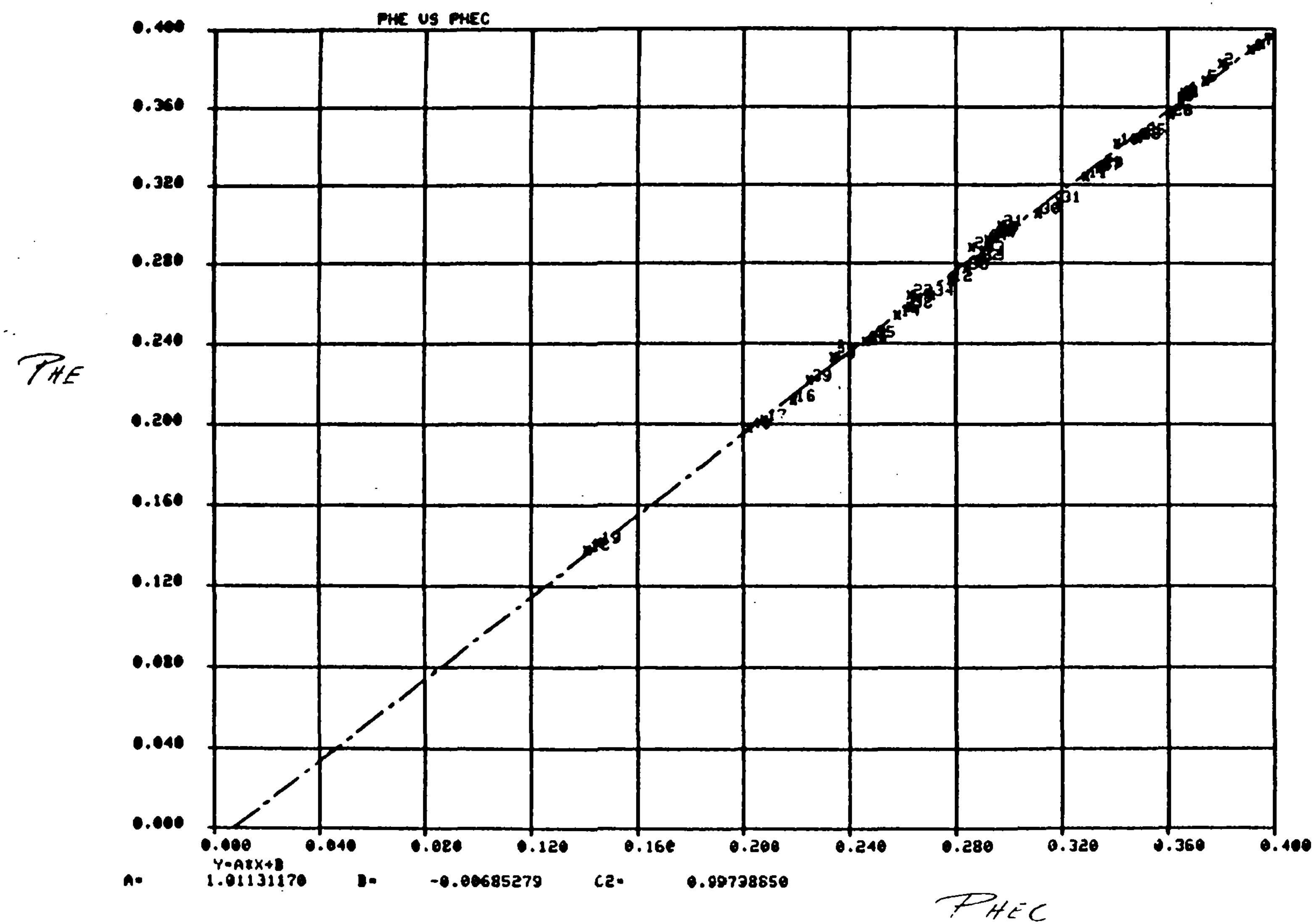


FIG. 2

SHOWS THE RELATION BETWEEN HELIUM MEASURED POROSITY, STATOIL (PHE), AND HELIUM POROSITY MEASURED BY GECO (PHEC).

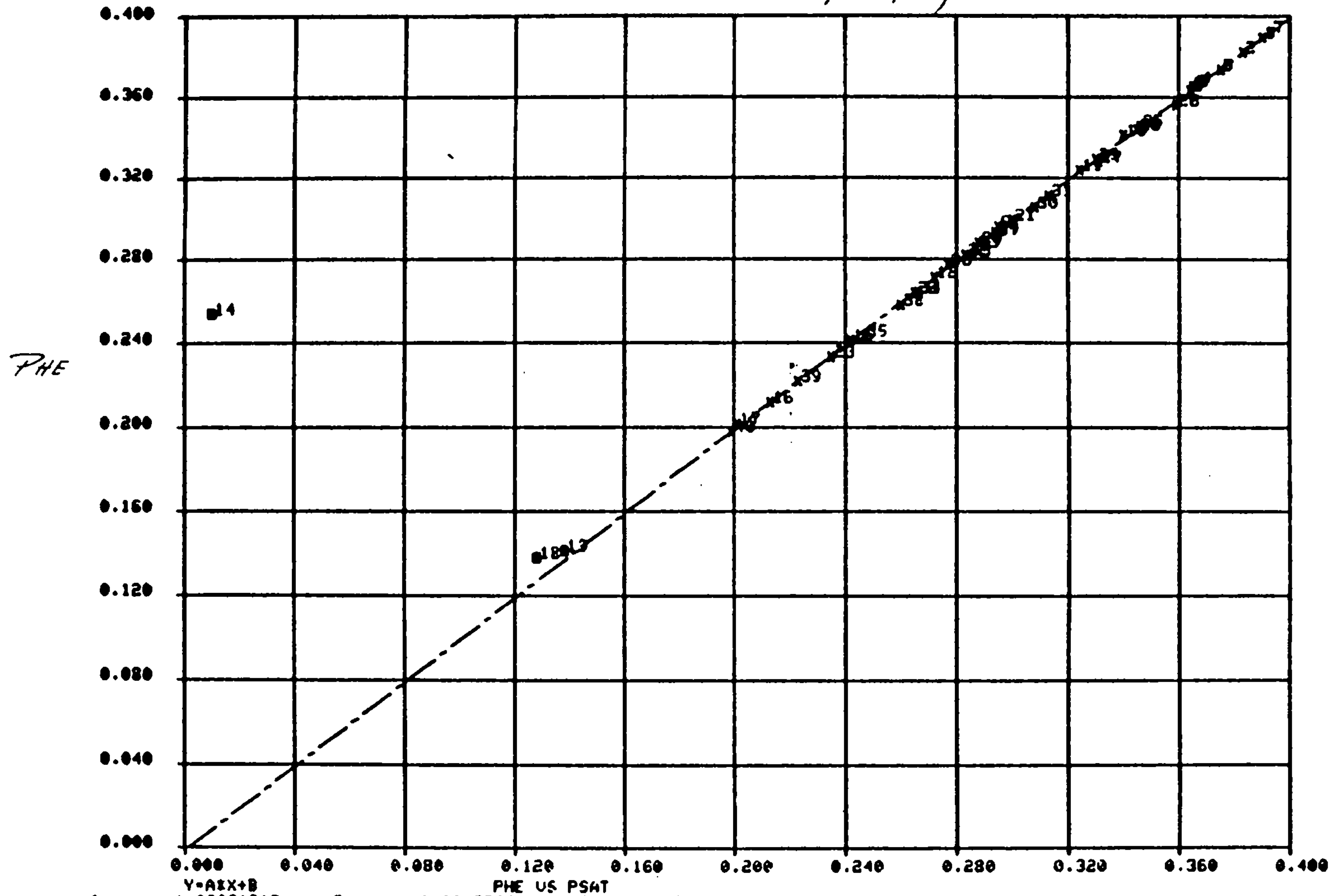


PLOTTED BY: ILP

FIG. 1

SHOWS THE RELATION BETWEEN THE POROSITY MEASURED BY HELIUM INJECTION METHOD (PHE) AND THE POROSITY MEASURED BY SATURATION METHOD (PSAT). BOTH MEASUREMENT DONE BY STATOIL.

DATA POINTS DELETED (14, 18, 19)



PHE VS PSAT

Y=AX+B

A= 1.00081818 B= -0.00135631 C2= 0.99957988

PLOTTED BY: ILP