NORSK INSTITUTT FOR VANNFORSKNING
Blindern

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COST 68/2 - SLUDGE CHARACTERIZATION

A Study on

ESTIMATION OF SLUDGE CENTRIFUGE CAKE SOLIDS CONCENTRATION

by

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OUTLINE

1. SAMMENDRAG

Formålet med dette prosjektet var i første rekke å utvikle en metode for å beregne slamkakens tørrstoffinnhold etter sentrifugering.

Det viste seg at en laboratorie-sentrifuge gir en god indikasjon på slamkakens tørrstoffinnhold og kan antakelig brukes for oppskalering (dette ble ikke bestemt eksperimentelt). Slamkakens tørrstoffinnhold bestemt på denne måten vil sammenliknes med ideell drift av fullskala sentrifuge (100% gjenvinning) og må derfor betraktes som den tørreste slamkake som man kan oppnå ved svært høy grad av gjenvinning.

2. ABSTRACT (in English)

The objective of this project was to develop a potential tool for estimating sludge centrifuge cake solids.

It is concluded that a test-tube centrifuge does indeed give reasonable estimates of cake solids and might well be used for scale-up purposes (although this was not determined experimentally). The cake solids thus estimated are the solids from an ideal prototype operation at 100% solids recovery, and thus can be considered as the best cake possible with very high recoveries.

3. INTRODUCTION

Several years ago, a test was developed at the Norwegian Institute for Water Research for the estimation of sludge centrifuge performance. (Vesilind 1969, Vesilind 1970 A.) This test can be used for estimating the solids recovery of any sludge in a given solid bowl centrifuge. The major weakness of this test is that it does not provide an estimate of the sludge cake concentration.

The literature is void of any attempts to estimate cake solids, with the exception of a rather academic exercize of the possibility of such estimations (Vesilind 1970 B).

The major problem with estimating cake solids is that they are entirely dependent on the operational characteristics of the machine, and very strongly a function of the solids recovery. This latter relationship is not simple, and has been the source of a great deal of confusion. A "rational" cake solids curve has been proposed to sort out the conflicting data found in the literature (Vesilind 1969).

In light of these difficulties, it seems reasonable to limit the objective to the development of a test which would yield the "ideal" cake solids concentration; as if the machine was operating as an ideal liquid-solid separator, and attaining 100 per cent solids recovery. This simplifies the problem, but limits the applicability of the test. Nevertheless, many machine installations are designed to operate close to 100 per cent recovery, and the results from the laboratory test would thus be of value in the design of ultimate disposal methods (such as incineration, etc.).

Accordingly, the objective of this study was to develop a simple laboratory test which would yield reasonable estimates of cake solids concentrations.

4. EXPERIMENTAL PROCEDURE

The experiments were performed with a Wifug desk-top centrifuge which holds 8 15 ml test tubes horizontally from the axis.

The centrifugal accelerations were calculated using the average radius of the test tube (Figure 1). Centrifuge speeds were measured by a strobe light (General Radio).

Compacted sludge was measured in the Wifug directly by using cut-off plastic 10 ml graduated cylinders in place of the test tubes. These cylinders have a flat bottom and allow for direct reading of the height of the sludge interface.

Representative 10 ml samples were poured into the test tubes and centrifuged for a sufficiently long time to allow for total compaction. This time varied from only 15 minutes for some of the higher speeds to several hours for the slower speeds. The sludge volume was determined visually by reading the sludge-liquid interface.

The sludges tested were all from the Kjeller experimental station. The sources were as follows:

a) Activated sludge - return sludge from the extended aeration plant, no primary clarification.

b) Lime sludge - underflow from precipitation of primary-treated effluent.

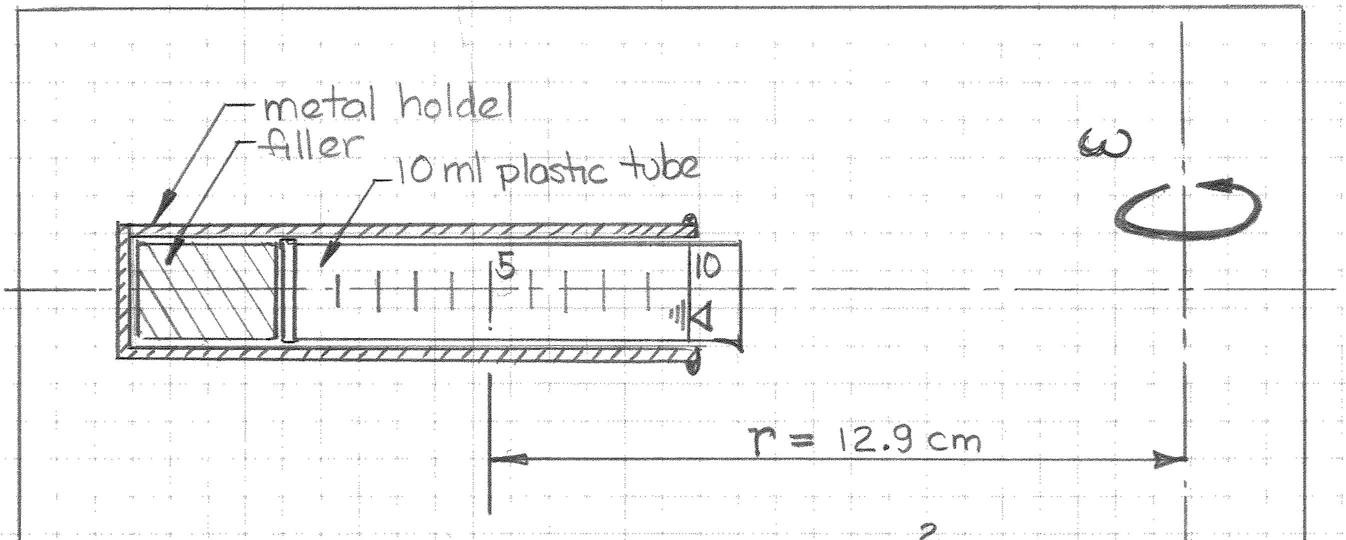
c) Alum sludge - underflow from precipitation of primary-treated effluent.

d) Raw sludge - primary clarifier.

e) Iron sludge - underflow from precipitation (ferric chloride) of primary-treated effluent.

Activated sludge flocculation was by a cationic Hercofloc polymer.

FIGURE 1 | CENTRIFUGE TEST TUBES



Centrifugal Acceleration (gravities) = $\frac{\omega^2 r}{g}$
where ω is in radians per second

5. RESULTS AND DISCUSSION

Cake solids concentrations for 5 different sludges at various gravitational accelerations are shown on Figures 2 through 6.

Activated sludge is a very difficult sludge to dewater, and the results shown on Figure 2 indicate that for the two sludges tested, it does not seem reasonable to expect centrifuge cakes of greater than 8 or 10 per cent solids. This is confirmed in practice, where centrifuges are generally used to only thicken activated sludge and dewatering (to a solid cake) is seldom attempted or achieved.

Figure 2 also shows that increased centrifugal forces have a rapidly diminishing effect on sludge cake concentrations. It would thus not be reasonable to use centrifugal accelerations greater than about 1000 gravities for activated sludge, and 500 gravities might in fact be much more economical when wear and tear is considered.

The data on the lime slurry, Figure 3, show that it was possible to concentrate this material to about 25 per cent solids. Such a cake can be handled as a solid material. It is again clear that there is very little gained by increasing the centrifugal forces to above 1000 or 1500 gravities.

The iron sludge (Figure 4) compacted to only about 10 per cent solids; still a liquid. There seemed to be little effect due to initial concentration.

Alum sludge behaved the same way (Figure 5), with even wetter cakes. This is again confirmed by previous experience on the dewatering of alum sludges. Seldom is it possible to obtain a solid cake, and such sludges are either disposed of as liquids or combined with other sludges prior to dewatering.

FIGURE 2. ACTIVATED SLUDGE COMPACTION.

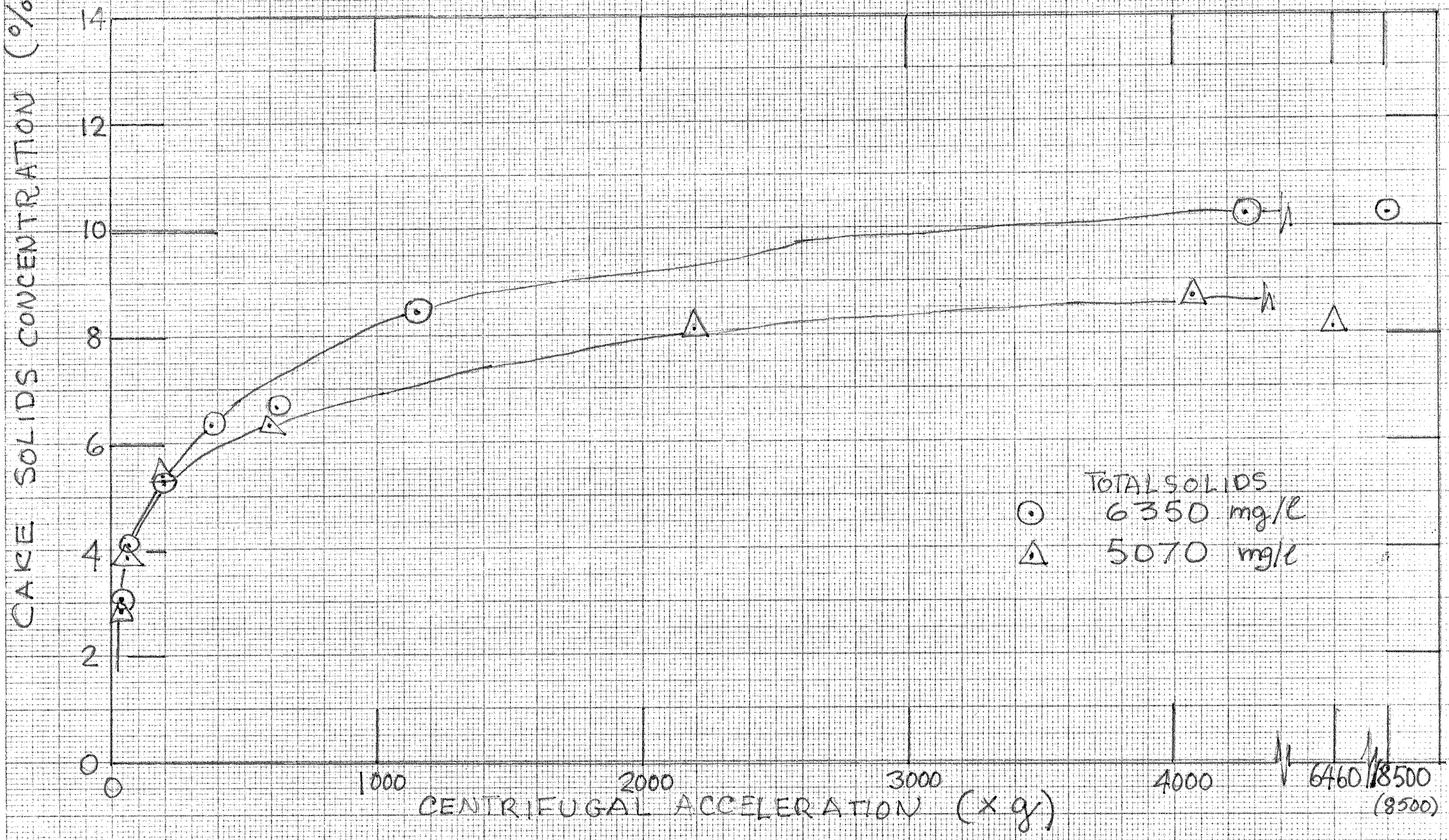


FIGURE 3. LIME SLUDGE COMPACTION.

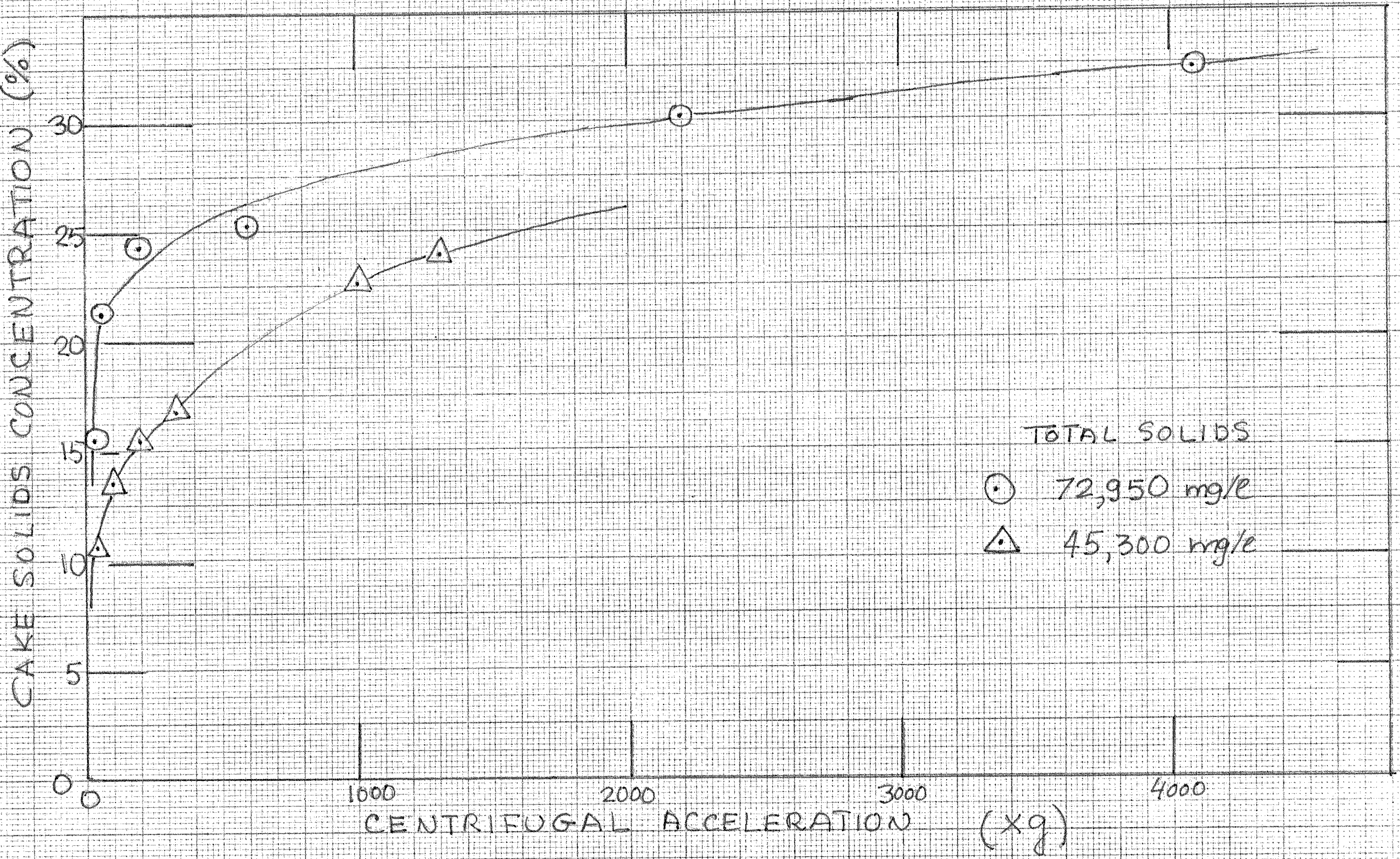


FIGURE 4.1 IRON SLUDGE COMPACTION.

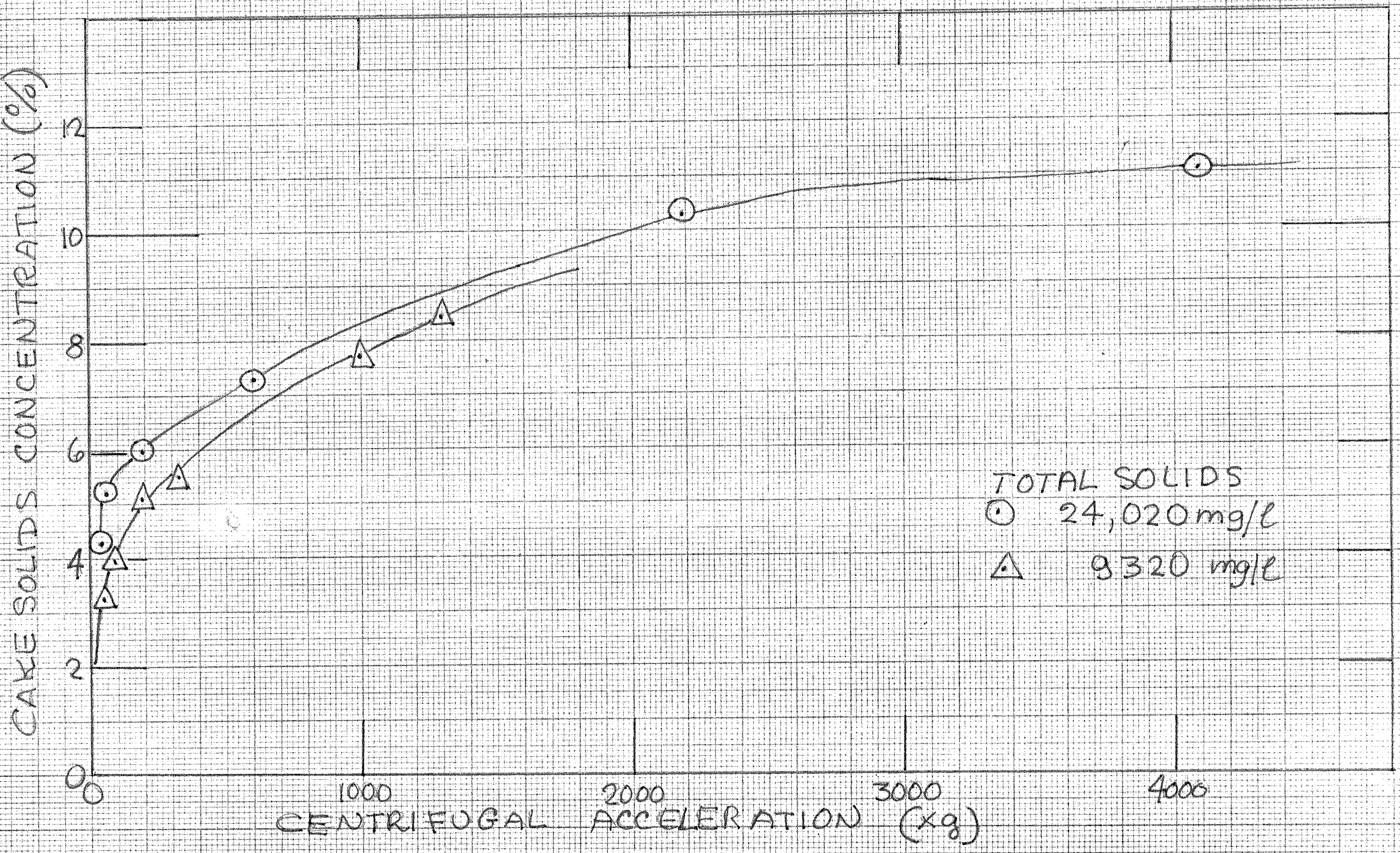


FIGURE 5. ALUM SLUDGE COMPACTION.

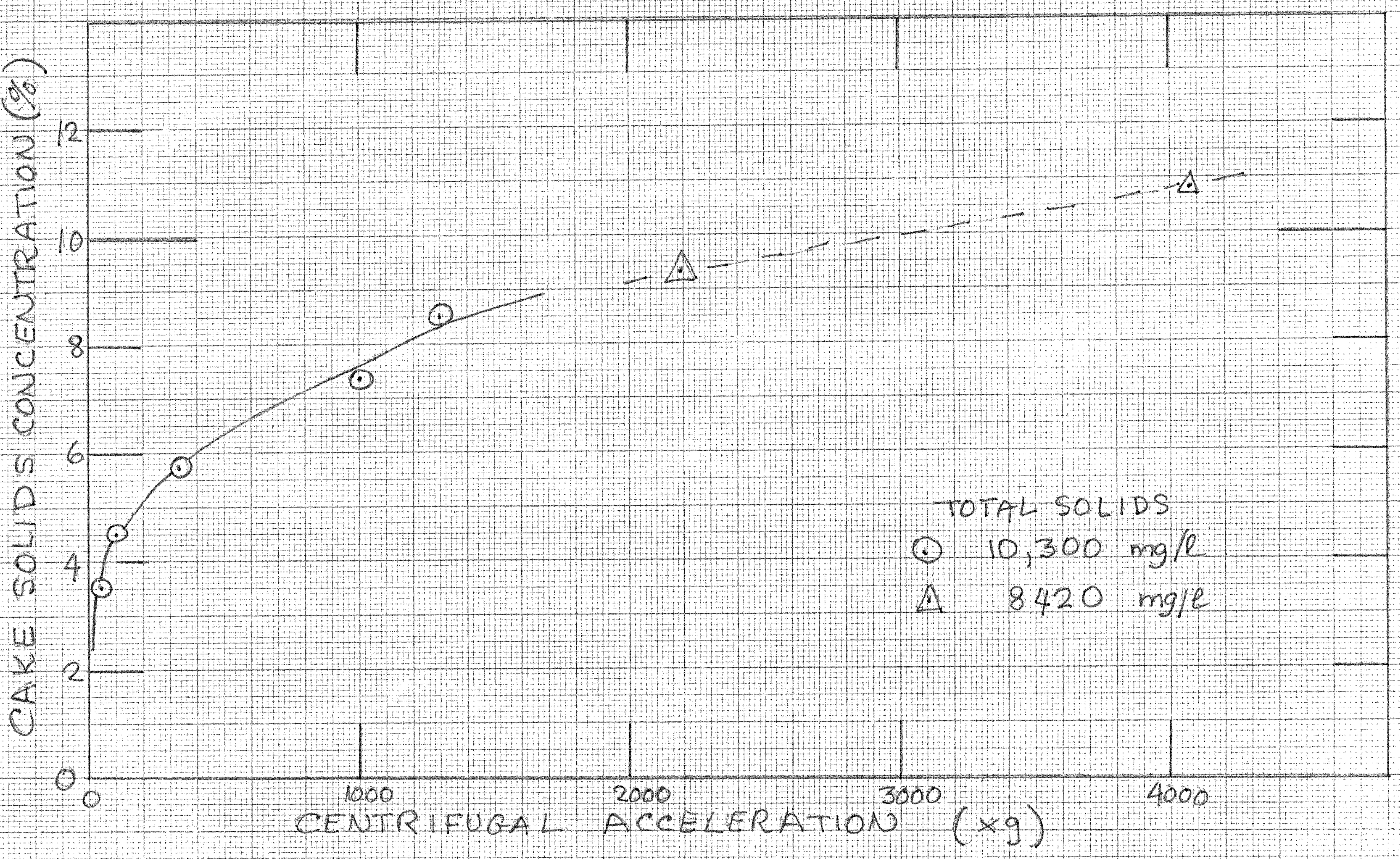
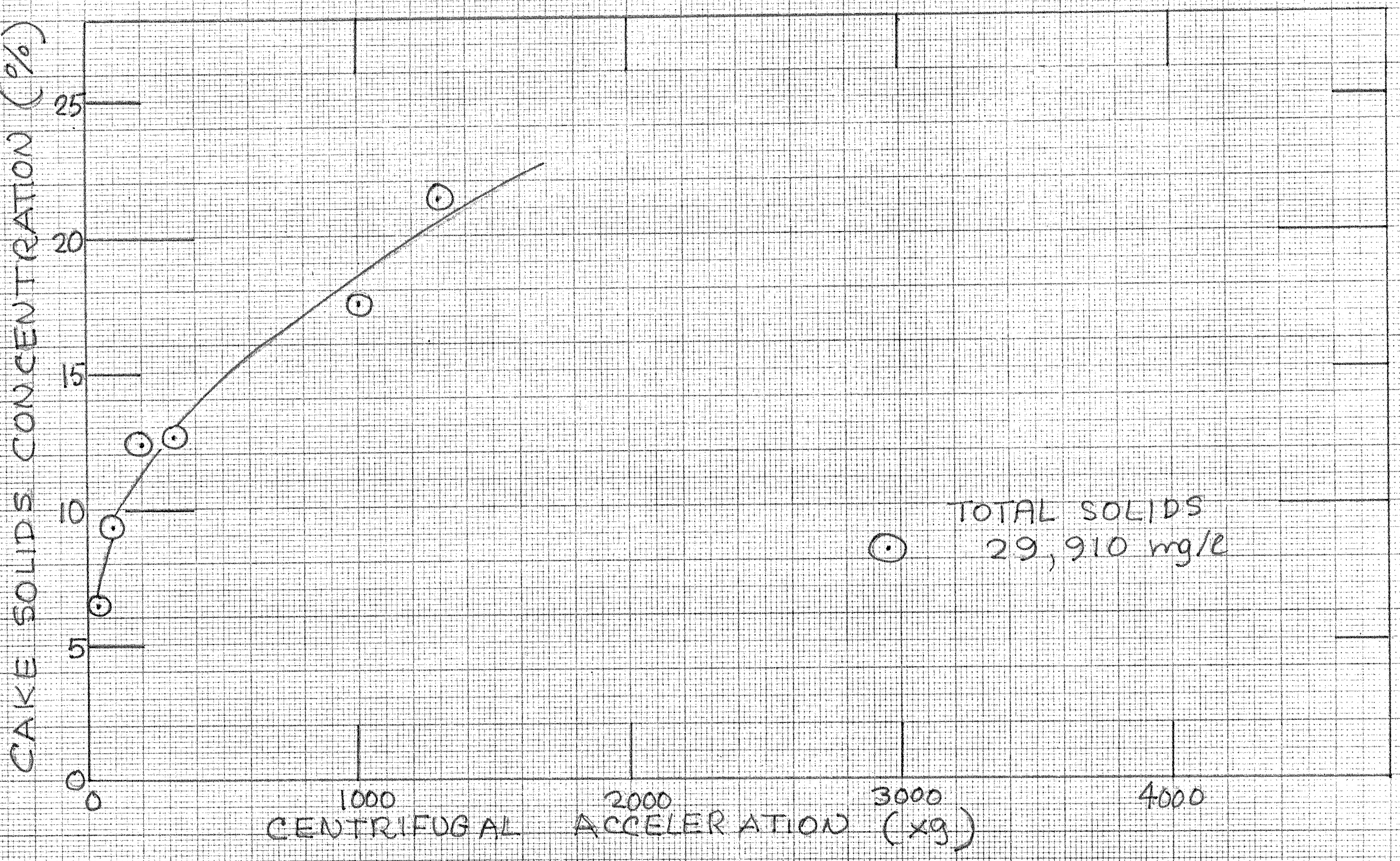


FIGURE 6. RAW PRIMARY SLUDGE COMPACTION.



The data for the raw primary sludge, Figure 6, indicates that this material is very much influenced by centrifugal force, and it is possible to drive out much of the water by using higher speeds. One problem with testing raw primary sludge, incidentally, is the very poor precision. The points on Figure 6 are average values for several tests, and even these are questionable.

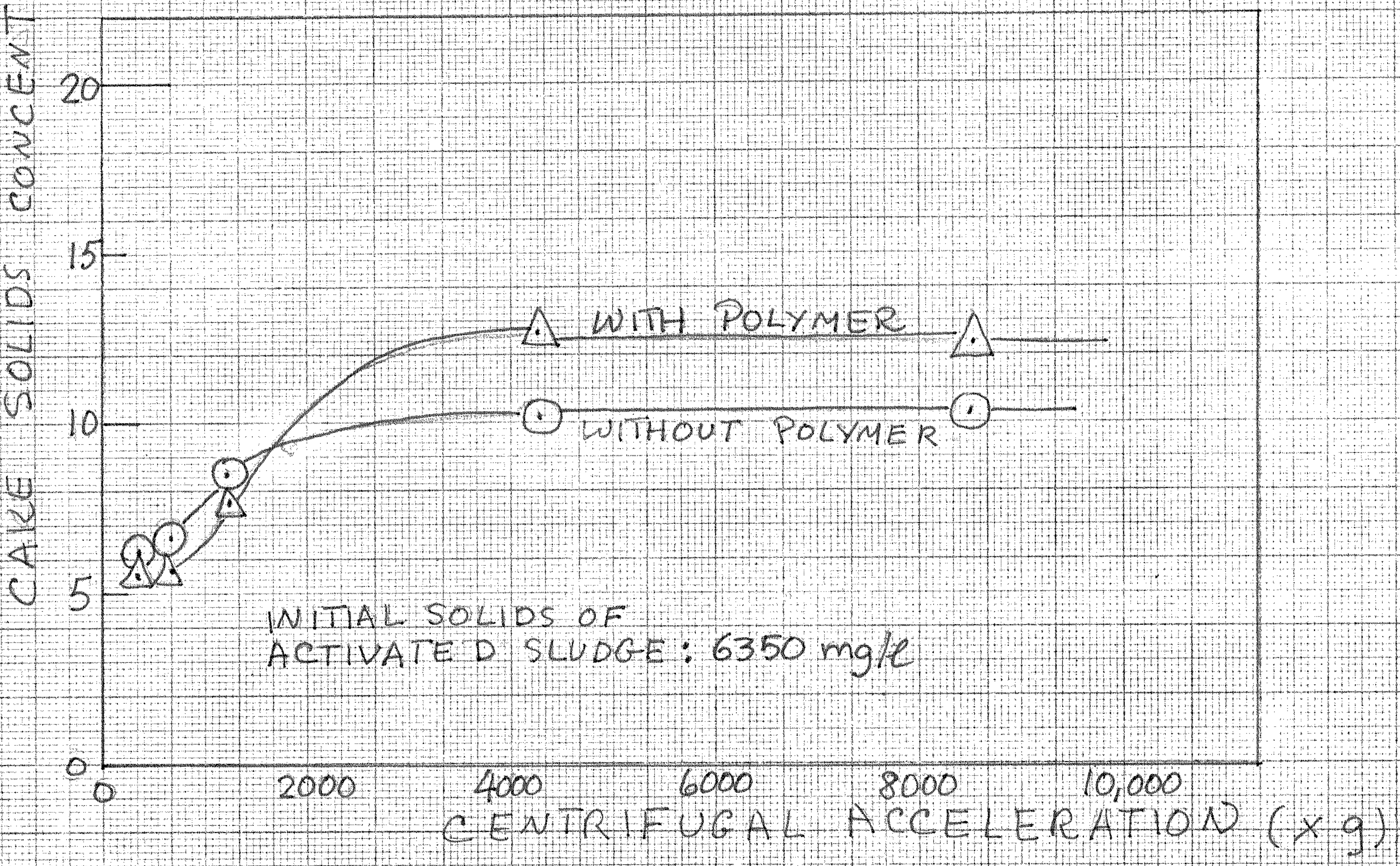
The addition of sludge conditioners changes the structure of the sludge and as a result influences its dewatering and thickening characteristics.

Test tube experiments can also be used for estimating the effect of sludge conditioning agents on sludge cake solids. Figure 7 shows the results of a series of experiments on activated sludge with no conditioning, and with flocculation with an organic polyelectrolyte.

As expected, the polymer conditioned sludge will produce drier cakes. It should be noted that even with polymers, it would be very difficult to obtain cake solids greater than about 12 per cent, even at very high centrifugal forces.

It is necessary to emphasize that the cake solids concentrations measured in this manner are not the dryest possible cakes obtainable from centrifugation. The dryest solids can be obtained in a centrifuge by operating at a very low solids recovery, thus allowing all of the fine, wet solids to escape in the centrate and capturing only the large easy-to-compact solids. In most cases, such an operation is not recommended and will, if prolonged, cause great difficulties in plant operation. Accordingly, most installations operate at approximately 95 per cent solids recovery.

FIGURE 7. EFFECT OF POLYMER ON CAKE.



The cake solids estimated by the test-tube procedure, are of course with 100 per cent solids recovery, and thus are applicable only in situations where such operations are approximated. Once 100 per cent recovery is attained in a centrifuge, higher speeds and longer retention times (lower feed rates) result in drier cakes.

6. CONCLUSIONS

1. The desk-top test-tube centrifuge can be used to determine reasonable "ideal" (at 100% solids recovery) sludge cake solids concentration for continuous prototype machines. The method has not, however, been tested against actual operation.
2. In addition, it is possible to get an estimate of the effect of centrifugal speed on cake dryness. Some sludges have a limit of compaction where higher speeds will have negligible effect on cake dryness and would only increase the wear and tear on the machine.
3. This procedure should be tested against full scale centrifuge operation by running the laboratory tests at prototype installations.

7. REFERENCES

1. VESILIND, P.A. (1969) "Estimation of Sludge Centrifuge Performance from Laboratory Experiments". Project No. T-3/69, Norsk institutt for vannforskning, Blindern, Oslo.
2. VESILIND, P.A. (1970 A) "Estimation of Sludge Centrifuge Performance". Journal, San.Eng.Div., ASCE 96, SA 3.
3. VESILIND, P.A. (1970 B) "Can We Predict Centrifuge Cake Solids?" Proc. 20th Southern Wat. Poll. Contr. Conf., Chapel Hill, N.C.

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APPENDIX

Date: 16 July 1973

Centrifuge: Wifug Tubes: 10 ml plastic

rpm	500	820	1520	2660	3050	555	1140	436	280
x g	36	97	325	1000	1300	44	190	27.5	11.5
Time (min)	75	60	35	30	45	60	45	60	120

Sludge: Lime slurry, TS = 45,300 mg/l

Final Ht. (ml)	3.9	3.3	2.7	2.0	1.9	3.6	2.9	4.0	4.9

Final height in settling test (%); 58

Sludge: Raw primary, TS = 29,910 mg/l, SS = 28,420 mg/l

Final Ht. (ml)	4.6	3.2	2.35	1.7	1.4	4.2	2.4	3.9	6.85

Sludge: Alum sludge, TS = 10,300, SS = 10,050

Final Ht (ml)	2.9	2.3	1.8	1,4	1.2	2.6	1.9	3.0	3.7

Final height in settling test (%); 50

Sludge: Iron sludge, TS = 9320, SS = 8960

Final Ht (ml)	2.8	2.4	1.7	1.2	1.1	2.6	1.8	3.1	3.65

Final height in settling test (%); 30

Sludge: Sand and water, TS = 53%

Final Ht. (ml)	3.5	3.5

Date: 25 July 1973

Centrifuge: Wifug   Tubes: 10 ml plastic

rpm	2060	265	394	620	1170
x g	600	10	17	56	195
Time (min)	20	4 hr	100	40	25

Sludge: Lime slurry, TS = 72,950 mg/l

Final Ht. (ml)	2.9	5.95	4.8	3.5	3.0

Sludge: Activated sludge, TS = 5070 mg/l

Final Ht (ml)	0.8	2.8	2.0	1.5	1.1

Sludge: Iron slurry, TS = 24,020 mg/l

Final Ht (ml)	3.4	6.1	5.8	4.8	4.2

Sludge: Alum sludge, TS = 8420 mg/l

Final Ht (ml)	1.25	2.85	2.5	2.0	1.7

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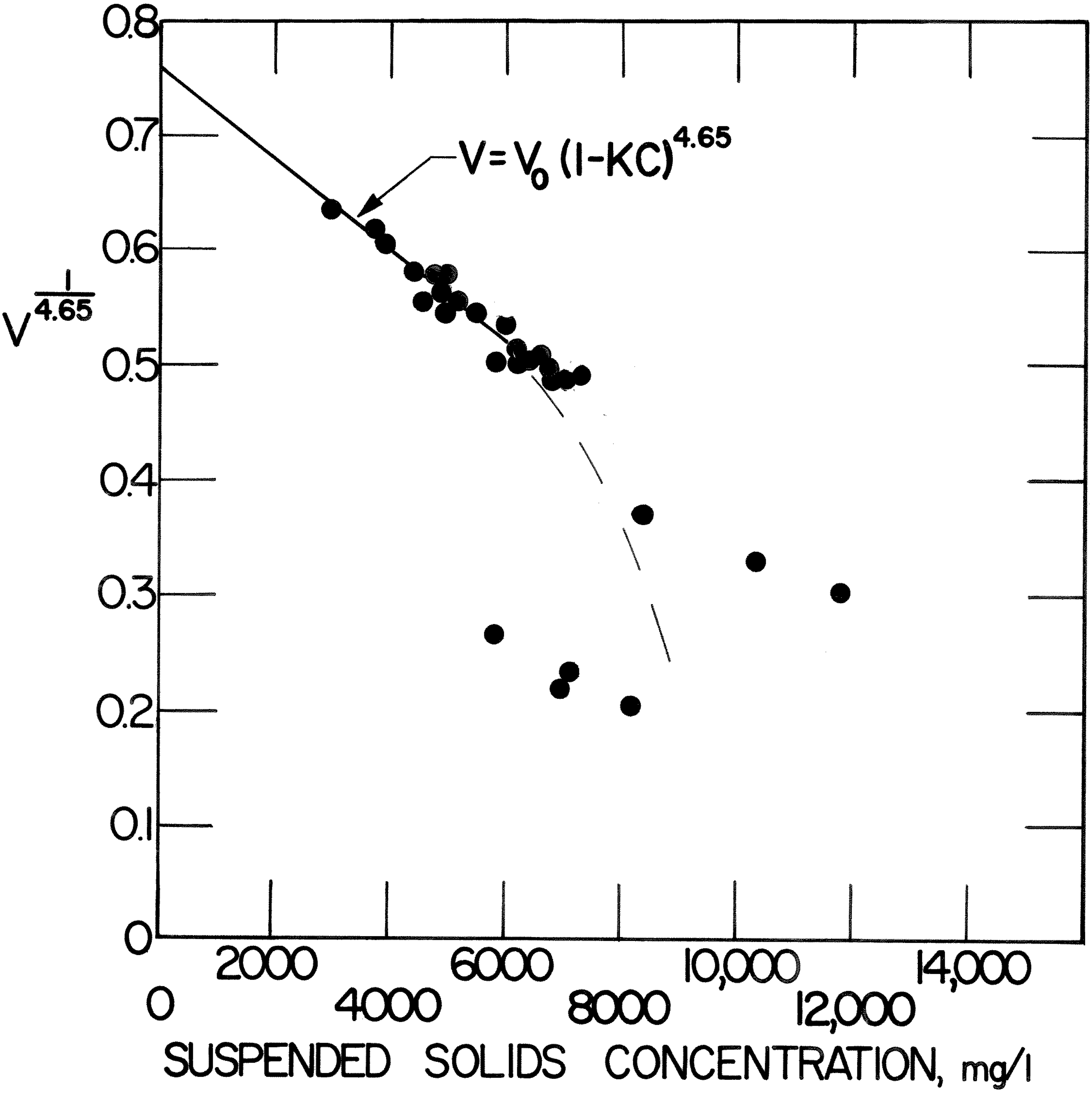

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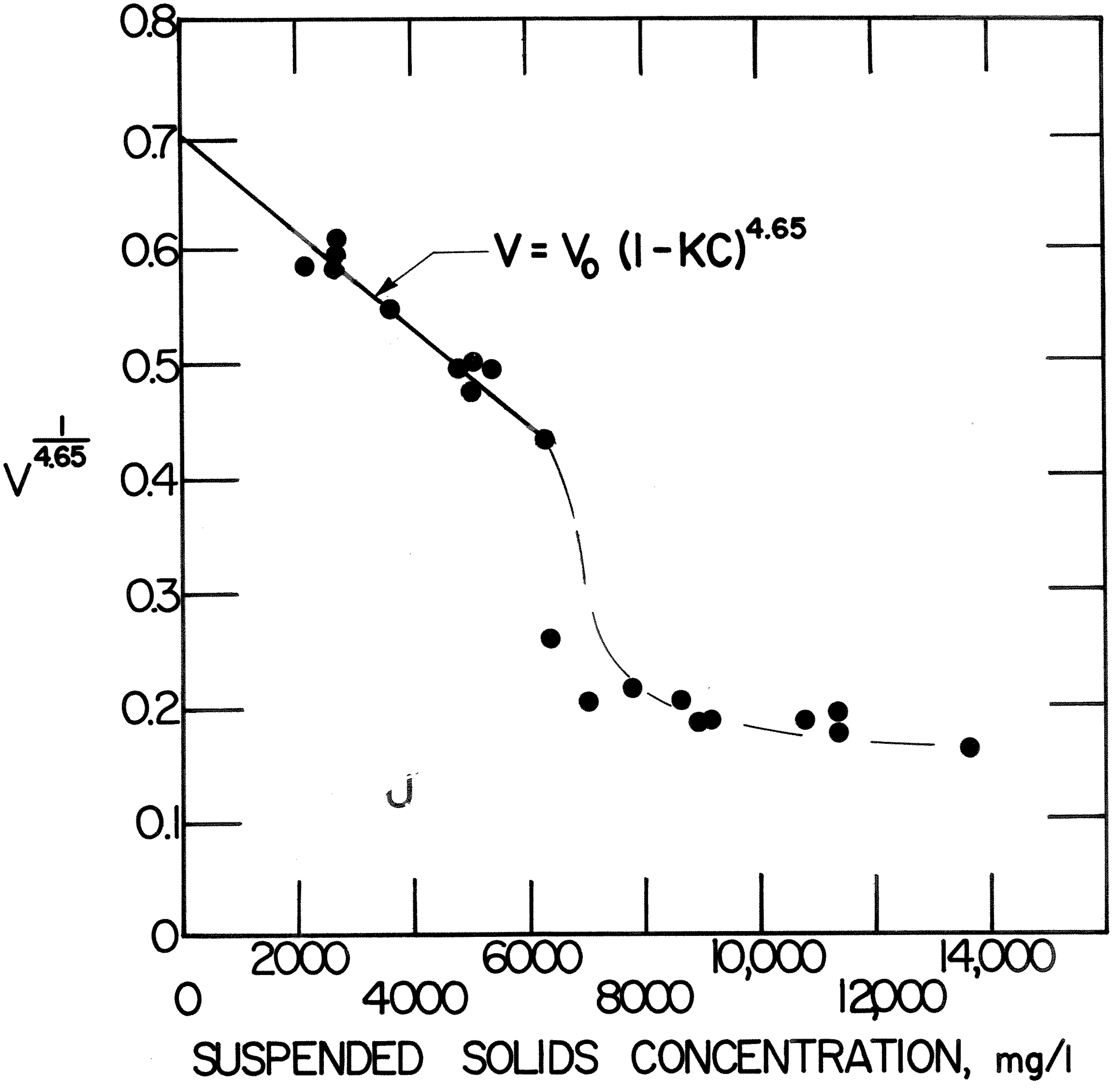
Vatten 4/64 Vesilind

Figure 1



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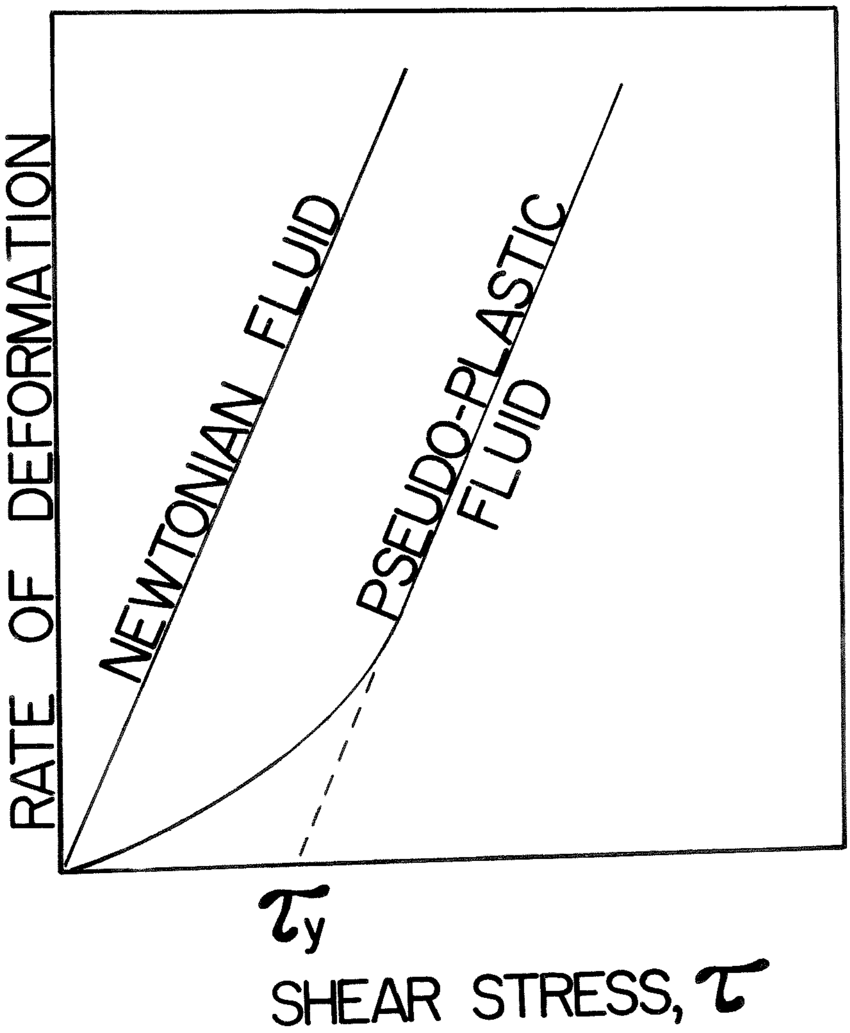
Water 4/69 Vesilind

Figure 2


RATE OF DEFORMATION
NEWTONIAN FLUID
PSEUDO-PLASTIC FLUID
τ_y
SHEAR STRESS, τ

[illegible]

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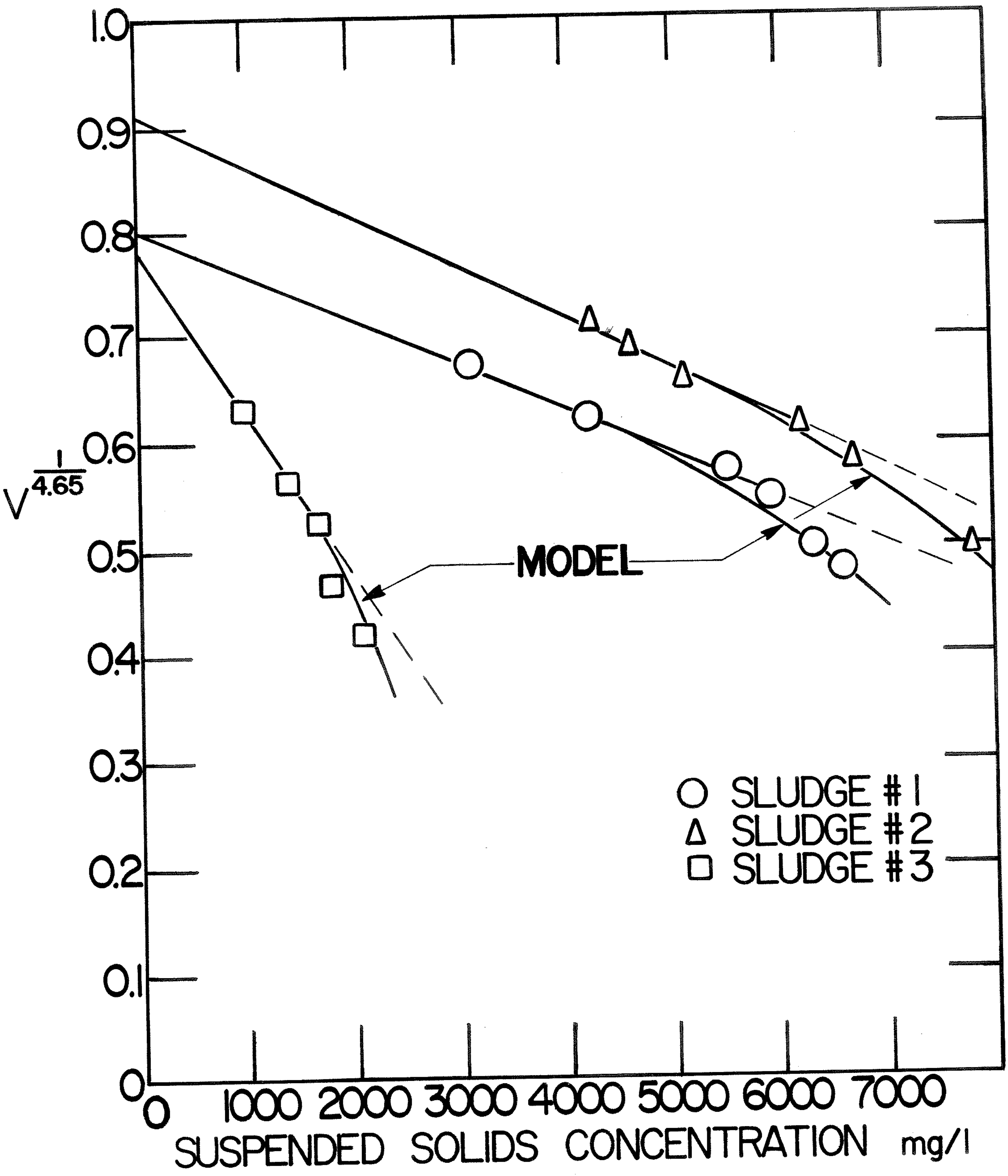
Figure 5



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