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A PRELIMINARY FEASABILITY REPORT ON THE
VACUUM FILTRATION OF COMBINED SEPTIC TANK
AND RAW SLUDGE FROM THE BÆRUM COMMUNITY

0-85/68

Norsk institutt for vannforskning

Blindern

NORSK INSTITUTT FOR VANNFORSKNING

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SANDVIKA

Deres ref.:

Deres brev av:

Vår ref.:

OSLO 3,

Vesilind/msv December 10th 1968

Sir:

In accordance with your discussion of 22 November 1968 with siv.ing Torje Simensen, we have performed sludge filterability tests on the sludge samples received from you on 29 November and 2 December 1968. The results of this study are herein enclosed.

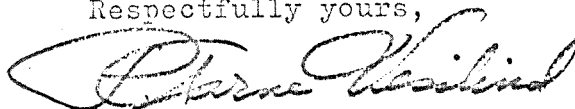
It was understood that we were allowed only a limited amount of time to conduct these experiments and to submit the report. Accordingly, only a few variables were investigated, with the primary purpose of determining if the sludge could be filtered at all. Some key conclusions, based on the results of this limited study, are

1. The sludge can be filtered by vacuum filters if chemical conditioners are used.
2. Both inorganic and organic chemical conditioners can be used.
3. It is reasonable to expect a filter yield of about 50 kg of dry solids per square meter of filter area per hour.

It must be emphasized that this report is by no means a thorough study of the problem, and should not be used as a basis for design. Many economic as well as operating variables have not been investigated, as discusses in the report. Further, it is not at all certain that vacuum filters will be the most economical means of dewatering this sludge. It is therefore recommended that a thorough study be conducted on the best means of treatment and disposal. All that we are able to conclude at this time is that vacuum filtration is one possible method of dewatering.

We appreciate your confidence in the Institute and hope that we can be of further service in the near future.

Respectfully yours,



P. Arne Vesilind
Sanitary Engineer

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THE USE OF VACUUM FILTERS FOR DEWATERING SEWAGE SLUDGES

The objective of any dewatering operation is to sufficiently reduce the moisture content of a sludge in order to allow for its ultimate disposal by landfill, incineration, barging to sea, or other means. The vacuum filter has for many years been the most popular mechanical device for sludge dewatering.

Operation

Figure 1 shows a schematic of vacuum filtration operation. The rotating vacuum drum, partially submerged in sludge, draws the water through the filter medium. A layer of solids is deposited on the filter medium and these solids are further dewatered on the drum. The sludge cake thus formed drops off (or in some cases is scraped off) on to a conveyor belt. High pressure jets wash the filter medium to prevent it from clogging with fine solids.

Design

The best available scale-up theory, based on the flow of fluid through a porous media, is the concept of "specific resistance". This theory takes into account the major variables affecting filtration, i.e. the applied pressure (P), the filter area (A), the solids concentration (c), and the filtrate viscosity (μ). It can be shown that the filtration rate is given by

$$\frac{dV}{d\theta} = \frac{P A^2}{\mu (r c V + R_m A)}$$

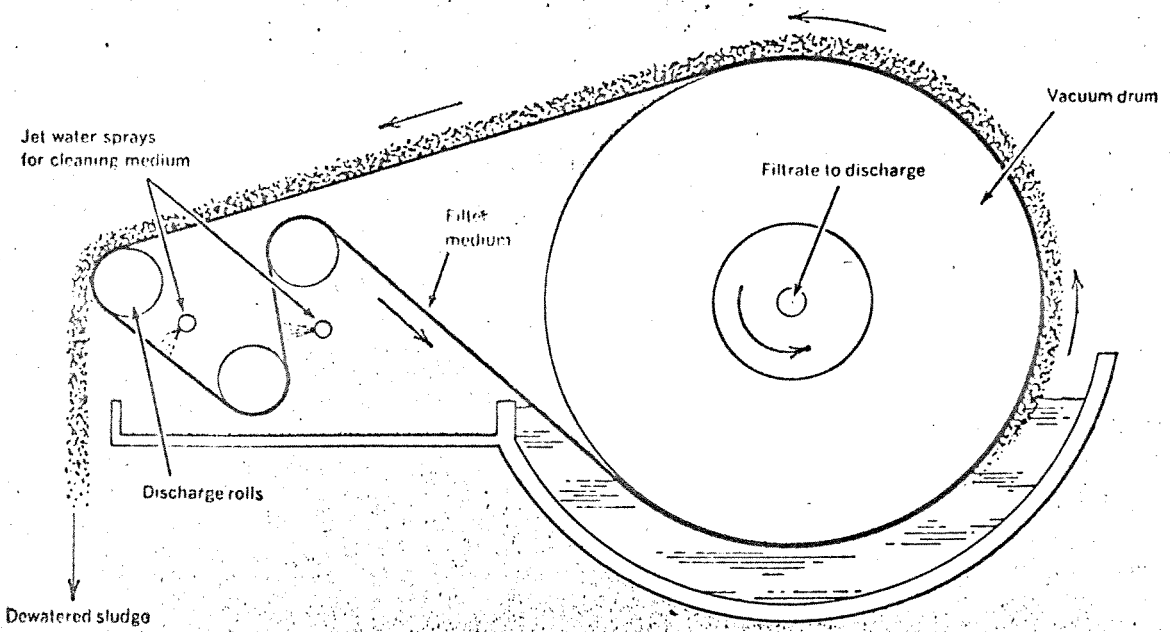


FIGURE 1 SCHEMATIC OF VACUUM FILTER

where

V = the volume of filtrate obtained in time Θ

r = the specific resistance

R_m = the resistance of the filter medium.

Integration of this equation, at a constant pressure, gives

$$\frac{\Theta}{V} = \frac{\mu r c V}{2 P A^2} + \frac{\mu R_m}{P A}$$

which is an equation of a straight line,

$$\frac{\Theta}{V} = b V + a$$

where

$$b = \frac{\mu r c}{2 P A^2}$$

and

$$a = \frac{\mu R_m}{P A}$$

The slope of the line is b , and if this is known, the specific resistance may be calculated as

$$r = \frac{b 2 P A^2}{\mu c}$$

The value of b may be obtained by plotting Θ/V versus V .

This theory is based on constant filtration pressure. The pressure influences specific resistance according to the relationship $r = r' P^s$, where s is a measure of the effect of pressure and is called the coefficient of compressibility.

The specific resistance has been successfully used in scale-up from laboratory tests to prototypes. The proposed scale-up equation (1) is

$$L = 0.0357 \left(\frac{100-C_f}{C_i-C_f} \right) \left[\frac{m P C_i (100-C_i)}{\Theta R \mu} \right]^{\frac{1}{2}}$$

where

L = yield of dry cake solids, lb/ft²/hr

C_i = initial moisture content of sludge, %

m = proportion of time in which suction acts, %

Θ = time for one revolution of filter drum, min.

P = average suction pressure, lb/ft²

μ = viscosity of filtrate, centipoises

R x 10⁷ sec²/gm = specific resistance.

In metric units, this equation is

$$L = 3.19 \frac{(100-C_f)}{C_i-C_f} \left[\frac{m P C_i (100-C_i)}{\Theta R \mu} \right]^{\frac{1}{2}}$$

where L is in kg/m²/hr and P is in kg/cm².

It is also possible to estimate the yield from filter presses using the specific resistance. The accuracy of this scale-up, however, is not very good.

The ranges of specific resistance values of some typical sludges are shown in the following table.

TABLE 1: SPECIFIC RESISTANCE OF VARIOUS SEWAGE SLUDGES

Sludge	Specific resistance ($\times 10^9 \text{ sec}^2/\text{gm}$)	Reference
Mixed primary and secondary	10 to 20	2
Same, after digestion	3 to 30	2
Raw primary sludge	10 to 50	3
Activated sludge	5 to 10	3

In practice it has been found that in order to achieve economic filtration rates with sewage sludge the specific resistance needs to be of the order of $0.1 \times 10^9 \text{ sec}^2/\text{gm}$, and thus a sludge conditioning process is required which must dramatically reduce the specific resistance (4).

Sludge conditioning

Conditioning may be by elutriation or by the addition of chemicals, or both. Many chemicals are available and in use for such sludge conditioning. Ferric chloride and lime have been popular for many years in the USA, while aluminum chlorohydrate has found favor in England. The newest and perhaps most promising chemicals are the organic polyelectrolytes. It has generally been found that cationic polyelectrolytes can be competitive in price with the inorganic conditioners and concurrently provide other advantages such as clean and safe operation, less material handling, and a reduction in corrosion and toxicity problems.

Elutriation (sludge washing) has been successfully employed at many installations. Elutriation may be followed by chemical treatment, and the chemical dosages in such cases are dramatically reduced. Disposal of the dirty washwater may, however, cause problems.

Besides the dosage, other variables may effect the efficiency of any one chemical as a conditioner, including the degree of agitation, sludge conditioning prior to contact, time of contact, agitation in the filter pan, and others. Some of these can be estimated in the laboratory (by relative efficiencies) but most have to be studied with the prototype. Design of flexible operation is therefore quite important.

Economics

The initial cost of vacuum filters depends obviously on the quality of the filter. In the USA, the cost ranges from \$ 95 to \$ 275 per square foot of filter area (approx. N.Kr. 7300 to 20.700 per square meter). The cost of the building to house the filter usually doubles the capital outlay. (5)

Operating cost, per ton of dry solids treated, is about \$ 20 in the U.S. (N.Kr. 140) (6). About 40 % of this cost is for chemicals, the remainder being for power and labor. The cost of some chemicals, delivered in bulk in Oslo is tabulated in the following table.

TABLE 2: COST OF SOME CHEMICAL CONDITIONERS

Chemical	Quality	N.Kr/kg
Lime	11 ton min.	0,14
Ferric Chloride	1 ton min.	1,20
Cationic Polyelectrolyte		
Reten 222 (Hercules Powder Co)	5 ton min.	32,60
PURIFLOC C-31 (Dow Chemical)	10 ton min.	6,75

PURPOSE AND SCOPE OF THIS INVESTIGATION

The primary objective of this study is to determine the feasibility of using vacuum filters to dewater a combination of raw and septic tank sludge. These studies are performed on a bench-scale Buchner funnel apparatus which is designed to give the value of the specific resistance to filtration. It is understood that since there are innumerable chemicals which might be used as sludge conditioners, and each chemical is further influenced by operational variables, a thorough study is required to determine which chemicals would be best suited for this application. The study herein reported is only a preliminary investigation, and only a limited number of chemicals have been used. A reasonable decision on the best methods, materials and procedures can be made only after a more extensive investigation.

EXPERIMENTAL TECHNIQUE

A Buchner funnel apparatus, shown on Figure 2, was used in all tests to determine the specific resistance. The procedure used was identical to that recommended in any number of publications. The pressure was kept constant by adjusting the water rate through the aspirator. The temperature of the sludge was tanken during the test and the viscosity found from standard temperatur, viscosity curves. The diameter of the filter was 7 cm, giving an area of 38.5 cm^2 . Chemicals were added to the sludge in a 100 ml cylinder and distributed in the sludge by vigorously shaking the cylinder. The solids determinations were done using 10 ml samples in triplicate, heated in aluminum dishes at 105°C .

After the vacuum was turned on, the volume of filtrate was read at convenient time intervals. These data were plotted as volume (V) versus the ratio time/volume (θ/V). The slope of this line, as previously stated, is b. If, for example, b was found to be 12.5, the pressure, P, was 2000 gm/cm^2 , the viscosity μ , was 0.0150 poise, and the solids concentration, c, was 0.0497 gm/ml, the specific resistance was calculated as

$$r = \frac{2b P A^2}{\mu c} = \frac{2 \times 12.05 \times 2000 \times (38.5)^2}{0.015 \times 0.0497} = 9.6 \times 10^{10}$$

All specific resistance calculations were done in this manner. The data curves are included in the Appendix.

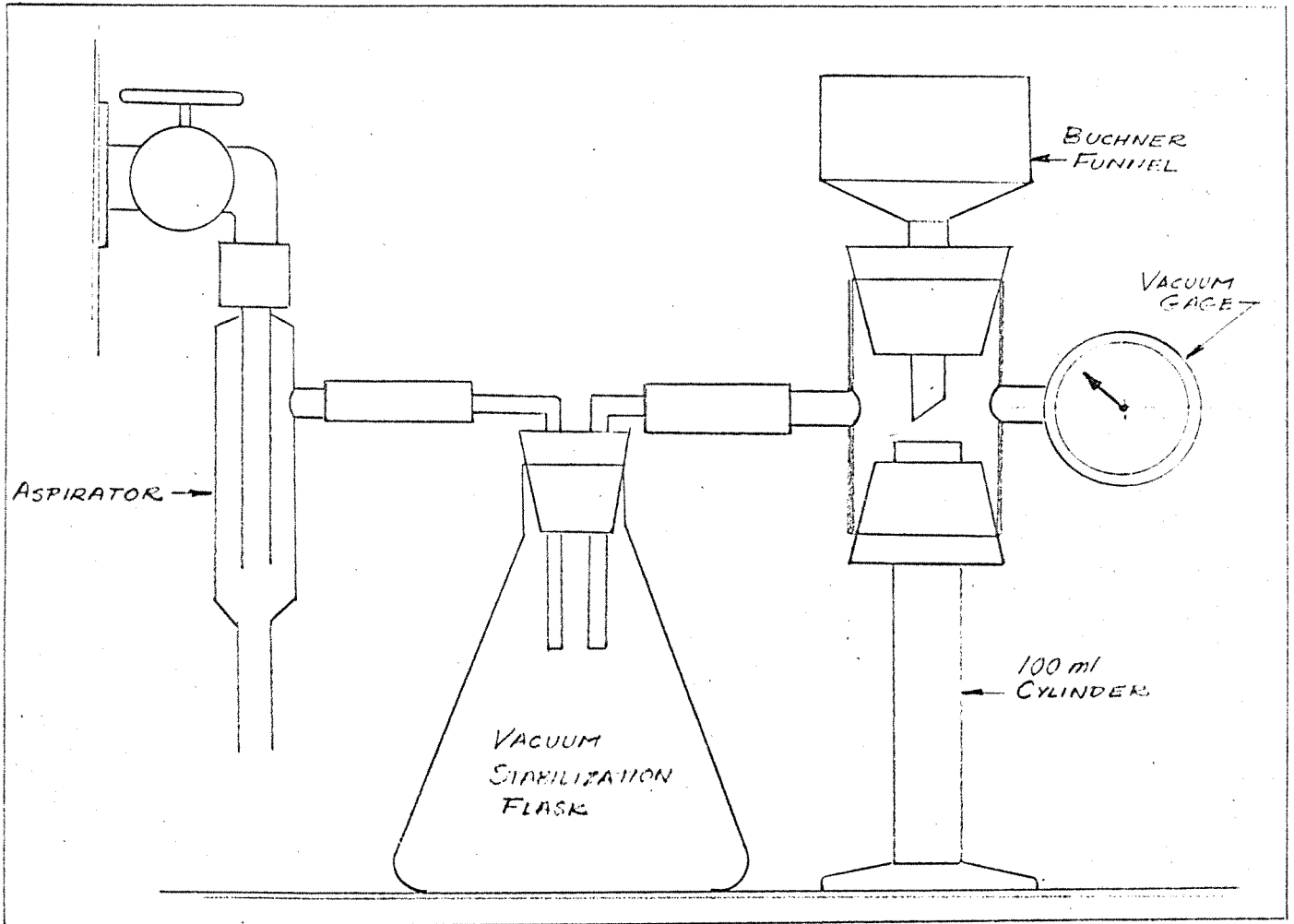


FIGURE 2 LABORATORY APPARATUS

EXPERIMENTAL RESULTS

Five chemicals were tested as possible conditioners. In addition, elutriation and freezing were also investigated. The results from two inorganic conditioners, lime, $\text{Ca}(\text{OH})_2$, and Ferric Chloride, FeCl_3 , are shown on Figure 3. The usual limit of economic operation, 1×10^8 , is also shown on this figure. It is clear that lime, even at about 50 % of the dry solids by weight, does not significantly influence the specific resistance, and that the addition of lime, by itself, will not condition the sludge adequately for vacuum filtration.

Ferric chloride, on the other hand, seems to be a reasonable conditioner for this sludge. The addition of ferric chloride at about 4 % of the dry solids by weight would condition the sludge adequately to provide for economical operation.

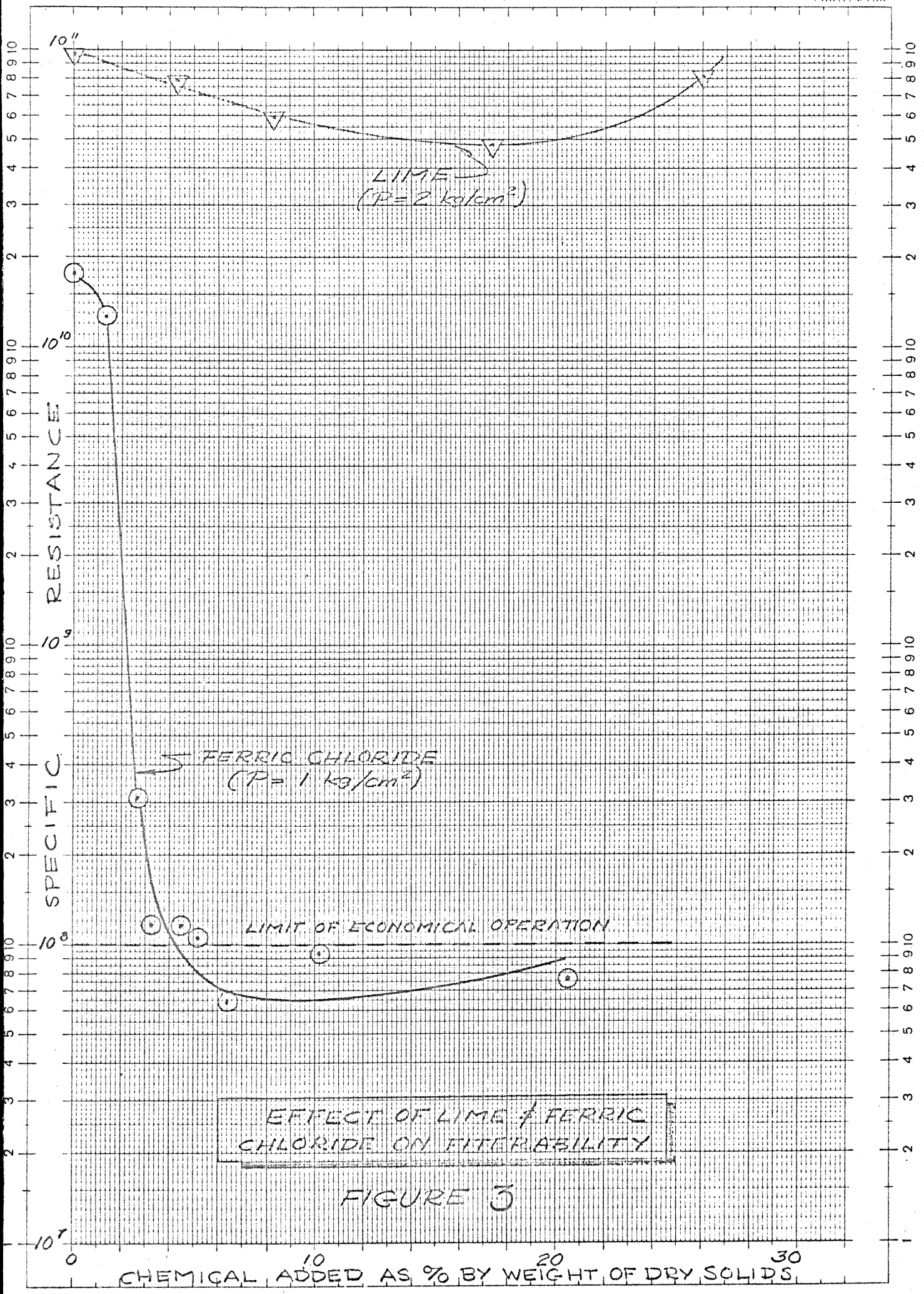
The results from the three organic conditioners used are shown on Figure 4. The NALCO 600[†] seems to be economically effective at about 1.5 % of the dry solids weight, and the RETEN 220[‡] is effective at about 3.5 %. Both of these are cationic polymers, but neither was produced specifically for use with sludge. PURIFLOC C-31,[§] however, which is specifically manufactured for sludge, is effective at about 0.7 %.

The cost of NALCO 600 is unknown, but the RETEN 220 costs about N.Kr. 32.60/kg. At a dose of 3.5 %, this would require about N.Kr. 1140.00 to treat 1 metric ton of sludge (dry solids)

[†] NALCO 600 is a product of NALCO Italiana, Rome, Italy

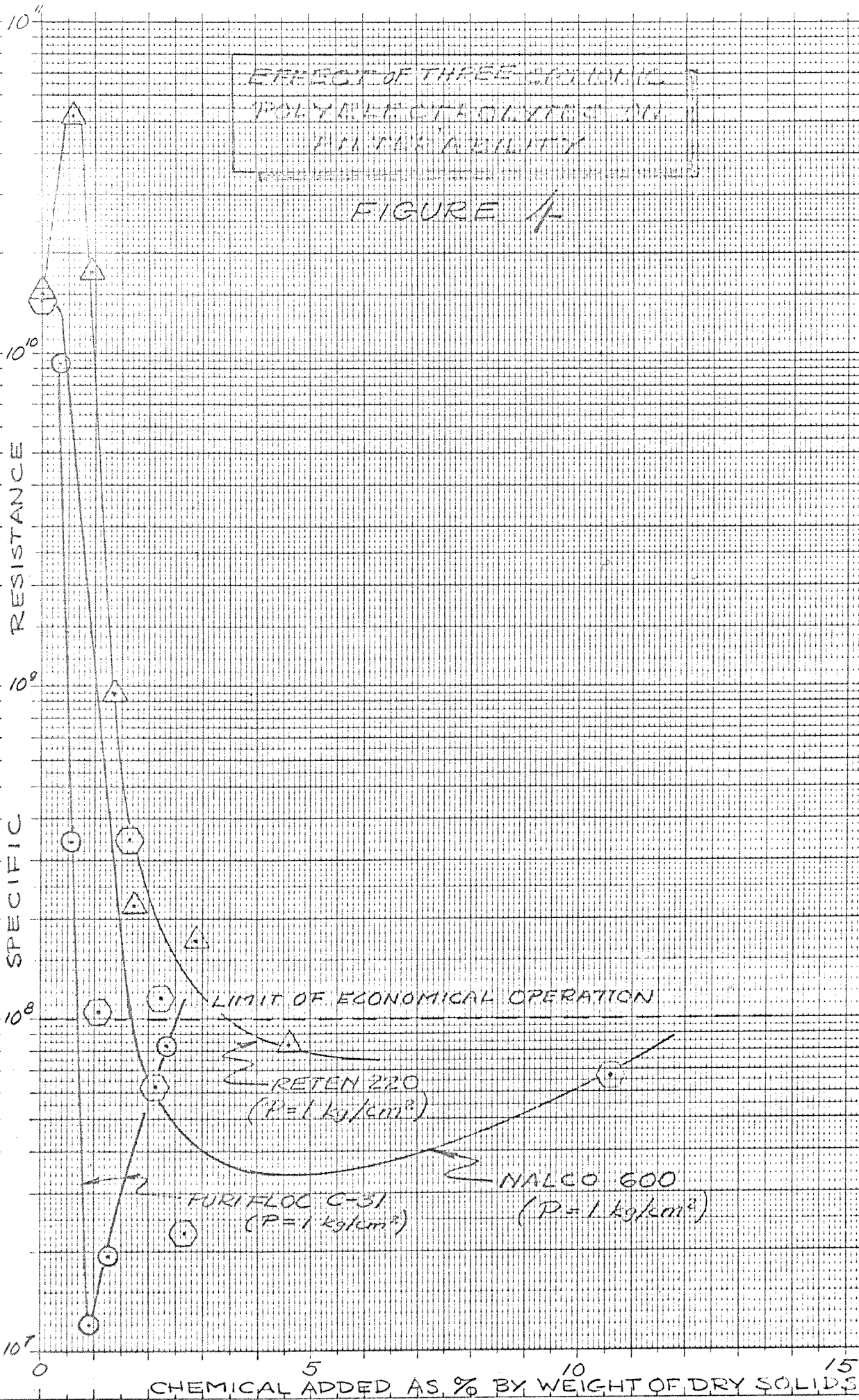
[‡] RETEN 220 is a product of the Hercules Powder Co.,
Wilmington, Delaware, USA

[§] PURIFLOC C-31 is a product of Dow Chemical Co., Midland,
Michigan, USA



EFFECT OF THREE DIFFERENT POLYMER FLOCCULANTS ON FILTERABILITY

FIGURE 1



Eine Achse logarithmisch geteilt von 1 bis 10000. Einheit 625 mm. die andere in mm mit Prozentangaben

By comparison, the ferric chloride, costing N.Kr. 1.40/kg, and dosing at 4 %, would cost about N.Kr. 48.00 to treat 1000 kg of dry solids, and PURIFLOC C-31, which sells for N.Kr. 6,75/kg, would cost about N.Kr. 47.00 to treat 1 ton of dry solids.

Ferric chloride, however, can be toxic at high enough concentrations, and the method of disposal for the filtrate has to be considered. It is also somewhat corrosive, and the chemical feeding equipment would not last as long as with organic polymers.

Elutriation (sludge washing) proved impractical. These results are tabulated below.

TABELE 3: RESULTS OF ELUTRIATION EXPERIMENTS

Sludge Treatment	Specific Resistance	Solids Content of Wash Water
None	9.6×10^{10}	-
1 part sludge to 2 parts wash water. Reconcentrated to 2 times original volume	5.2×10^{10}	2200 mg/l
1 part sludge to 5 parts wash water. Reconcentrated to 2 times original volume	3.3×10^{10}	1300 mg/l

Although elutriation by itself does not seem to increase the filterability, it may prove economical in conjunction with chemical addition, since elutriation has been found to lower the chemical dosage requirements.

Freezing also proved impractical. The specific resistance before freezing was about the same as after freezing and

and thawing. This result was not expected, since freezing generally tends to improve sludge dewaterability. It is possible that the sludge investigated had already been frozen once. If this was the case most of these data are worthless, since they apply only to sludge which has been frozen. It is recommended that a check be made to make sure that the sludge delivered to the Institute had not frozen previously and then thawed out.

It has been determined that the relationship between the vacuum pressure and the specific resistance is exponential, so that if we plot the log of r versus the log of P , a straight line should result. Such a plot, for an untreated sample of sludge, is shown on Figure 5. The slope of this line, s , called the coefficient of compressibility, was found to be 0.64. It is quite possible that with treatment, such as with ferric chloride, this slope may change, but for preliminary estimates, the specific resistance at any vacuum pressure can be calculated by

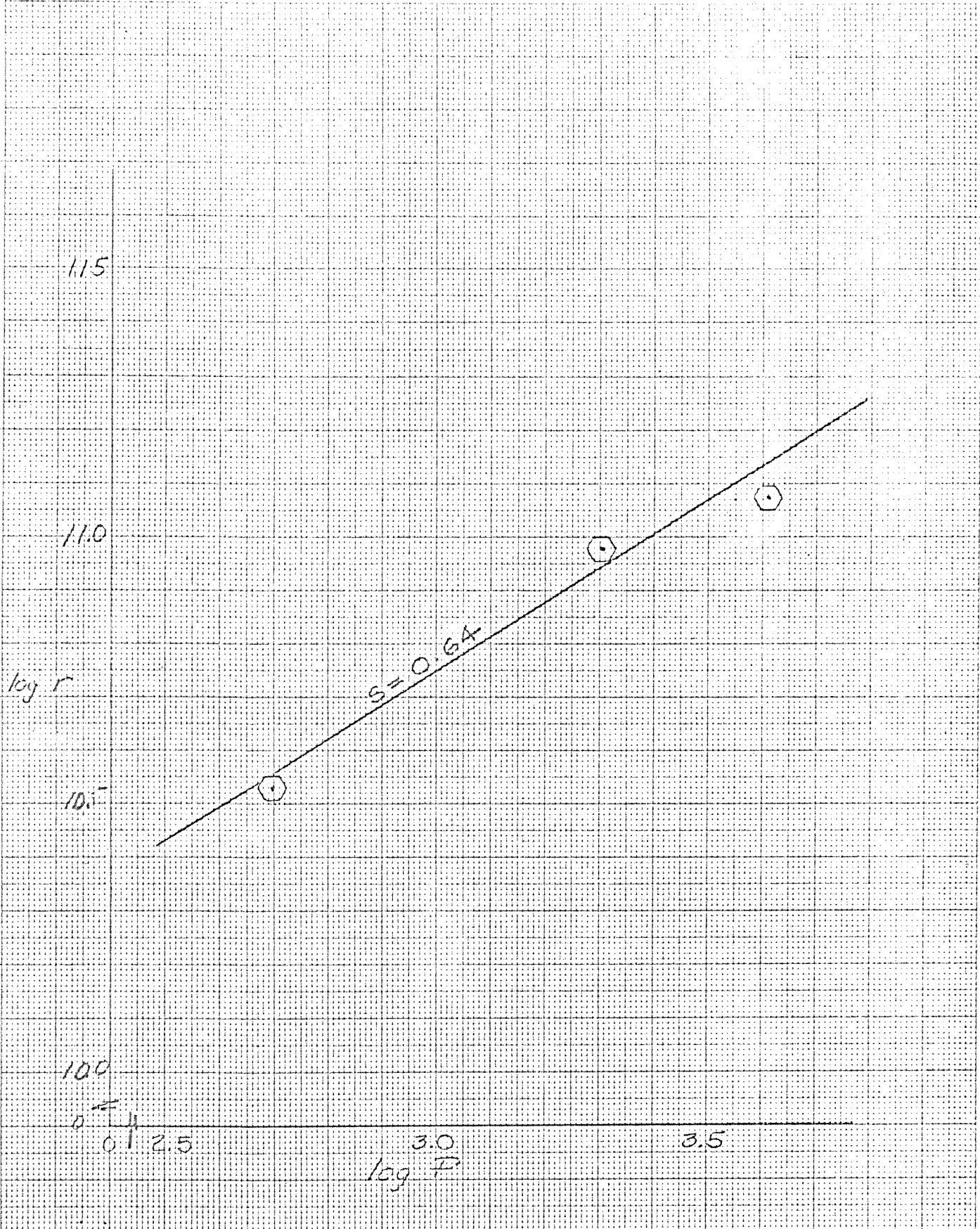
$$r = r' P^{0.64}$$

where P is the pressure, in gm/cm^2 and r is the specific resistance measured at this pressure.

For example at a ferric chloride dose of 4 %, the specific resistance is about 1×10^8 , at a pressure of 1000 kg/cm^2 gm/cm^2 . *AL*

First calculate the specific resistance at unit pressure, r' , as $r' = (1 \times 10^8)/(1000)^{0.64} = 6.4 \times 10^7$. The specific resistance at any other pressure, say 500 gm/cm^2 , is then $r = (1.20 \times 10^6)(500)^{0.64} = 6.4 \times 10^7$.

The final solids concentration of the cake was about 31 % with



COEFFICIENT OF COMPRESSIBILITY

FIGURE 5

FeCl_3 treatment. This corresponds to a volume reduction of 75 %. With the organic polymers, the cake solids concentration was about 23 % with NALCO 600 and RETIN 220, and 28 % with PURIFLOC C-31. In all cases the solids were thick enough to transport on conveyor belts.

A preliminary design can be done on the basis of the above information. Assume that by a proper addition of chemicals, the specific resistance can be lowered to 5×10^8 , and that the final cake solids will be 30 % by dry weight (70 % moisture content). If the initial solids is about 8 % (92 % moisture content), and if we assume some process variable such as $P = 1 \text{ kg/cm}^2$, m , the proportion of time in which the suction acts as 60 %, θ , the time for one revolution of the filter drum as 6 minutes, and the viscosity μ , as 1.3 centipoise, the filter yield can be estimated by the equation previously Presented as

$$L = 3.19 \frac{(100 - C_f)}{C_i - C_f} \left[\frac{m P C_i (100 - C_i)}{\theta R \mu} \right]^{\frac{1}{2}}$$

$$L = 3.19 \frac{(100 - 70)}{92 - 70} \left[\frac{60 \times 1 \times 92 \times (100 - 92)}{6 \times \frac{5 \times 10^8}{1 \times 10^7} \times 1.3} \right]^{\frac{1}{2}}$$

$L = 42,5 \text{ kg}$ of dry solids processed per square meter of filter area per hour.

DISCUSSION

The above results seem to indicate that the sludge can be dewatered by vacuum filtration. The economic and operational variables inherent in such a process have not, however, been thoroughly investigated.

Vacuum filter efficiency can be influenced by numerous seemingly insignificant but in reality important operational variables. These include the sludge age and temperature, the variation in the proportion of septic and raw sludge, the sludge volatile content, the amount of drum submergence, the type of filter media, the location of chemical addition, the time of chemical contact, and the chemical stirring rate. Some of these can be investigated in the laboratory, and in fact should be studied before a filter for any specific sludge is recommended.

In addition, only five chemicals have been investigated. There are presently on the market many hundreds of chemicals which can be used for sludge conditioning. Further, any two (or three) of these chemicals in combination may prove to be the most effective means of conditioning.

The economic variables can be equally as complicated, with the initial cost, operating costs for power, labor and chemicals, location of the filter, supporting equipment, final disposal of the sludge cake, and disposal of the filtrate being important considerations.

It is therefore emphasized that although this study has shown that vacuum filtration is technically possible, the

economics of this process have not been studied. It is indeed possible that after a more thorough investigation, vacuum filtration can be shown to be impractical, and some other method, such as centrifugation perhaps, would prove superior.

Vesilind/msv
9.12.1968

CONCLUSIONS

1. The sludge, as delivered to the Institute, can be dewatered by vacuum filtration, if previously conditioned by chemicals.
2. Ferric chloride seems to be a good inorganic chemical. Lime by itself will not work.
3. Cationic polyelectrolytes will lower the specific resistance sufficiently to filter, and PURIFLOC C-31 seems to be economically competitive with ferric chloride.
4. It does not seem unreasonable that a filter yield of about 50 kg of dry solids per square meter of filter area per hour can be dewatered. Assuming a filter area of 10 m², and an initial solids content of 8 % by weight, it should be possible to dewater about 6.2 cubic meters of raw and septic tank sludge per hour.

REFERENCES

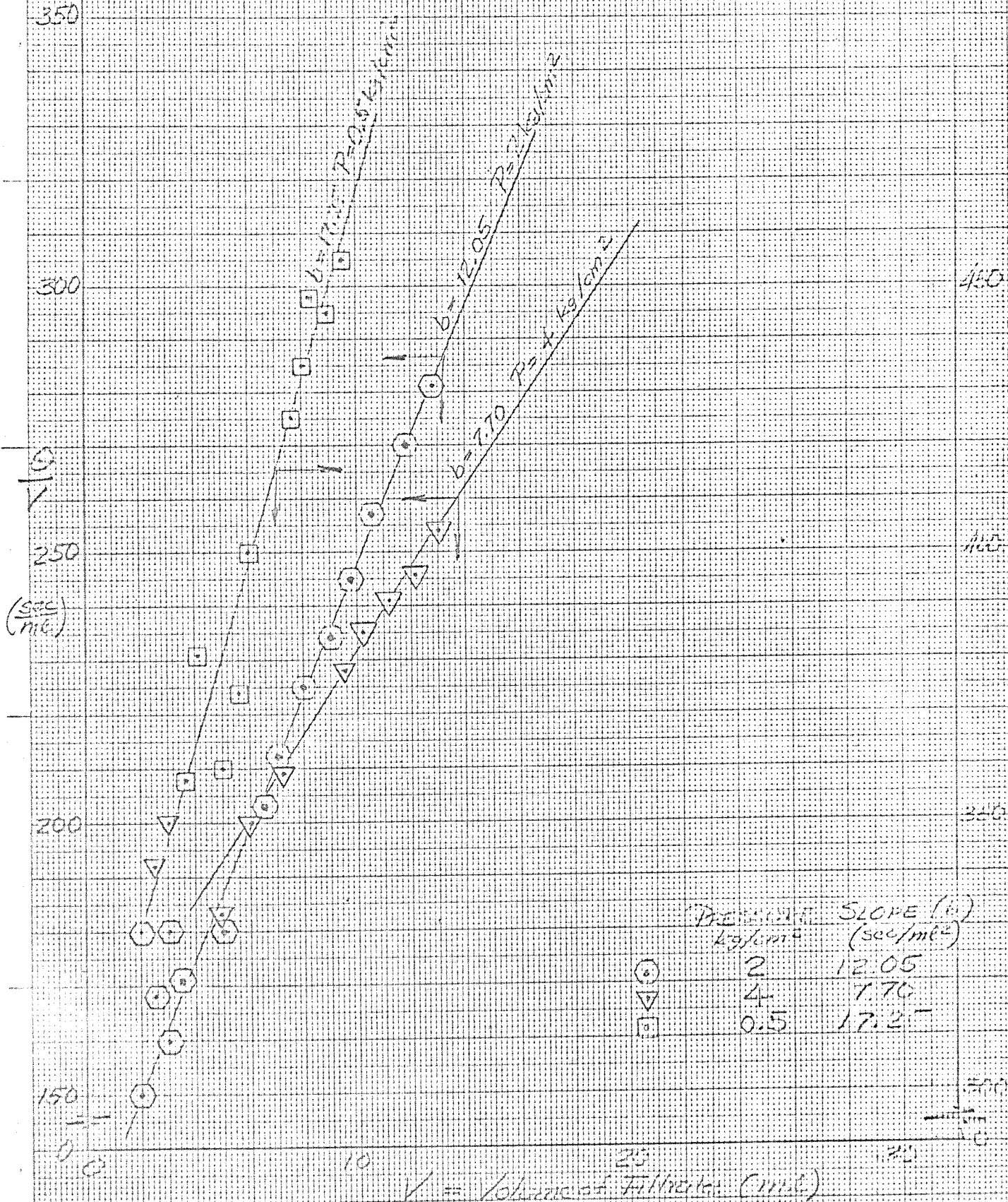
1. B.R.S. Jones: "Vacuum Sludge Filtration" Sewage and Ind. Wastes 28, p. 1103 (1956)
2. J.D. Swanwick et al: "Some Recent Investigations Concerning the Dewatering of Sewage Sludges". Jrnl. Inst. Sew. Purif. p. 394 (1962)
3. R.S. Gale et al: "Investigations of Pressure Filtration of Raw Sewage Sludges". Wat. Poll. Control 66 p. 553 (1967)
4. R.S. Gale: "Some Aspects of the Mechanical Dewatering of Sewage Sludge". Filtration and Separation (March/April 1968)
5. J.W. MacLaren: "Evaluation of Sludge Treatment and Disposal" Canadian Municipal Utilities p. 23 (May 1961)
6. J.C. Dietz: "Some Factors Influenceing the Selection of Sludge Handling and Disposal Methods for Municipal Sewage Treatment Plants". Proc. 13th Ind. Wastes Conf. Purdue Univ. (1958)

A P P E N D I X

Run No: 1

Date 29/11/68

NO. CHEMICALS, SLOPE AS REQUIRED



Run No: 2

Date: 20/11/20

NO CHEMICALS; ELECTRIATED ONLY

$\frac{\theta}{V}$

b Treatment

⊙ 2.065

Electrode 1:2, Sludge:Water
Wash water drained, final sludge
volume = 2x original

▽ 1.562

Electrode 1:5, Sludge:Water.
Same as above

300

250

200

150

200

150

100

0

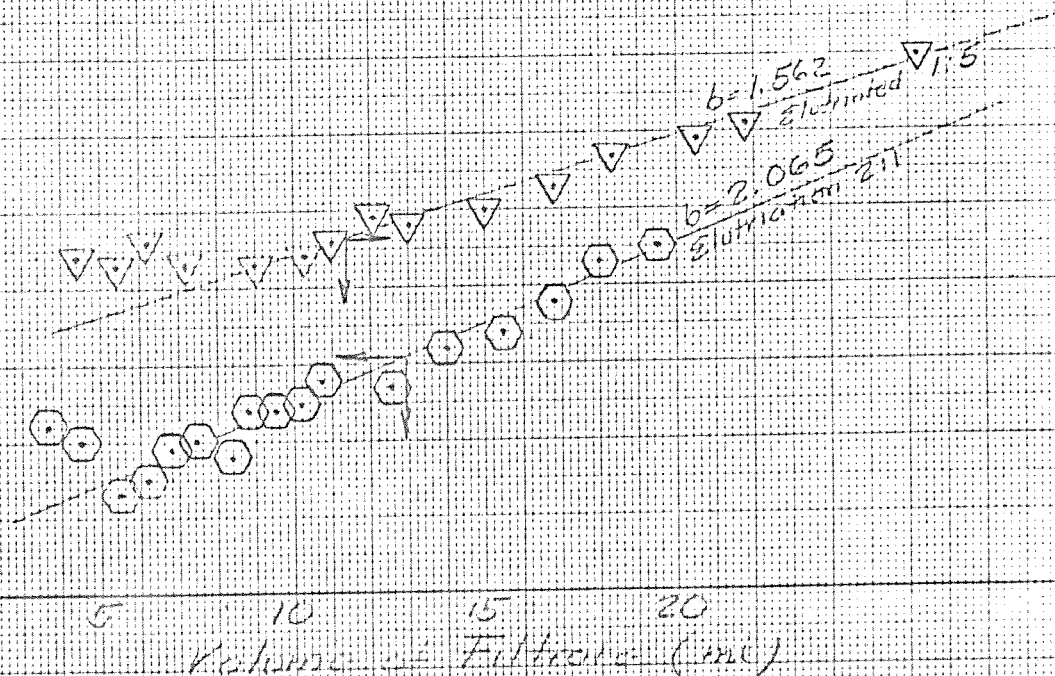
5

10

15

20

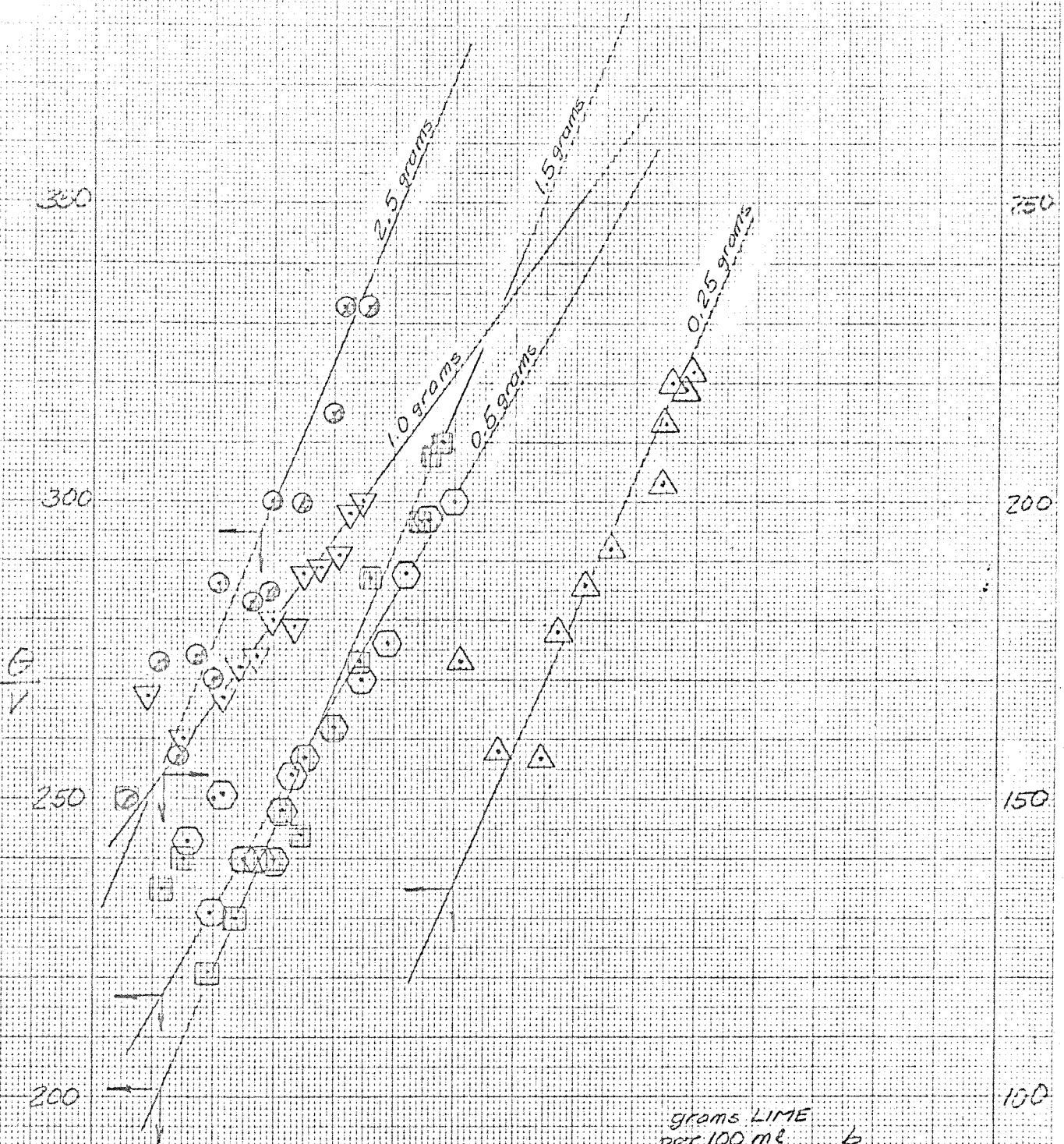
Volume of Filtrate (ml)



Row No. 3

Date 2/12/48

LIME AS CONDITIONER



grams LIME
per 100 ml b

○	0.5	8.70
▽	1.0	6.95
□	1.5	11.77
◇	2.5	12.20
△	0.25	11.50

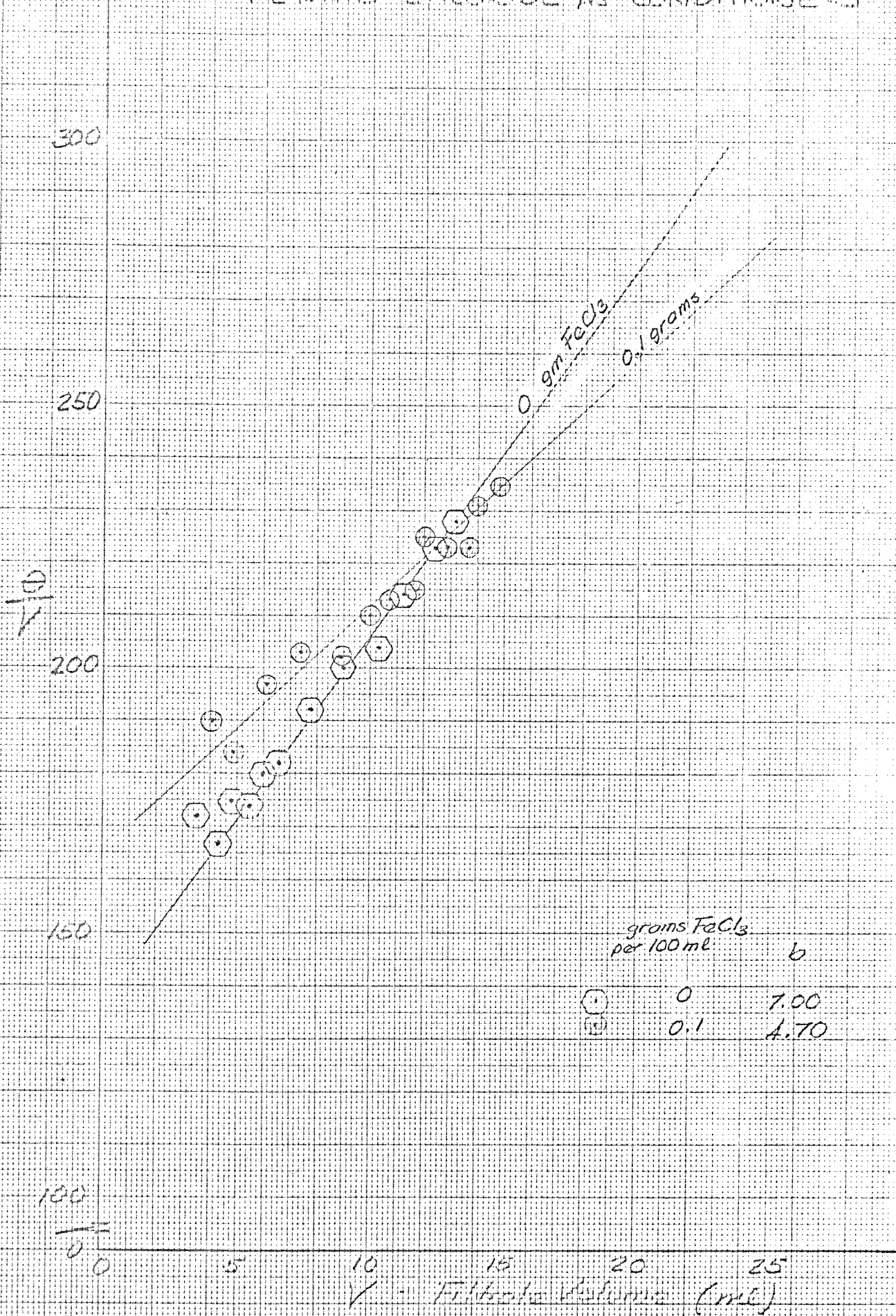
V for 0.25gm ONLY 0

0 5 10 15 20 25
V, Filtered Volume (ml)

Run No. 4

Date 3/12/64

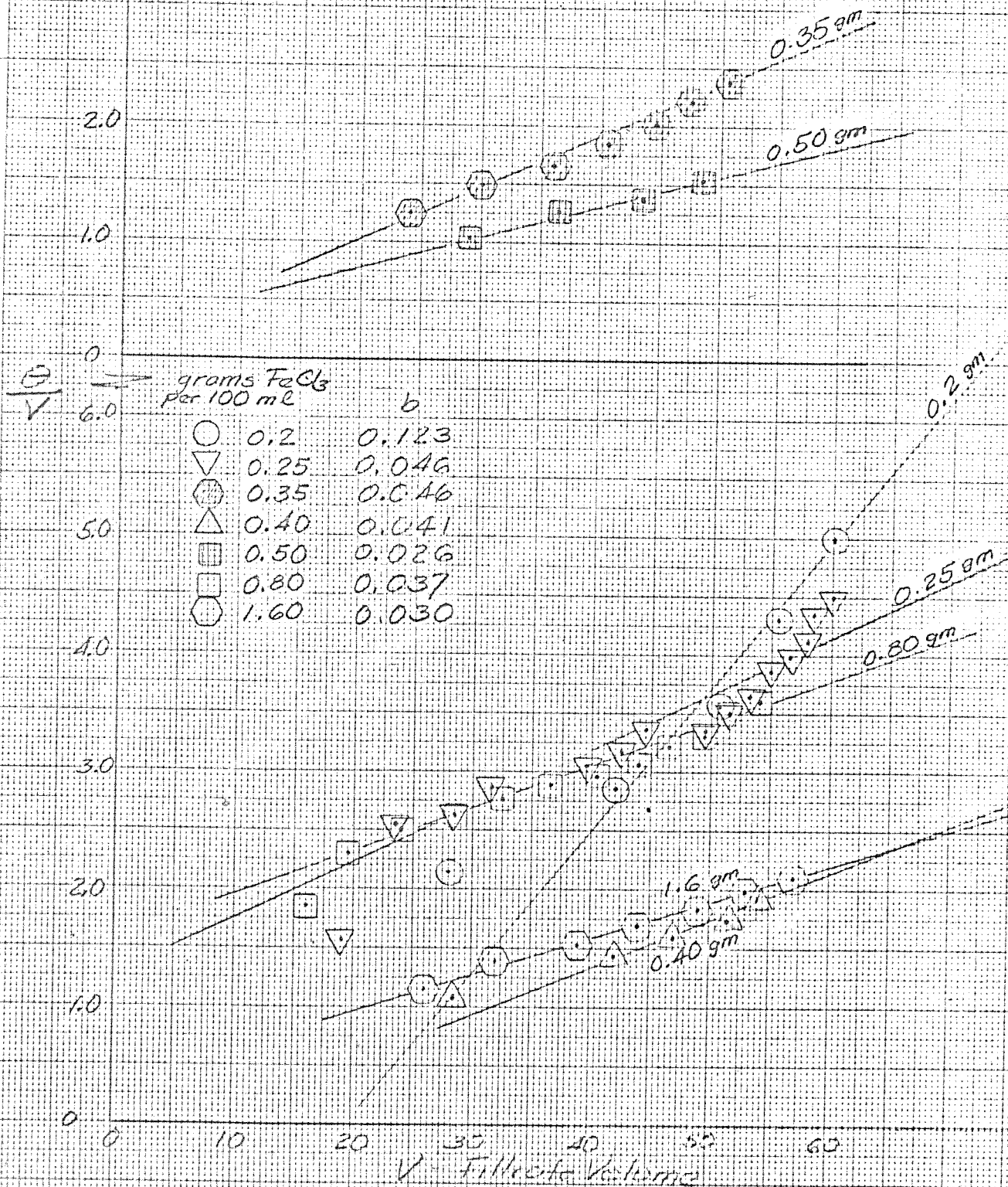
FERRIC CHLORIDE AS CONDITIONER



grams FeCl ₃ per 100 ml	b
0	7.00
0.1	4.70

V - Filtrate Volume (ml)

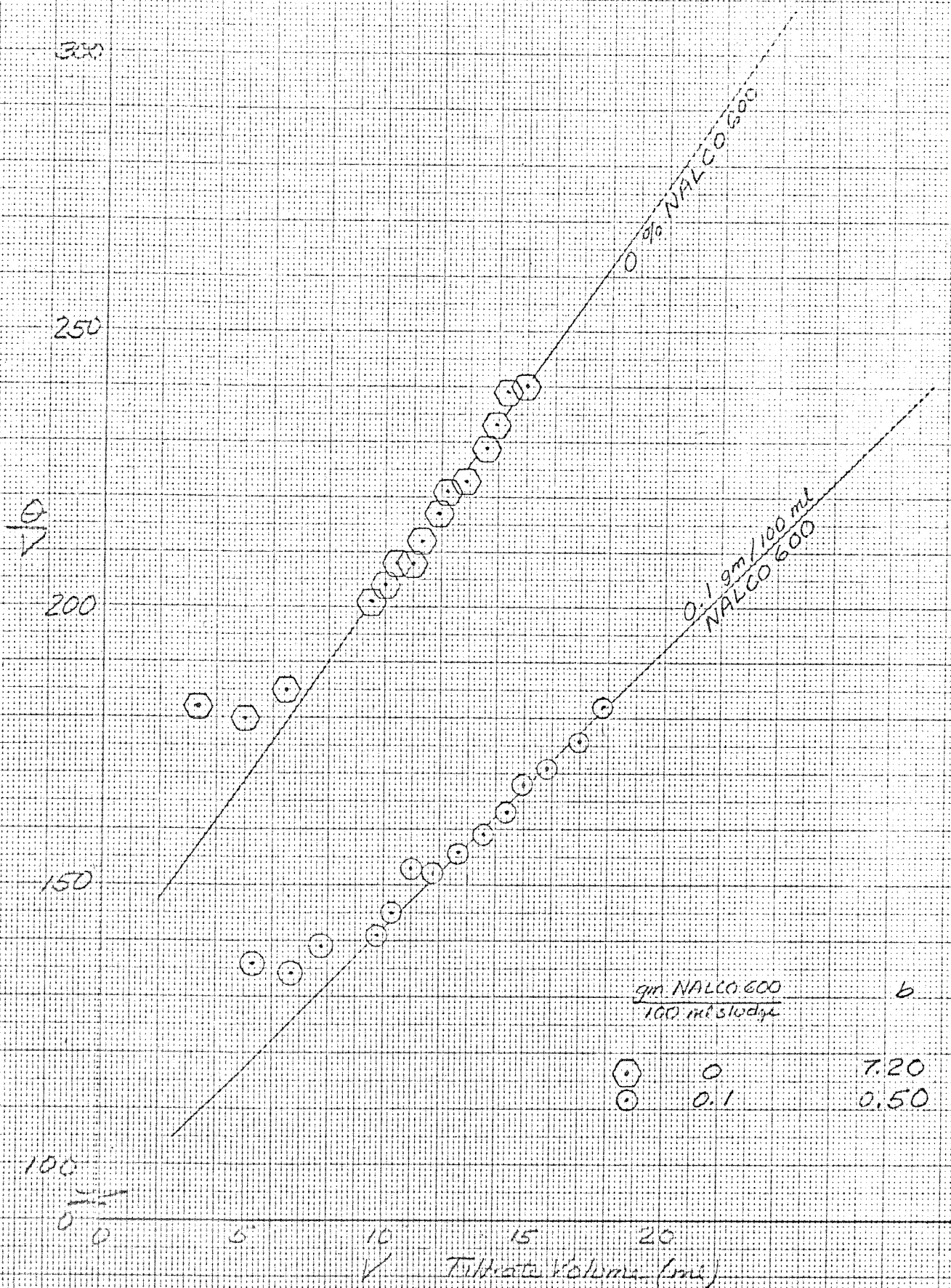
FERRIC CHLORIDE AS CONDITIONER



Run No: 5

Date: 4/12/58

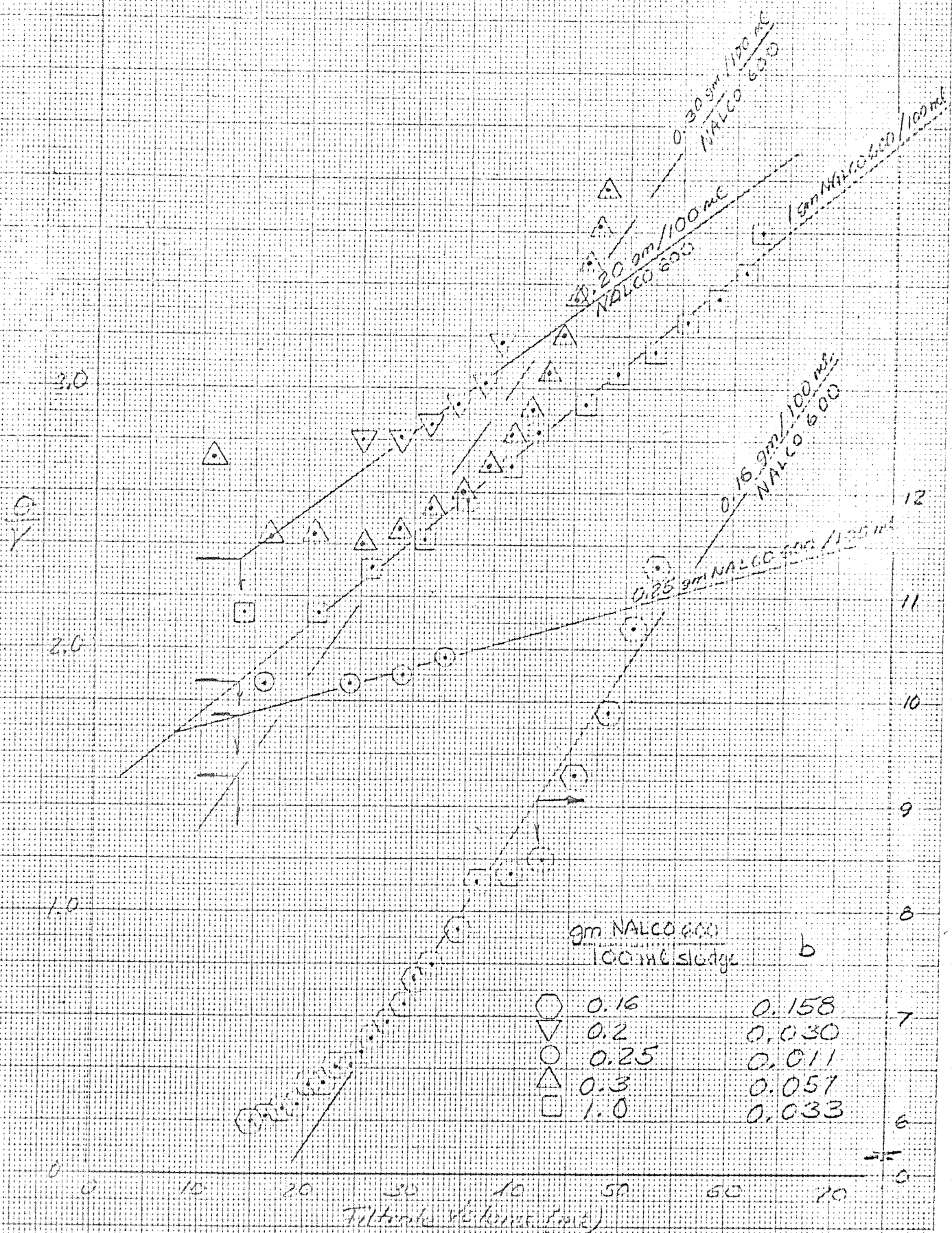
NALCO 600 AS CONDITIONER



Run No. 5 (CONT)

Date: 3/12/59

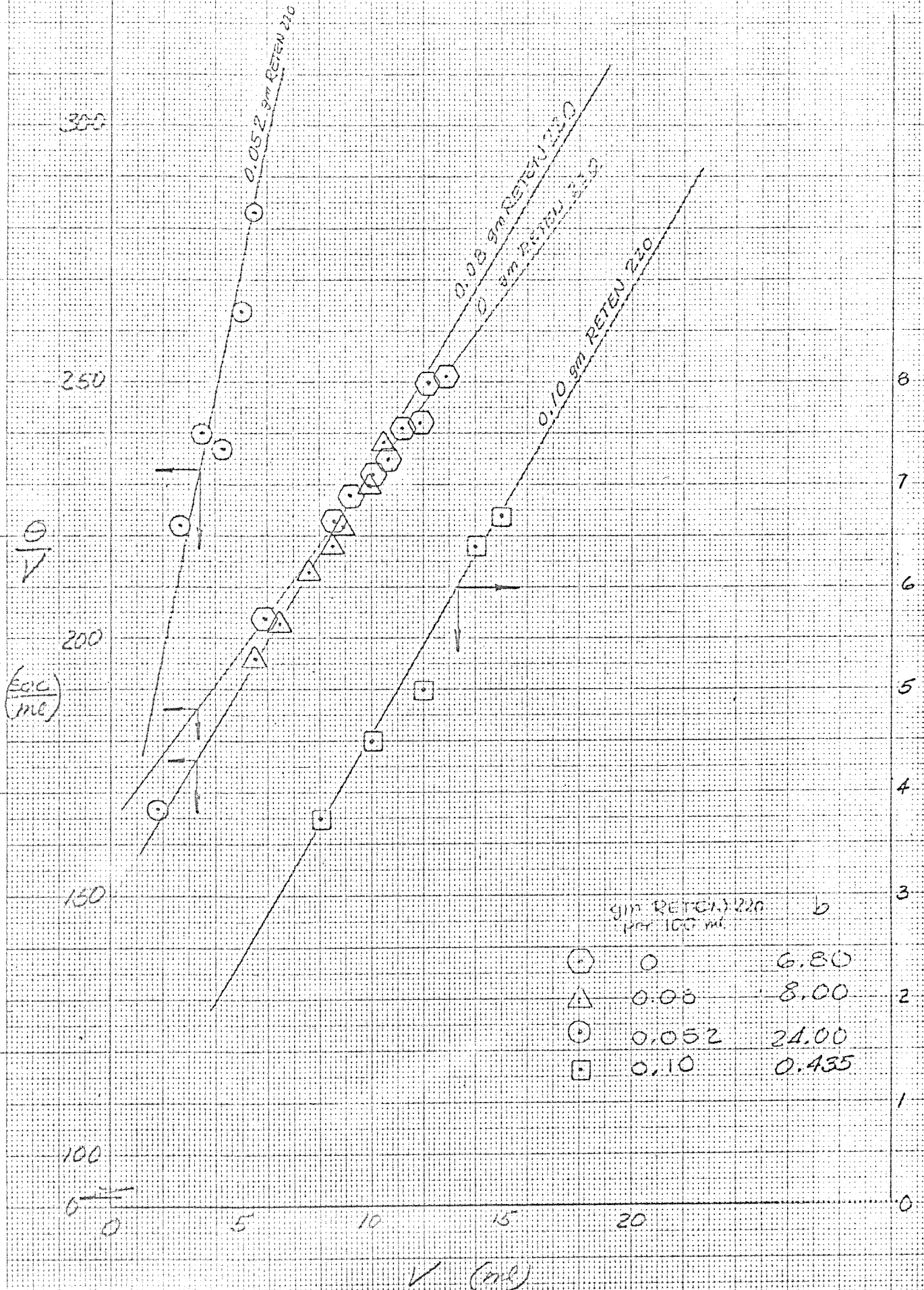
NALCO 600 AS CONDITIONER



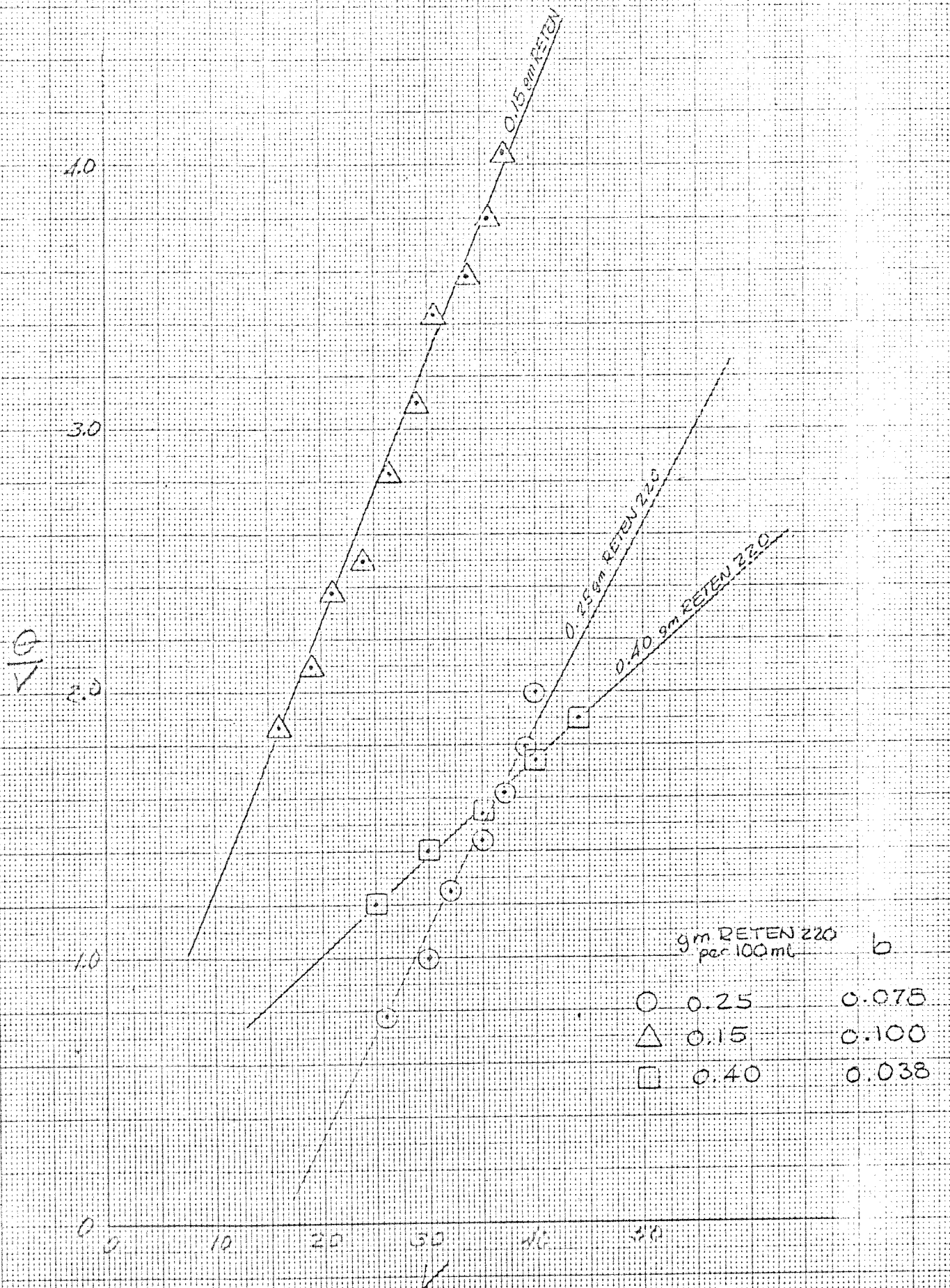
Run No: 6

Date 5/12/68

RETIN 220 AS CONDITONERS



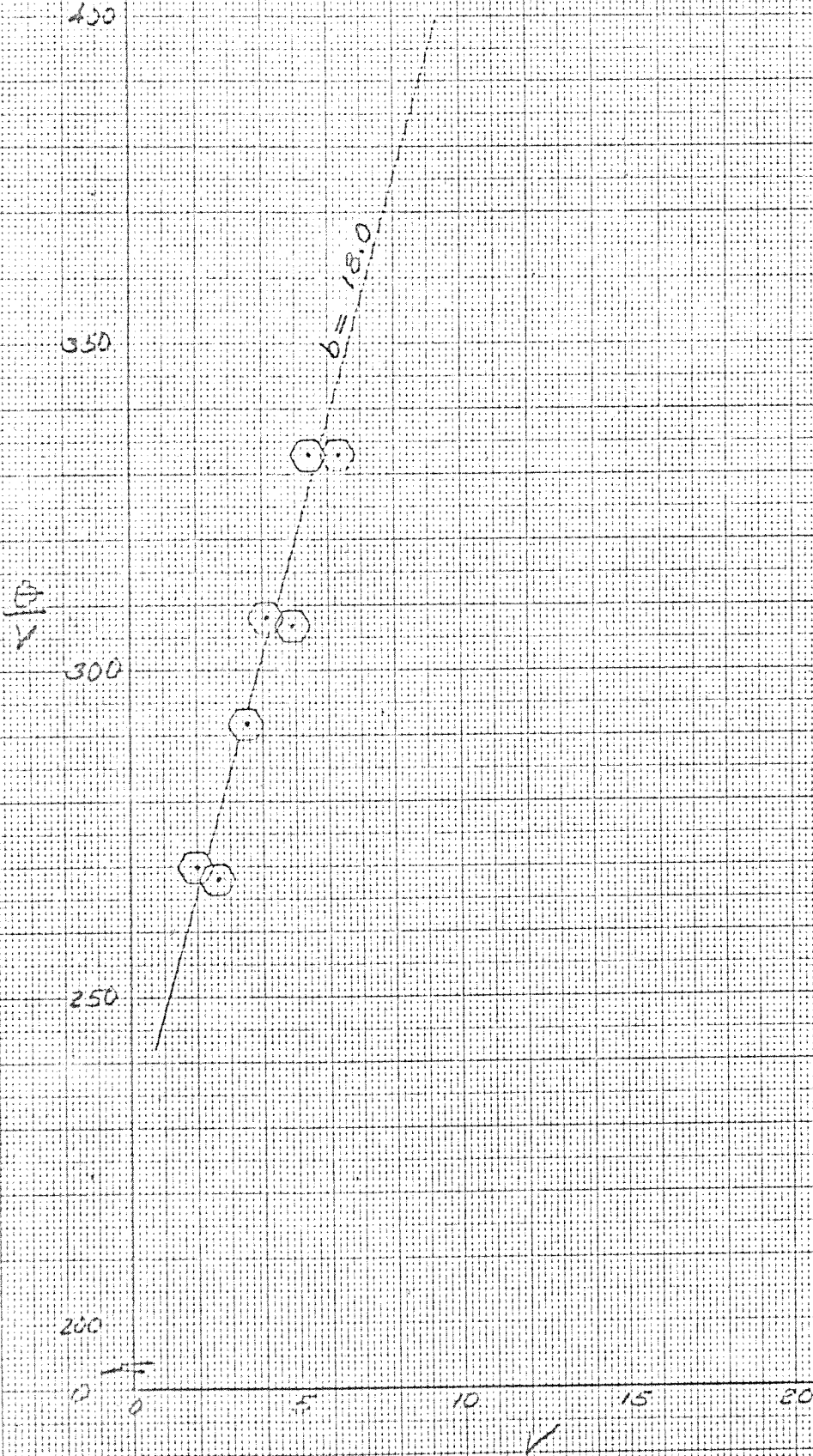
RETEN 220 AS CONDITIONER



Run No: 7

Date: 5/12/68

SLUDGE FROZEN & THAWED



Run No 8

9/12/63

PURIFLOC C-31 AS CONDITIONER

