PERMEABILITY OF CONSOLIDATED BOSPHORUS CLAYS

THESIS

By

ÖVER ÖZENÇ

ACKNOWLEDGEMENT

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ABSTRACT

The effects of four independent variables; soil type, preconsolidation load, the rate of application of consolidation pressure, and granulometry, on the permeability of consolidated clays are studied. To find out the relative importances of these factors, a statistically predetermined set of experiments are run on three soil types with various combinations of different levels of variables.

Although the effects of these four variables show considerable changes as the void ratio of soil decreases due to consolidation, at the final stages, soil type is found tobe the most important factor, followed by the preconsolidation load. The other two variables are found to be less significant compared to these two factors.

Secondly, the correlation between the permeability of a soil and several of its physical properties are investigated. Although the number of samples were relatively few, considerably reliable equations are found which relate permeability to the activity, plasticity index and void ratio of soils at different stages of consolidation.

TABLE of CONTENTS

INTRODUCTION

Permeability is an important property of soils. It enters all problems involving flow of water through soils, such as drainage of subgrades and backfills, settlements due to consolidation, seepage under sheet piles and especially in earth dams. The effective strength of soils are also controlled indirectly by their permeability.

Because of the great importance of permeability, much research is done on this subject. But almost all of this work has been done on the permeability of compacted soils due to the fact that most earth structures such as earth dams are constructed by the use of compacted material. The most extensive researches on permeability are the works of L.Bjerrum - J.Huder (1) and L.K.Mitchell, D.E.Hooper, R.G.Campanella (6). Both of these references mentioned researches are on the permeability characteristics of compacted clays. A similar research was done by Suha Uluçay as his Master of Science thesis in Robert College, In his work, he has studied the effects of soil type, water content, granulometry and compactive effort, on the permeability of compacted Bosphorus clays.(12). A research on permeability of consolidated clays was done by M.T.Tümay as his Ph.D. thesis in Istanbul Technical University. In this research, he investigated the change in the coefficient of permeability with the direction of flow in consolidated soil specimens.

The object of this thesis is to study the effects of four independent variables on permeability of consolidated clays. The variables chosen are : soil type, preconsolidation load, granulometry and the rate of application of consolidation pressure.

In order to determine the effects of these parameters, a set of statistically predetermined experiments were planned. The samples for these experiments were arranged in a Greco-Latin matrix form so that it would be possible to evaluate the extent of the effects of independent variables by variance analysis (14).

Thus, nine soil samples were prepared from three different types of soil at three granulometric levels, preconsolidated under three different loads. These samples were tested at three different loading rates in a manner that confirms with the requirements of the Greco-Latin model.

For the experiments an oedometer and a Geonor permeameter were used. But in order to be able to use those apparatus for the desired purposes, some modifications were made.

From the data obtained from these tests, consolidation curves were plotted for the preconsolidation and consolidation steps, and void ratios at the end of each step were computed. For each sample, void ratios obtained at the end of the intermediate steps were divided by the void ratio of the sample at the beginning of the first consolidation step. Thus, e/e_o values were obtained. Then, permeability versus e/e_o curves were plotted (Figures 12, 13 and 14). From different e/e_o levels of these curves, three Greco-Latin matrices were constructed. Those matrices were analized by a computer program and significances of the effects of each variable at different stages of consolidation were obtained.

CHAPTER I

THEORY

Permeability is defined as the property of a soil that permits the flow of water through its pores. It is known that two states of fluid flow exist in nature; namely, laminar and turbulent flows. In laminar flow, fluid particles follow smooth, regular paths which are parallel to each other and to the container walls, and in this state of flow, the viscious forces are predominant. In turbulent flow, the motion of fluid particles are irregular and unsteady, and the inertial forces are predominant.

Between these two states of flow, a theoretical boundary is established. The value of Reynold's number is an indication of the flow state. Reynold's number is given by the following formula

$$R = \frac{v\, D\, \gamma_w}{\mu\, g}$$

in which,

v = velocity

γ_w = unit weight of fluid

μ = viscosity of fluid

g = gravitational acceleration

D = diameter of the passage. (7)

If the value of Reynold's number is less than 2000, the flow is laminar and if it is greater than 2000, the flow is turbulent. It is readily seen from the formula that Reynold's number is jointly proportional with velocity and passage diameter. Since both of these values are small in most soils, it is apparent that the flow through soils is generally laminar.

The law which determines the behavior of flows in soils is known as Darcy's Law. That law may be formulated as :

$$Q = k\ i\ A$$

in which, Q = total discharge

A = total soils cross-section

i = hydraulic gradient

k = Darcy's coefficient of permeability.

Darcy's Law may also be written as :

$$Q/A = k\ i = v$$

i, the hydraulic gradient is the ratio of the head difference between the points, between which the flow occurs, to the length of soil through which the water flows. Since i is dimensionless, k turns out to be in the dimensions of velocity, and v (= k i) is a superficial velocity. It is called superficial, because A is the total cross-sectional area of the soil, not the area of the voids through which the water actually flows. For that reason, it should not be confused with the actual seepage velocity, v_s. Since the area of the total soil cross-section is always greater than the area of voids in that cross-section v, the superficial velocity, is always smaller than the seepage velocity, v_s.

Factors Affecting Permeability :

The main factors affecting permeability are :

a) Grain Size : Water passes through the pores between the soil grains. Since the sizes of these pores are dependent on the grain size of the soil, permeability is also dependent on that factor. Both theory and experimental results show that permeability is approximately directly proportional to the square of the effective diameter of the soil. In case of sands, for example, Hazen found this diameter to be the grain diameter read from the 10% finer point on the gradation curve.

b) Properties of Pore Fluid : The rate of flow through the soil is related to the viscosity of the pore fluid. As the viscosity increases, permeability decreases. Since the viscosity of the pore fluid is related to its temperature, temperature is also a factor affecting permeability. Conventionally permeability of soils is given at 20°C. Permeability values obtained at other temperatures can be converted into 20°C permeabilities as :

$$k_{20^oC} = k_T \frac{\mu_T}{\mu_{20^oC}}$$

in which,

k_{20^oC} = permeability at 20°C,

k_T = permeability at temperature T,

μ_T = viscosity of water at temperature T,

$\mu_{20^\circ C}$ = viscosity of water at 20°C. (8)

c) Void Ratio : As the flow of water in a soil takes place through the voids of soils, void ratio has an important effect on permeability. e^2, (5), and $\frac{e^3}{1+e}$, (7), are the void ratio functions that have been found to be related to k. (Also, $\frac{e}{1+e^3}$ is found to be a function related to log k as a result of this thesis work.)

d) Shapes and Arrangements of Pores : Although the relation between permeability and the shapes and arrangement of pores is difficult to express mathematically, the effect of this factor is significant.

e) Degree of Saturation : There is a direct relationship between the saturation degree and permeability.

Mathematical relations between permeability and some of these factors may be derived from the equation of flow of water through soils given by Taylor :

$$Q = \left(D_s^2 \frac{\gamma_w e^3}{\mu(1 + e)} C \right) i A$$

in which,
Q = total discharge,
D = effective diameter of soil,
γ_w = unit weight of water,
μ = coefficient of viscosity of water,
e = void ratio of soil,
C = constant including the shape factor,
i = hydraulic gradient,
A = area. (7)

If we compare this equation with Darcy's $Q = k\ i\ A$, it is observed that,

$$k = D_s^2 \frac{\gamma_w}{\mu} \frac{e^3}{1 + e} \tag{12}$$

Methods to Measure Permeability :

Permeability of a soil may be determined by either direct or indirect ways. The direct determinations are the permeability measurements obtained by the conventional methods. Two main basic designs are used as conventional permeameters, namely, the constant head permeameters, and the falling head permeameters.

In the constant head permeameter (Fig. 1), the head loss is kept constant by keeping the head and tail water levels constant. That is achieved by means of overflows. In this method, permeability is obtained by determining the rate of discharge through the soil by collecting the tail water overflow in a graduated jar during a specific time interval, and substituting the measued values into Darcy's formula :

$$Q = k\, i\, A$$

$$Q = \frac{h}{L}\, k\, A$$

$$k = \frac{LQ}{Ah}$$

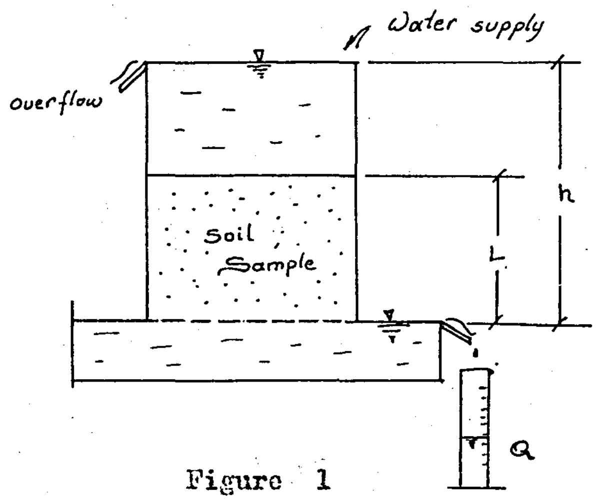


Figure 1

The falling head permeameter is the one which is generally used to measure the permeability of fine grained soils (Fig. 2).

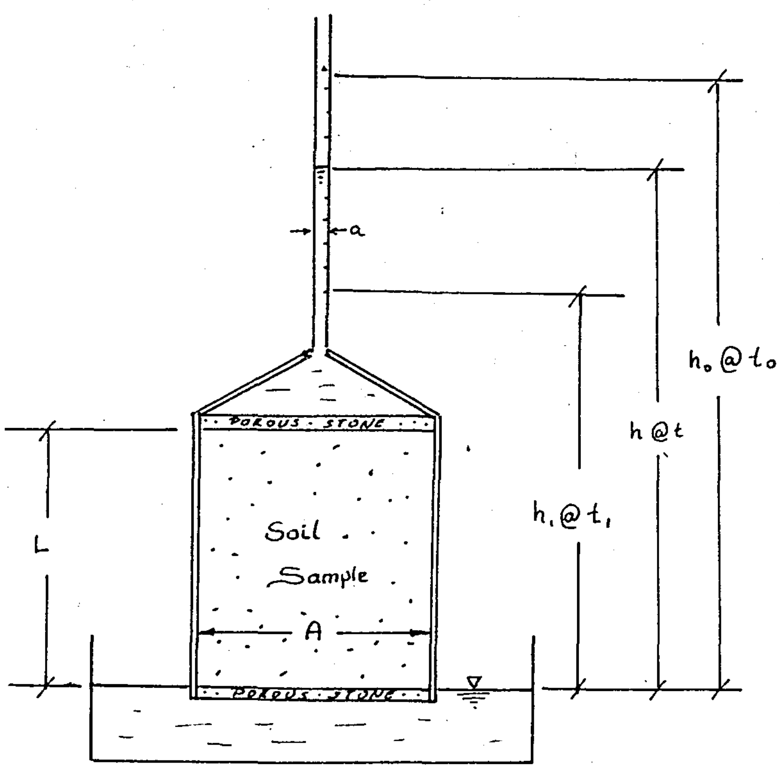


Figure 2

In this permeameter, the water level in the graduated standpipe is allowed to fall as the water enters into the soil sample. Thus, the hydraulic gradient is continuously decreasing. The rate of head change is $-\frac{dh}{dt}$, minus sign indicating that the head is decreasing. The quantity of water is $-a\frac{dh}{dt}$, a being the cross-sectional area of the standpipe. From Darcy's Law :

$$-a\frac{dh}{dt} = k\,i\,A = \frac{khA}{L}$$

$$-a\,dh = \frac{khA\,dt}{L}$$

$$-a\int_{h_o}^{h_1}\frac{dh}{h} = \frac{kA}{L}\int_{o}^{t_1}dt$$

$$-a\left|\ln h\right|_{h_o}^{h_1} = k\,a\left|t\right|_{t_o}^{t_1}$$

$$-a(\ln h_1 - \ln h_o) = \frac{kA}{L}t_1$$

$$\bar{a}\,(\ln h_o - \ln h_1) = \frac{kA}{L}t_1$$

$$a\ln\frac{h_o}{h_1} = \frac{kA}{L}t_1$$

$$k = \frac{aL}{At_1}\ln\frac{h_o}{h_1}$$

$$k = 2.3\,\frac{aL}{At_1}\log\frac{h_o}{h_1} \qquad (3)$$

in which,
a = cross-sectional area of the standpipe,
L = length of the soil sample,
A = cross-sectional area of the soil sample,
t_1 = time lapse at the end of the test,
h_o = head at the start of the test,
h_1 = head at the time t_1.

Besides the conventional methods, permeability of soils may be indirectly determined from their grain size distribution and from their consolidation characteristics.

As stated above, there is a direct relationship between the square of the effective diameter of soil grains and permeability. This relation becomes more significant as the effective diameter increases. For coarse grained sands and gravels, permeability can be reliably computed by Hazen's formula :

$$k = 100\ D_{10}^{2}$$

Permeability of silts and clays can also be calculated from data obtained in laboratory consolidation tests. When a pressure increment is applied on a saturated fine grained soil, it is accepted that, at the beginning the pore water takes all the pressure increment. Under this excessive pressure, pore water starts to escape from the soil through the pores of soil, thus the solid grains start to take the pressure increment as the total volume of soil decreases. At the end, a volume of pore water escapes from soil so that, all the pressure is carried by the solid particles. This process requires some time and this time interval is related to the escape velocity of water, therefore, permeability.

Consolidation is actually a three dimensional process in nature. But because of difficulties in experimentation, and especially the complexity of the theory, one-dimensional consolidation is generally used in laboratory experiments. And in most cases, for example as in the consolidation of a clay layer at some depth below the ground surface, and between two layers of porous material such as sand, a one dimensional analysis is not a rough approximation at all.

In developing the one-dimensional consolidation theory, the following assumptions are made :

a) The soil is homogeneous.

b) All the voids are filled with water.

c) Both the water and soil constituents of the soil are perfectly incompressible.

d) Action of a differential soil mass is similar to the action of a large soil mass.

e) Compression and flow are in one direction.

f) Darcy's Law is strictly valid.

g) The relationship between the pressure and the void ratio is linear for a small range of variables.

h) The coefficient of permeability is constant.

i) The time lag of consolidation is due entirely to the low permeability of soils. (3) and (8)

If we consider a differential volume of soil with dimensions of dx, dy, and dz, the time rate of change of volume due to water flowing in one direction from this volume is :

$$k \frac{\partial^2 h}{\partial x^2} dx\, dy\, dz$$

The volume of solids is :

$$\frac{dx\, dy\, dz}{1 + e}$$

The volume of voids is :

$$\frac{e}{1 + e} dx\, dy\, dz$$

The time rate of change in volume is :

$$\frac{\partial}{\partial t} dx\, dy\, dz \frac{e}{1 + e} = \frac{\partial e}{\partial t} dx\, dy\, dz \frac{1}{1 + e}$$

The change in volume of the soil mass to water flowing out must be equal to the change in void volume :

$$k \frac{\partial^2 h}{\partial x^2} dx\, dy\, dz = \frac{\partial e}{\partial t} dx\, dy\, dz \frac{1}{1 + e}$$

$$k \frac{\partial^2 h}{\partial x^2} = \frac{\partial e}{\partial t} \frac{1}{1 + e}$$

Let u represent the hydrostatic pressure $h \gamma_w$

$$h = \frac{u}{\gamma_w}$$

$$\frac{k}{\gamma_w} \frac{\partial^2 u}{\partial x^2} = \frac{\partial e}{\partial t} \frac{1}{1 + e}$$

Let a_v define the assumed linear relationship between pressure and void ratio :

$$a_v = - \frac{de}{dp}$$

Since hydrostatic excess pressure is transferred to the soil during consolidation,

$$dp = - du$$

$$a_v = \frac{de}{du} \text{ , } de = a_v \, du$$

Substituting,

$$\frac{k}{\gamma_w} \frac{\partial^2 u}{\partial x^2} = \frac{\partial u}{\partial t} \frac{a_v}{1 + e}$$

$$\frac{\partial u}{\partial t} = \frac{k(1 + e)}{w \, a_v} \frac{\partial^2 u}{\partial x^2}$$

The coefficient of consolidation C_v is defined as :

$$C_v = \frac{k(1 + e)}{\gamma_w \, a_v}$$

Then,

$$C_v \frac{\partial^2 u}{\partial x^2} = \frac{\partial u}{\partial t}$$

The solution yields :

$$u = \sum_{n=1}^{\infty} \left[\frac{1}{H} \int_0^{2H} u_i \sin \frac{n\pi z}{2H} \, dz \right] \left(\sin \frac{n\pi z}{2H} \right) \epsilon^{-n^2\pi^2 C_v t / 4H^2}$$

in which, H = distance of one directional flow,

u_i = hydrostatic head of the center of soil strata,

$n = 2m + 1$ where m is an integer.

It is more convenient to express the solution in terms of U, percent consolidation,

$$U = \frac{e_1 - e}{e_1 - e_2}$$

in which, e_1 = initial void ratio,

e = any intermediate void ratio,

e_2 = final void ratio.

In this case,

$$U = 1 - \sum_{m=0}^{\infty} \frac{2\int_0^{2H} u_i \sin \frac{Mz}{H}\, dz}{M \int_0^{2H} u_i\, dz} \epsilon^{-M^2 T}$$

in which, $M = \frac{1}{2}\pi(2m + 1)$

$T = \frac{C_v t}{H^2}$ (a dimensionless number called time factor) (3)

In a laboratory test, a specimen of soil is placed in a ring and subjected to a pressure increment. Consequent vertical settlement and elapsed time readings are taken and these values are plotted by either the square root method (H vs t) or by the log method (H vs log t).

From H vs t curve t_{90} (time required to reach 90% consolidation) is graphically determined. C_v the coefficient of consolidation is calculated as :

$$C_v = \frac{0.848\ H^2}{t_{90}}$$

If a H vs log t curve is plotted, graphically t_{100} (time required to reach 100% consolidation) and m_{100} (total settlement at 100% consolidation) values are determined. Half of the m_{100} value is taken as m_{50} (settlement at 50 % consolidation) and t_{50} (time required to reach 50% consolidation) is read from the curve at m_{50}. Then,

$$C_v = \frac{0.197\ H^2}{t_{50}}$$

In both cases, H is the average thickness per drainage surface for the load increment.

From the calculated void ratios, a curve of void ratio, e, vs log of pressure p, can be plotted. The slope of this curve is called the compression index C_c, or,

$$C_c = \frac{de}{d\ (\log p)}$$

The slope of the pressure vs void ratio curve is called the coefficient of compressibility, a_v. Since the log p vs e curve is usually plotted rather than the p vs e curve, a_v can be found from C_c as,

$$a_v = \frac{0.435\ C_c}{p}$$

in which, p is the average pressure increment, that is $\frac{p_1 + p_2}{2}$.

Thus, using values of a_v and C_v found from experimental results, permeability can be calculated as :

$$k = \frac{C_v\ a_v\ \gamma_w}{1 + e} \qquad (4)$$

CHAPTER II

MATERIALS and APPARATUS

Materials :

The experiments were run on three types of fine grained soils which are found in different places of the Bosphorus region. Their origins and properties were examined in Istanbul Technical University by Dr. R. Ulker at great extent.

These soils are mentioned by Dr. Ulker in his doctoral thesis (13) as :

a) Paşabahçe - kırmızı : is a low plasticity clay with high consistency.

It is found in the interior part of Paşabahçe valley as a layer of more than 8-10 m thickness. Due to the presence of a great amount of aluminum and iron in its composition, it has a dark red color. It is slightly affected by HCl solution and has a pH value of 5.3 .

b) Topser - sarı : is a low plasticity clay with high consistency.

It is found in Bosphorus region between + 20.00 and + 60.00 meter elevations. It contains quarts and sandstone blocks of 10-15 cm. diameters. It also contains fine sand of quarts origin. This soil has a yellow color which gets darker as it gets dry. It has no organic matter in its composition. HCl solution has no effect on this soil. Its pH value is 5.8 .

c) Kilyos - esmer : is a high plasticity clay.

It is found around Kilyos district in layers of about 8.0 m thickness. These layers are observed up to + 10.00 m elevation on the Asian side of Bosphorus, and up to + 25.00 m elevation on the European side. Some organic concentrations are found between the layers. Its color is dark brown. No effect of HCl solution is observed and its pH value is about 5.6 . This clay has a little amount of silt and a low percentage of organic matter in its composition.

The physical properties as found in nature of these soils are given by Dr. Ülker as :

	γ wet t/m^3	γ sat t/m^3	G_s	q_u kg/cm^2	ϕ	E kg/cm^2	Vane C
Paşabahçe kırmızı	2.14	2.14	2.72	1.70	16^o	59	0.11
Topser sarı	1.65	1.93	2.77	2.12	31.5^o	124	0.11
Kilyos esmer	1.74	1.74	2.81	1.82	5^o	141	0.14

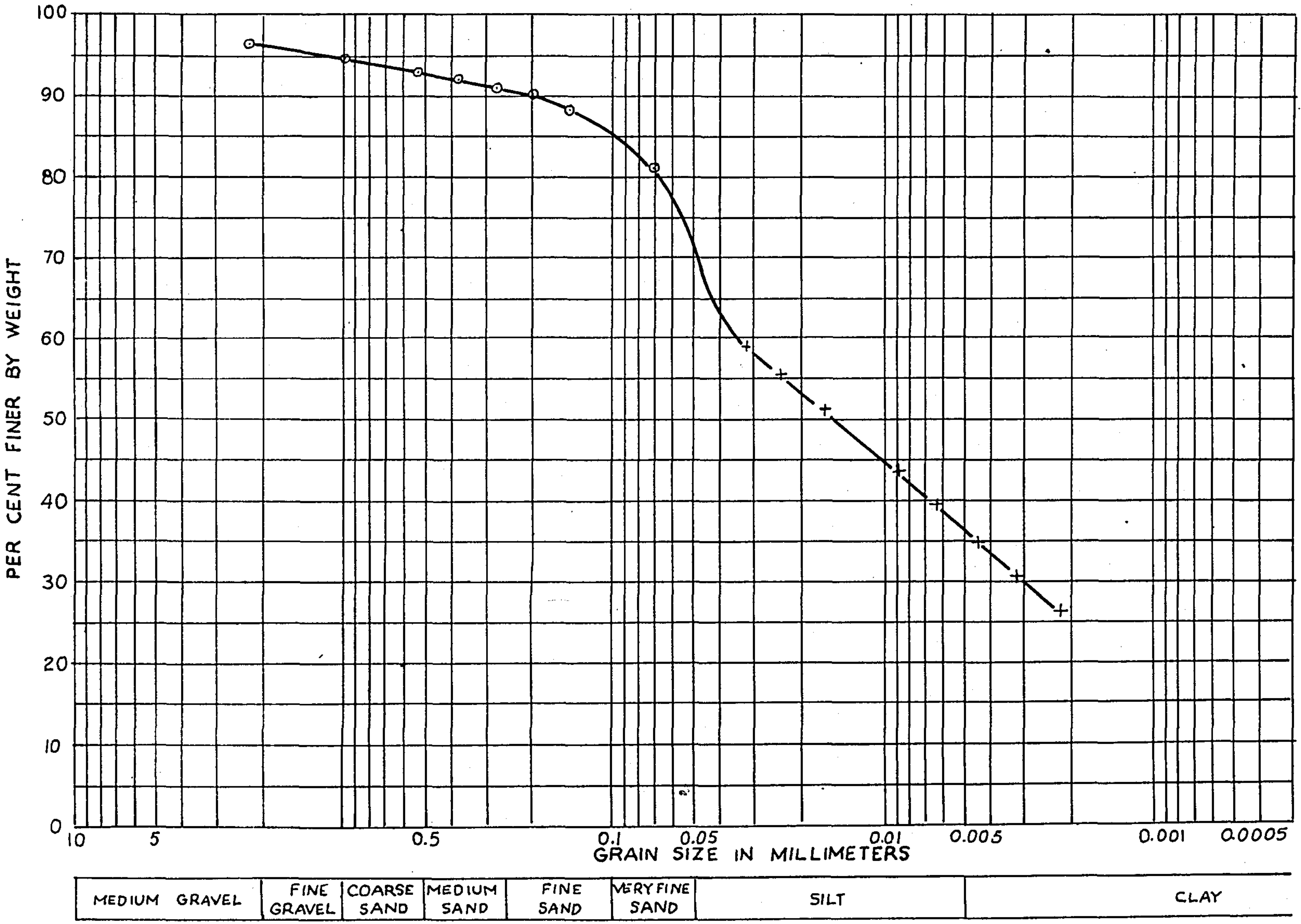
	W %	LL	PL	PI	e	n
Paşabahçe kırmızı	18.5	37.9	19.8	18.1	0.50	0.334
Topser sarı	22.6	34.5	21.6	12.9	0.77	0.435
Kilyos esmer	44.1	84.2	42.6	41.6	1.41	0.585

Results on undisturbed samples

	natural load kg/cm^2	C_c	C_v 10^{-4}cm/sec	m_v cm^2/kg	k cm/sec
Paşabahçe kırmızı	0.21	0.093	4.57	1.57x10^{-2}	7.15x10^{-9}
Topser sarı	0.22	0.080	6.5	1.04x10^{-2}	6.60x10^{-9}
Kilyos esmer	0.23	0.045	6.4	0.82x10^{-2}	5.15x10^{-10}

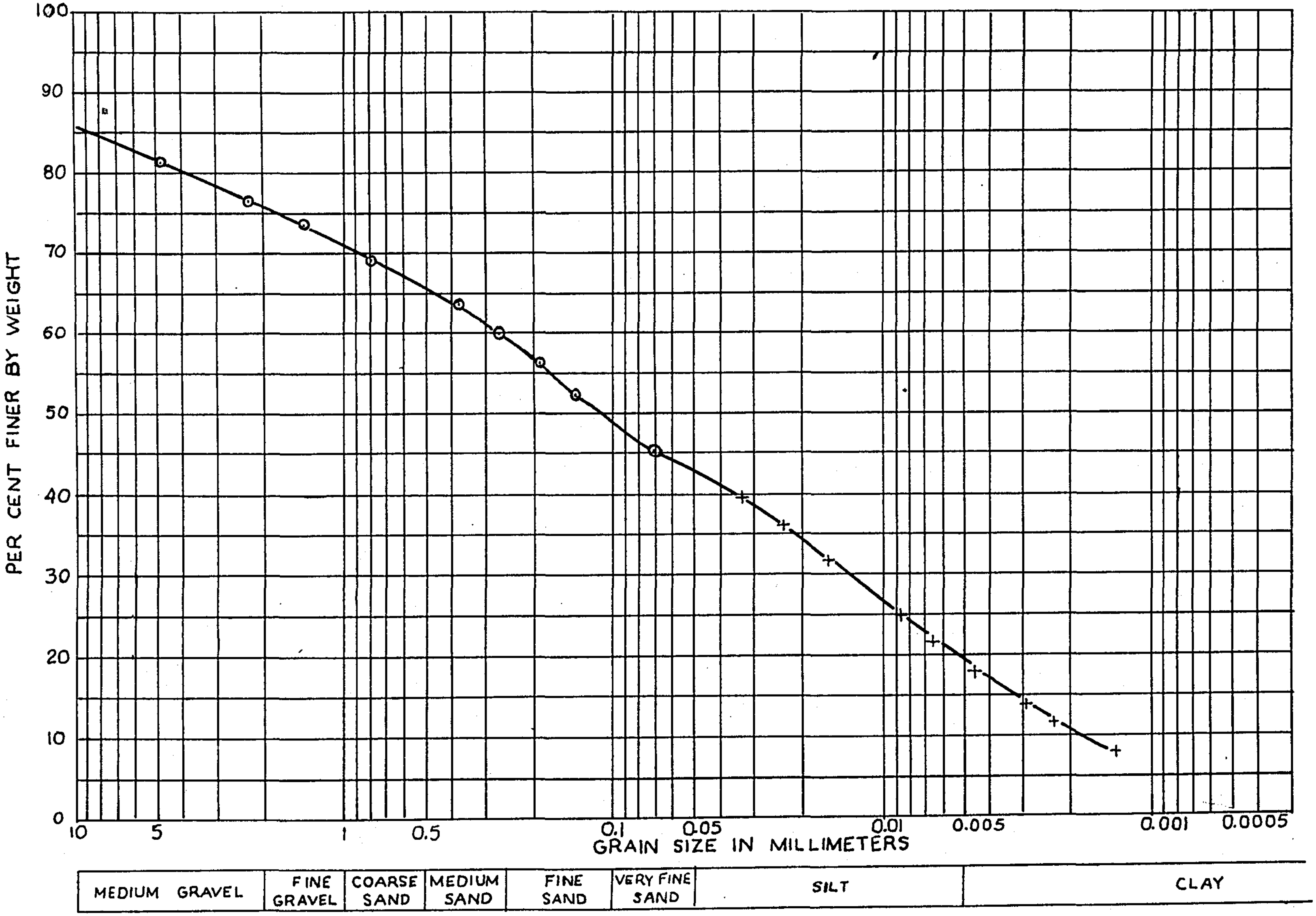
Gradation Curve Obtained by Dr. Ülker from the Original Sample.

PAŞABAHÇE



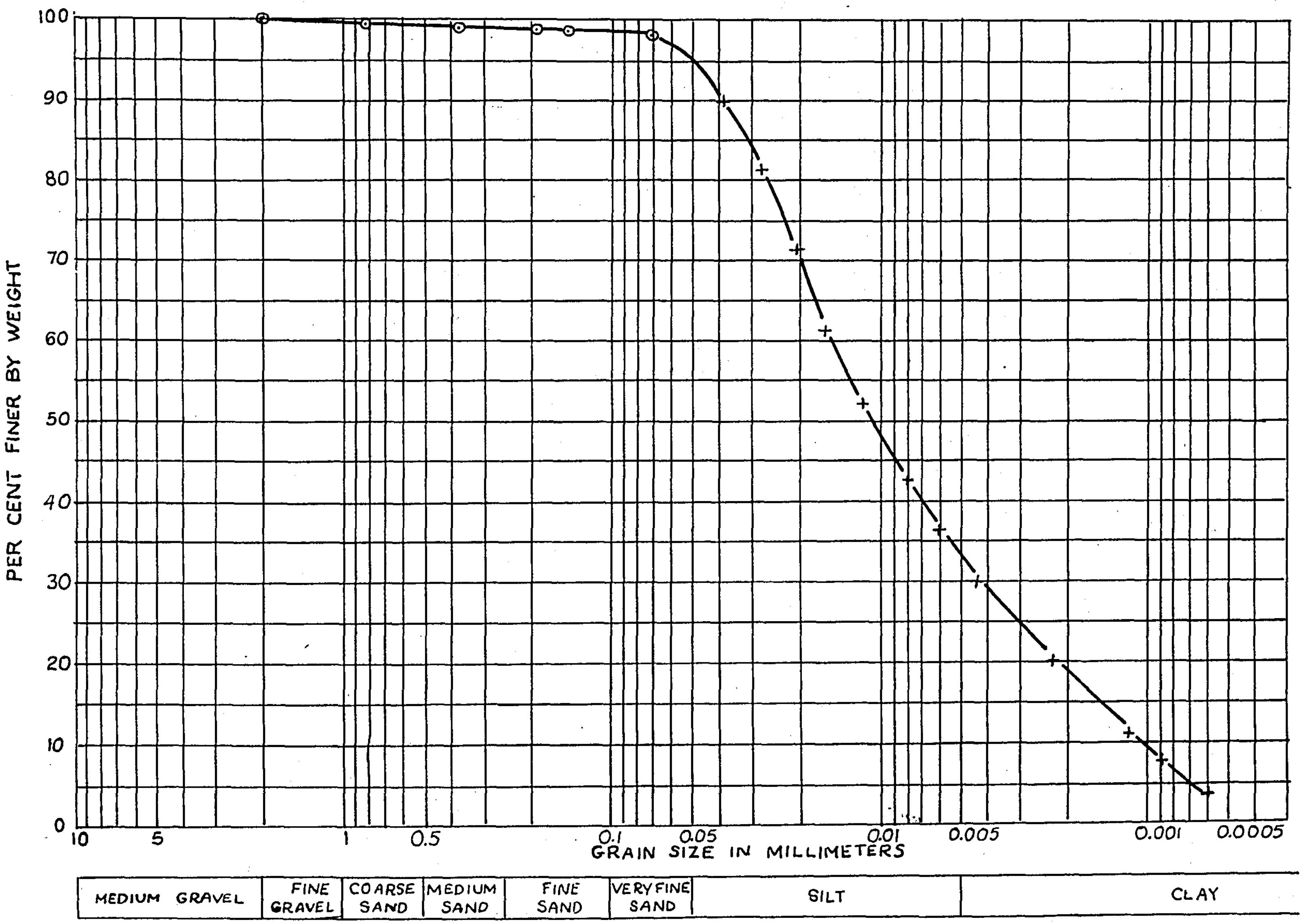
Gradation Curve Obtained by Dr. Ülker from the Original Sample.

TOPSER



Gradation Curve Obtained by Dr. Ülker from the Original Sample.

KİLYOS



The minerology of these soils have been investigated in Istanbul Technical University, at Harmondsworth Road Research Laboratory in England, and in Virginia Highway Research Council Laboratories in U. S. A. The results of this research is given by Mehmet Tümay and Ergün Toğrol in a paper. In this paper the results of five different methods in minerological determination :

a) By Liquid Limit / Plasticity index method,

b) By finding Liquid Limit using different pore fluids,

c) By finding ion exchange capacity,

d) By using electron microscope,

e) By x-ray diffraction method,

are summarized. (10)

Their conclusion is that, in Paşabahçe - kırmızı kaolinite and illite, in Topser - sarı kaolinite, and in Kilyos - esmer mountmorillonite are the predominant clay minerals.

The properties of these soils were also investigated by M. T. Tümay in his Ph.D. thesis. Liquid Limit values for different grain size levels of these soils were found by him using statistical techniques (11) as :

Granulometry / Soil type	- 18	- 36	- 72
Paşabahçe	36.91	37.70	42.72
Topser	37.70	36.31	41.73
Kilyos	88.10	91.09	92.39

Apparatus :

The experiments were performed at three steps. These steps are : preconsolidation, consolidation, and measurement of permeability. The first step was accomplished in the oedometer, and the other two were performed in the GEONOR permeameter.

The oedometer used for preconsolidation consists of a floating ring type of specimen container, a loading yoke, and in connection with that yoke, a system of lever arms to apply the desired load onto the specimen (Picture 1). The arrangement and dimensions of the system of lever arms is shown in Figure 3.

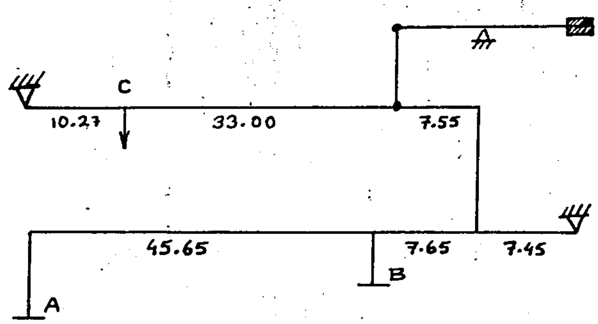
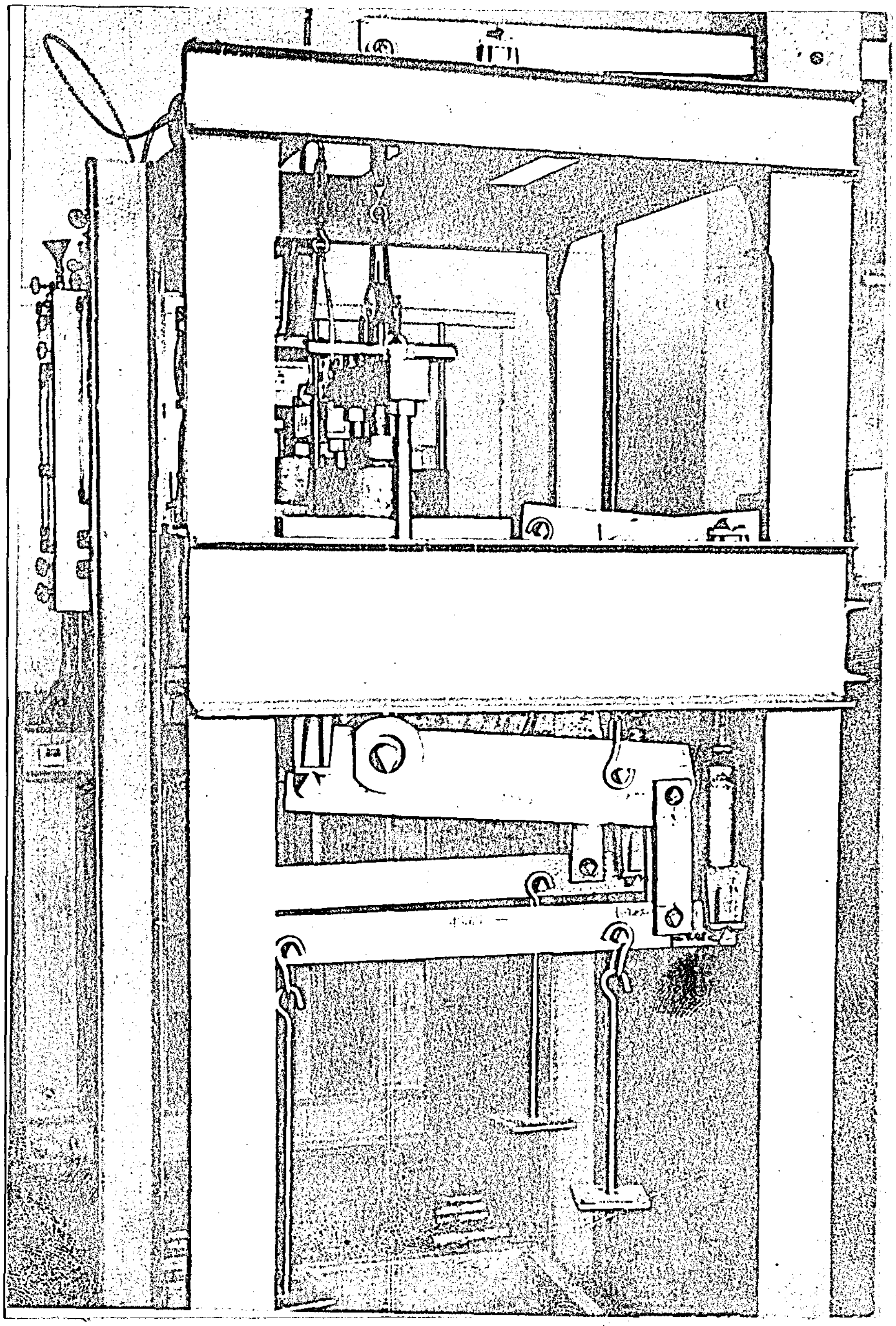


Figure 3

Through this system, a load placed on pan A is transferred to point C where the yoke is placed, as 40.57 times of its weight. And a load placed on pan B is transferred as 10.1 times of its weight onto the loading yoke.

A sample to be tested in the GEONOR permeameter should have a height of approximately 5 cm, and also a diameter of approximately 5 cm. Since it was impossible to obtain a preconsolidated sample with these dimensions by the use of a standard consolidation ring, the author was obliged to prepare a special consolidation mould to satisfy this requirement.

The mould was designed as two hollow cylinders that can be fitted into each other tightly enough not to let the slurry leak through the joint. The upper



Picture (1) - Oedometer

cylinder functions as a collar. The bottom one was the actual mould with the dimensions stated above. Those two cylinders were also cut into two equal parts in the direction of their central axis in order to make it possible to remove the sample from the mould without any disturbance. Two metal rings were also provided to clamp the parts together as a whole body. The mould was made of brass to avoid the corrosive effect of water during the consolidation process (Picture 2).

Picture (2)

The load was applied onto the soil sample by a brass disc which had a thickness of about 0.5 cm. That disc was dimensioned so that it moved in the cylinder easily, but it did not let the grains of the sand which was used as a porous media at the top of the sample, to pass between the edge of the disc and the walls of the mould. A small hole was opened at the center of the disc to let the pore water escape through.

A 5 cm long iron pipe was placed on top of that brass disc. This pipe was prepared very carefully with its top and bottom sections being exactly perpendicular to its central axis. This pipe and the brass disc acted as a piston in the mould. The load was applied at the top of the piston by placing the loading yoke of the oedometer onto the iron pipe, and transferred to the soil sample by the piston.

This consolidation mould is shown in detail in Figure 4.

GEONOR permeameter ("m-45 permeameter for compacted clays" as it is named by its manufacturer, Norvegian Geotechnical Institute) was used for both consolidation and permeability measurement steps (Picture 3 and 4).

This permeameter was actually designed for compacted clays, but it was efficiently used for consolidated clays.

GEONOR permeameter may be used either as a constant head or a falling head permeameter. It is also possible to apply sufficient pore pressure to the sample to dissolve all the entrapped air and provide 100% saturation. Since the triaxial cell pressure and pore pressure systems have different screw controls and different constant pressure cells, this saturation may be achieved by increasing both pressures in a way to keep their difference constant, without changing the effective stresses.

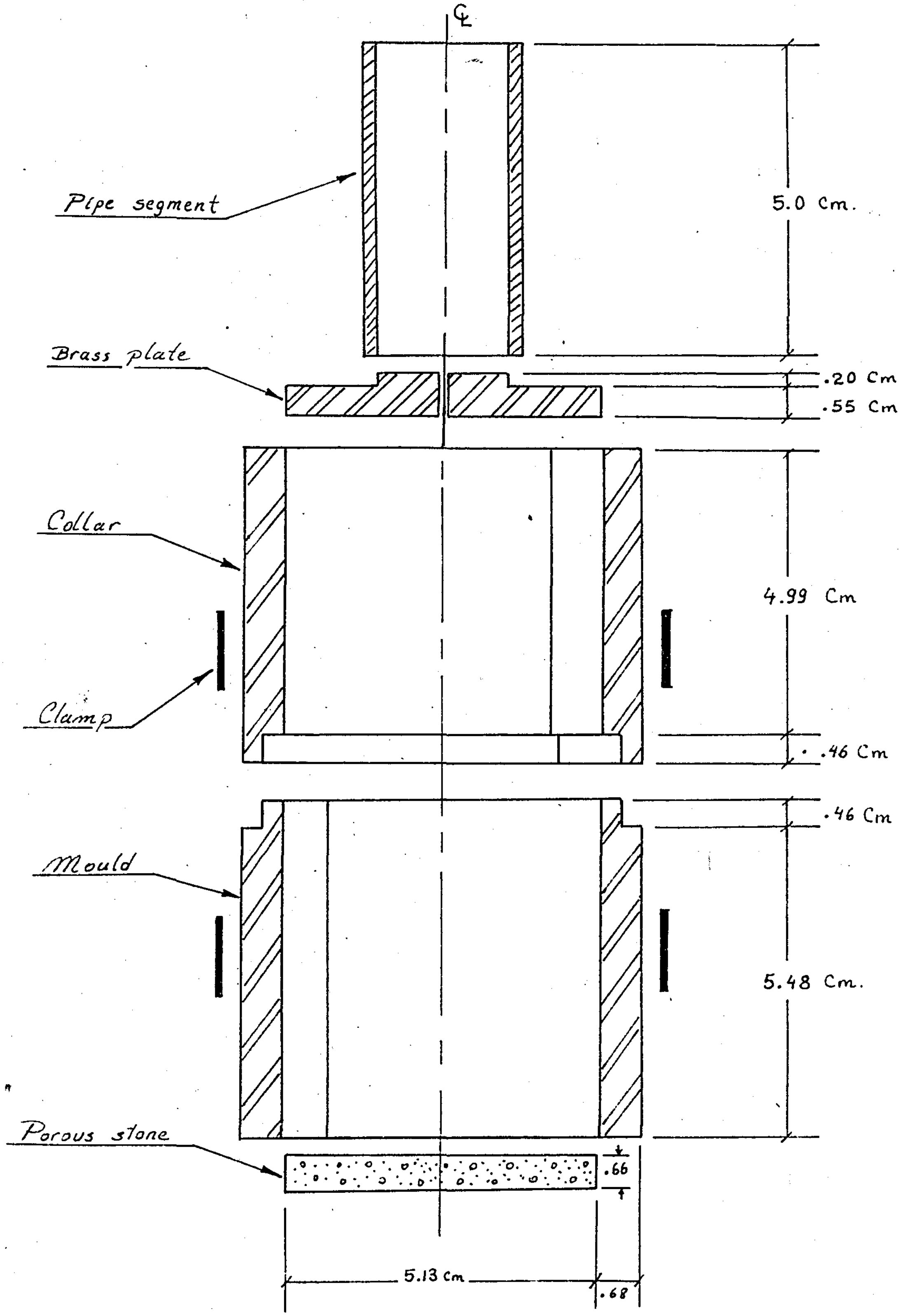
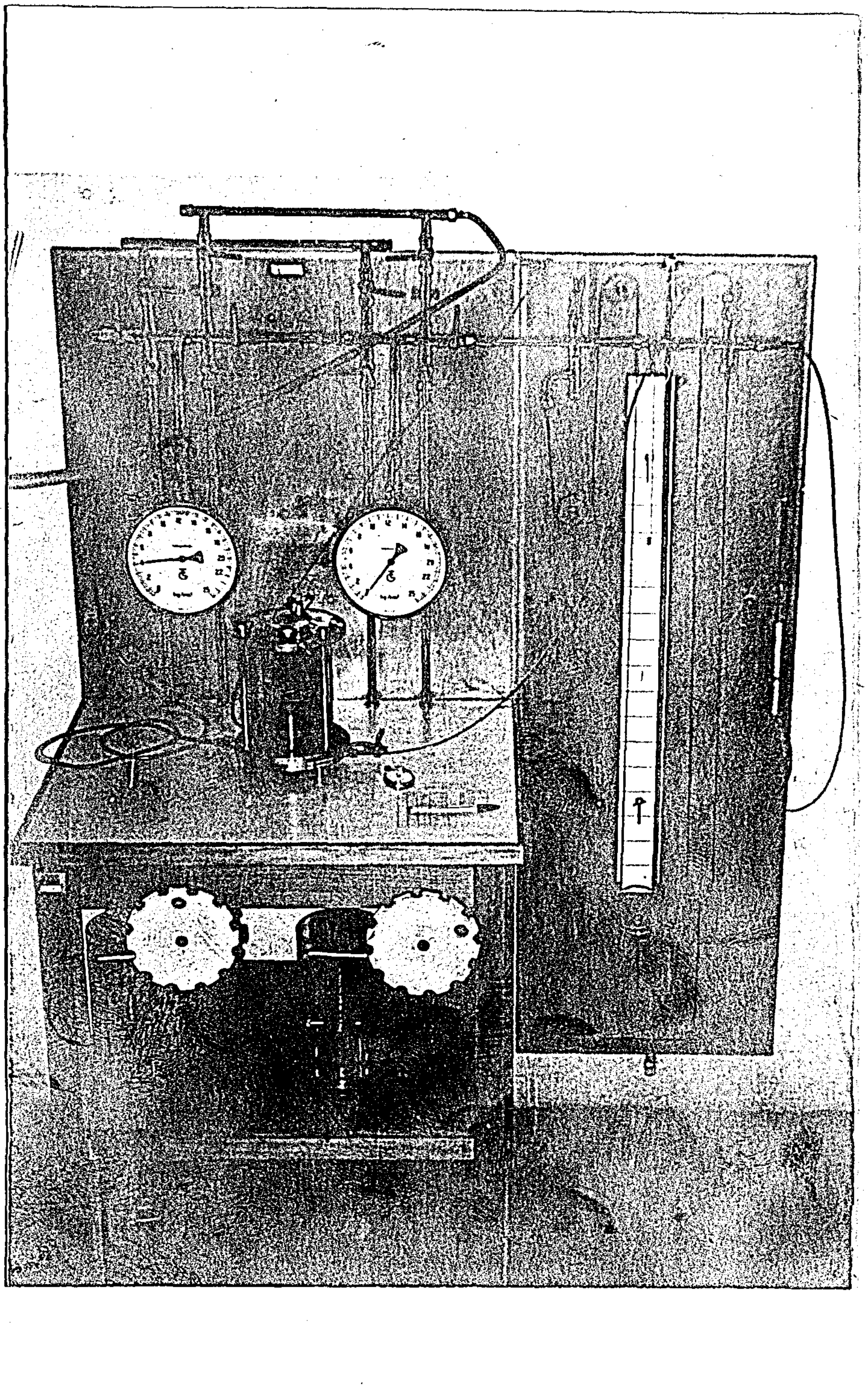
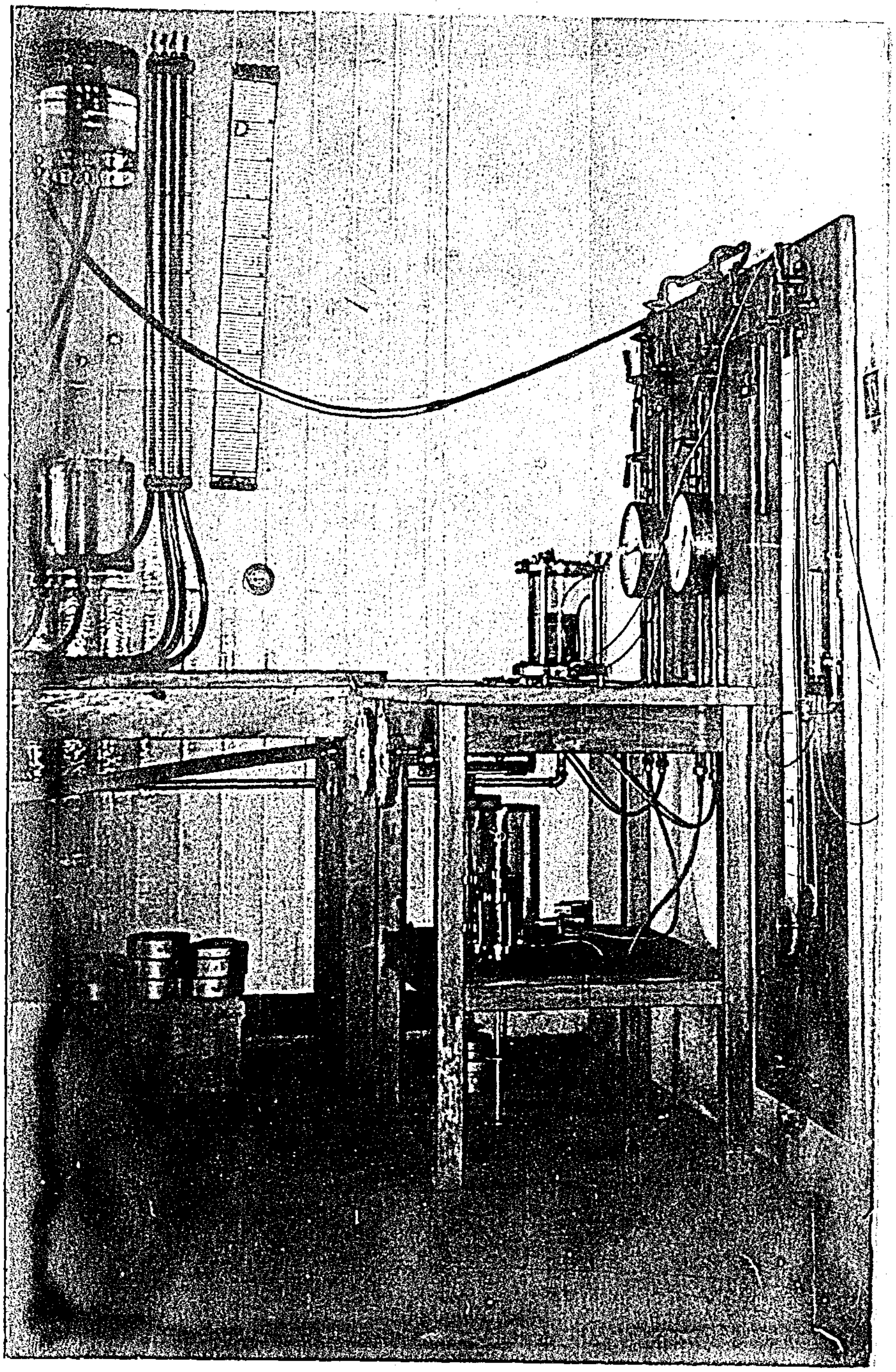


Fig. (4) – Consolidation mould.



Picture (3) - GEONOR permeameter.



Picture (4) - GEONOR permeameter.

This permeameter is divided in three main groups, namely, the cell pressure system, the pore pressure system, and the testing board. A diagram of the apparatus is given in Figure 5.

The cell pressure and pore pressure systems are identical, and are equipped, in addition to the valves and the pipe system, with a constant pressure cell and a screw control. The testing board is connected to a simplified triaxial cell and supplied with some lengths of 1/8" O-D plastic tubing. The plastic tubing on the board itself is approximately 5.25 m long and is partly filled with water and partly with mercury. The mercury length is dependent upon the permeability of the tested materials, and it is normally about 60 cm long. The ends of the plastic tubing are attached to conical pins on the pipe system, while the plastic tube is lead over grooved wheels mounted on board, so that the center of the mercury column forms a U shape. The two free ends of U are lead over movable wheels so that the position of the mercury column may be changed. If the mercury column is pulled over one side and up to the top of the scale, this will create an over pressure in the system, in other words, a hydraulic gradient through the sample. This procedure of moving the mercury column over on one side and keeping it there during the testing, is a test with "constant head". Tests can be also carried with "falling head", when the mercury column forms a U during the test. The velocity and the situation of the mercury is determined, and from these measurements permeability of the sample can be calculated.

During the experiments performed with consolidated clays, since the specimens were highly saturated (see preconsolidation data), a back pore pressure was not applied and only the cell pressure system was used to achieve consolidation.

In order to make the permeameter more efficient for this type of work, some additions were made to the GEONOR permeameter. First, a metal tape was placed

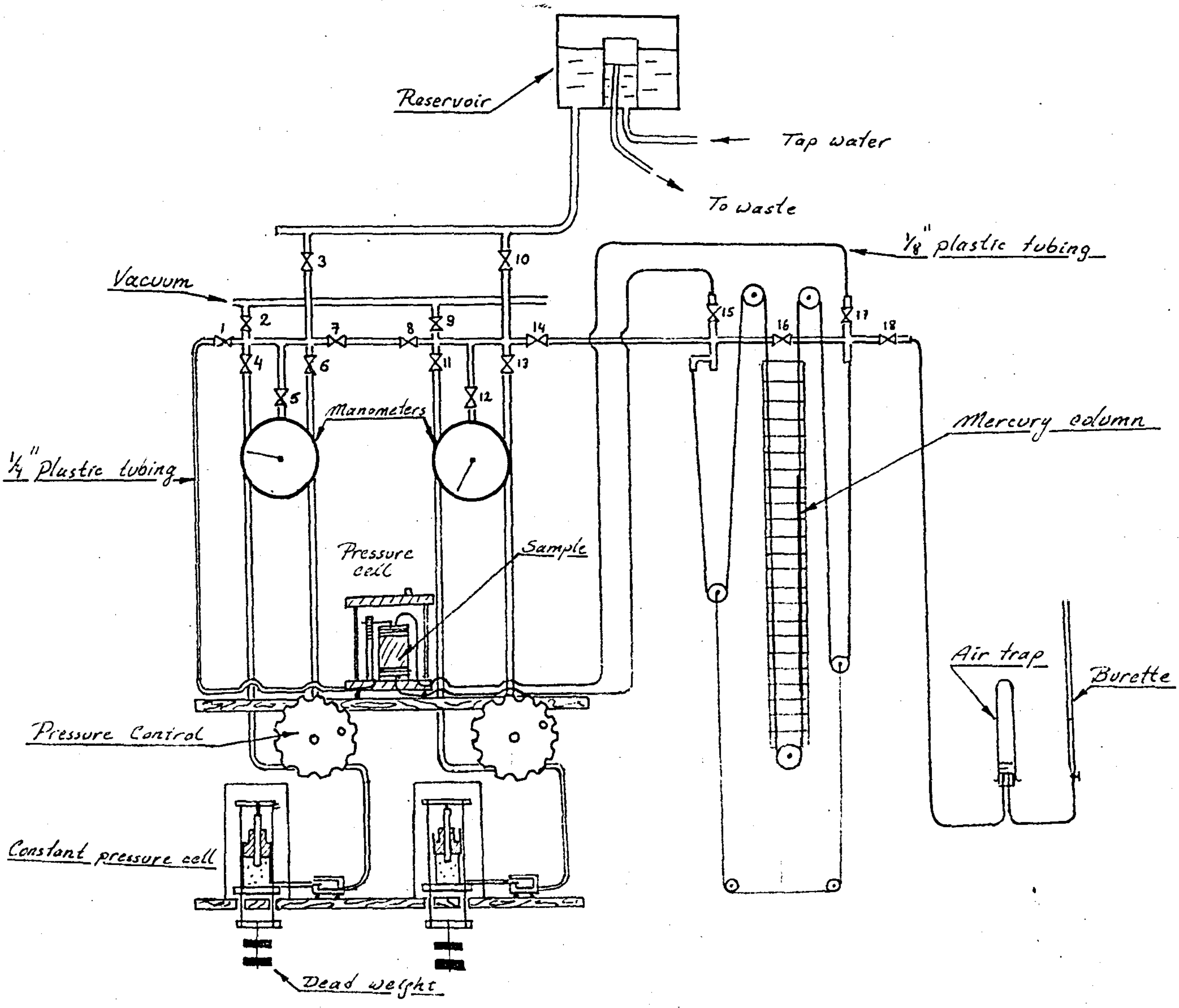


Fig. (5) - GEONOR permeameter.

behind the plastic tubing which contained the mercury column. That tape made it possible to have more accurate measurements.

Then, a modification was made in the constant pressure cell system. Oil in the pistons of this system has used to climb up in the plastic tubing connecting the cells to the main system and get into the copper pipes and even into the testing cell. To prevent this situation a box was prepared out of pyrexyglass as shown in Figure 7, and fastened between the piston and the main system. The volume of that "oil trap" was so arranged that, water-oil interference level was always within the box, and no oil entered into the main system and no water entered into the constant pressure cell. Since the pistons of the constant pressure cells were made of a corrosive material, preventing the water from getting into the cells was also desirable.

Finally, a scale rod was mounted into the testing cell. This made it possible to measure the vertical settlement of the specimen during the test with some approximation, by recording the movement of a needle indicator fastened on top of the sample (Picture 7). Details about the scale rod are presented in "Notes on the Procedure".

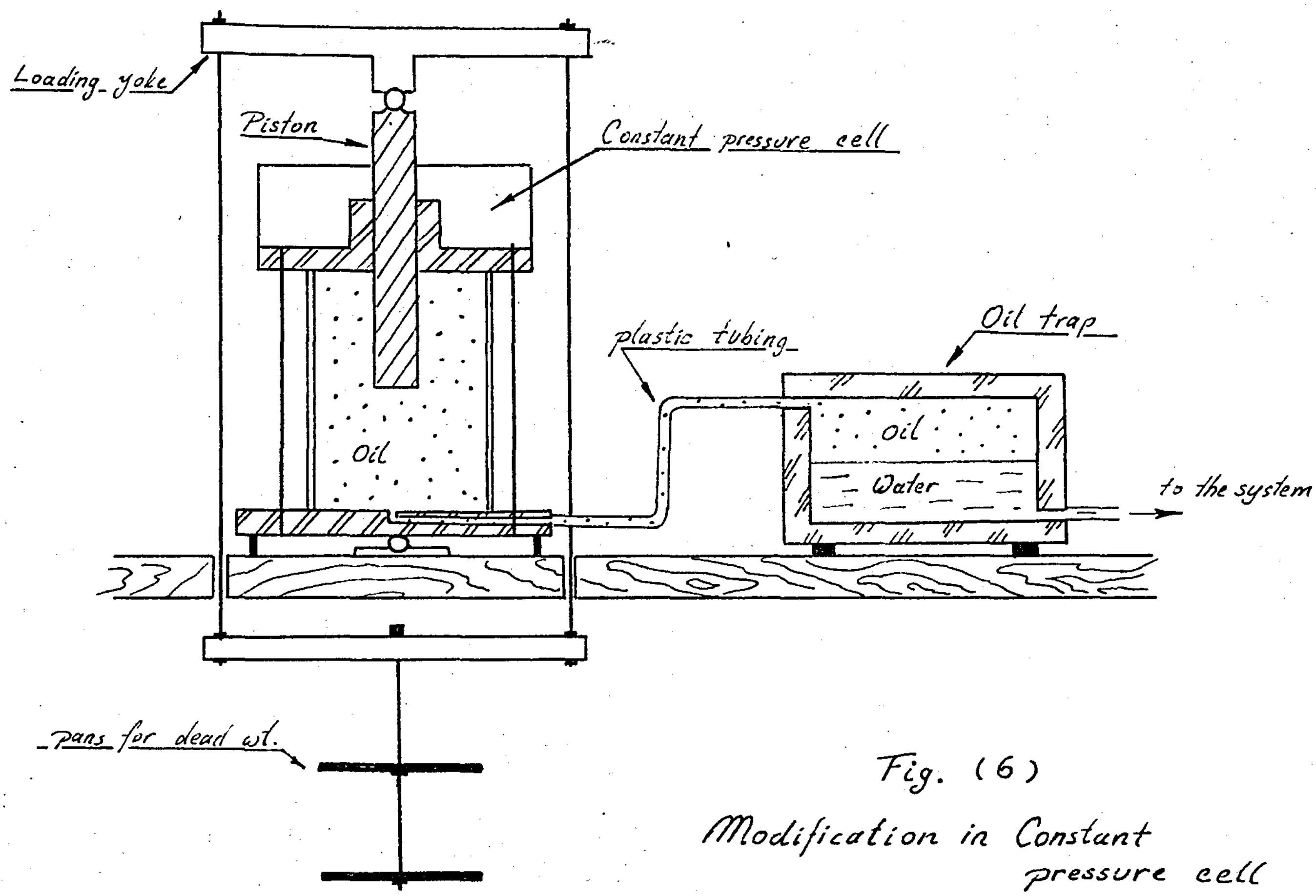


Fig. (6)
Modification in Constant pressure cell

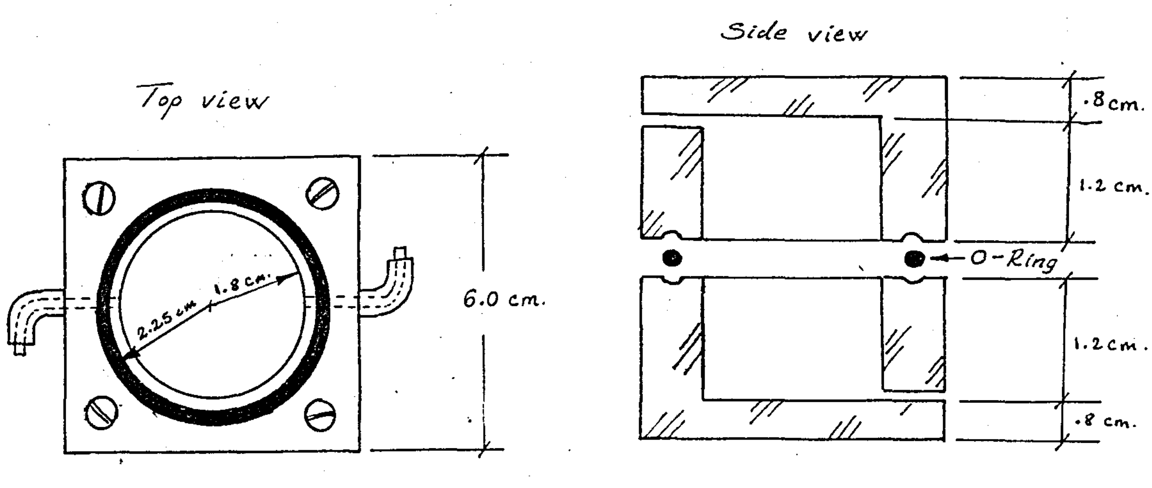
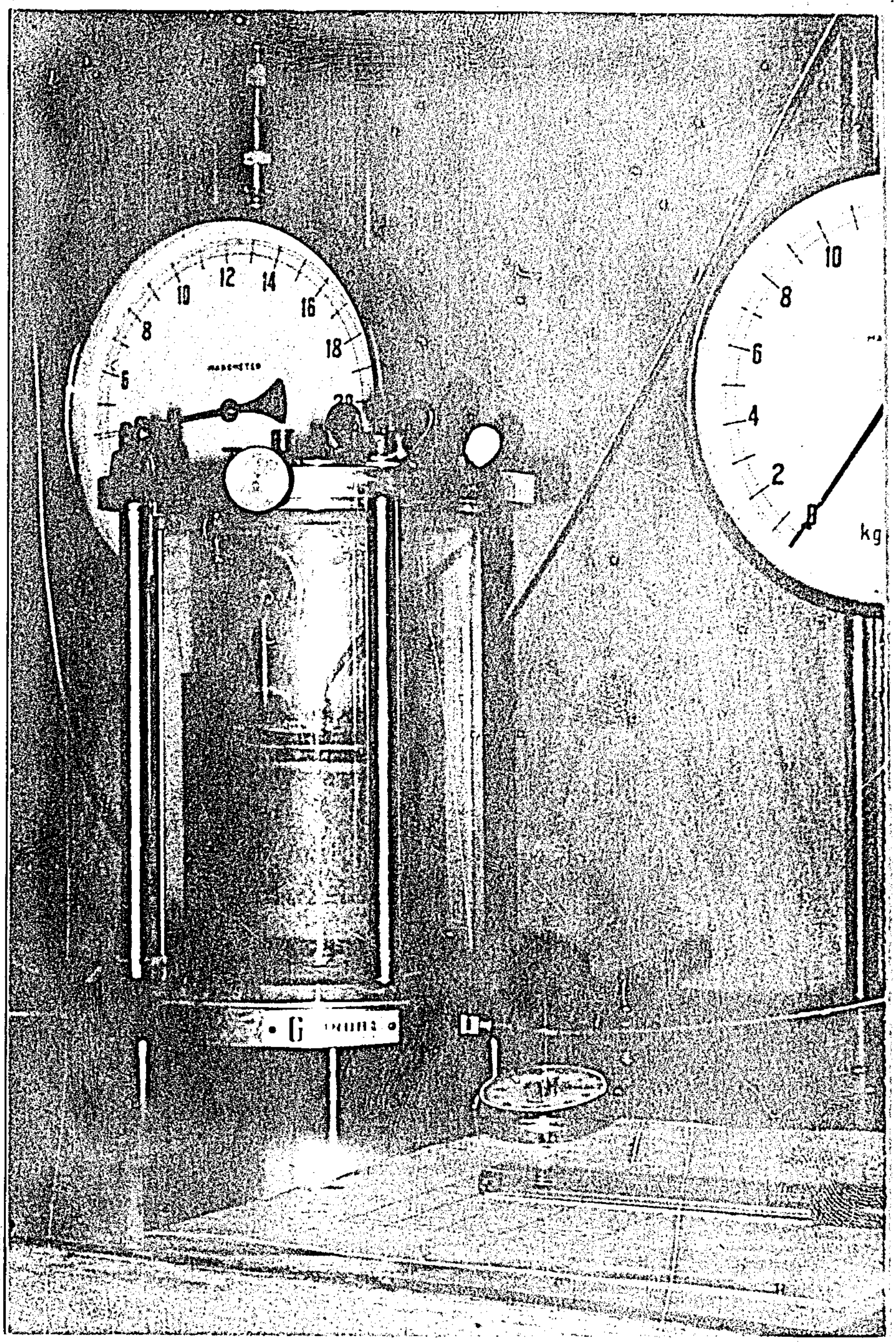


Fig. (7) _ Oil trap



Picture (7) - Testing cell

CHAPTER III

METHOD

Method :

The experiments were performed mainly to determine the effects of four independent variables on the permeability of consolidated clays.

These variables were chosen as:

1. Soil type
2. Granulometry
3. Preconsolidation load
4. The rate of application of consolidation pressure ($\Delta p/p$).

Three variations of each factor were used, and nine samples were prepared by arranging the variables in a Greco-Latin matrix combination.

The levels of each variable were :

1. Soil type :
   a. Paşabahçe - kırmızı : a low plasticity clay with kaolinite and illite clay minerals.
   b. Topser - sarı : a low plasticity clay with kaolinite clay mineral.
   c. Kilyos - esmer : a high plasticity clay with mount morillonite clay mineral.
2. Granulometry :
   a. - 40 ; the portion passing through No.40 sieve and retaining on No.100 sieve.
   b. - 100 ; the portion passing through No.100 sieve and retaining on No.200 sieve.

c. – 200 ; the portion passing through No.200 sieve.

These levels were separated by dry sieving from soil samples passing No.4 sieve. Since it was desired to find the effect of "granulometry obtained by dry sieving", a wet analysis was not performed.

3. Preconsolidation load :

a. 1.0 kg/cm^2

b. 2.0 kg/cm^2

c. 4.0 kg/cm^2.

4. $\Delta p/p$ ratio :

a. 0.5

b. 1.0

c. 2.0.

Each of the nine samples were given a sample number. Those numbers and the corresponding variable combinations are :

Sample No.	Soil type	Granulometry	P_c	$\Delta p/p$
1	Paşabahçe	–40	1.0	0.5
2	Paşabahçe	–100	2.0	1.0
3	Paşabahçe	–200	4.0	2.0
4	Topser	–40	2.0	2.0
5	Topser	–100	4.0	0.5
6	Topser	–200	1.0	1.0
7	Kilyos	–40	4.0	1.0
8	Kilyos	–100	1.0	2.0
9	Kilyos	–200	2.0	0.5

Preconsolidation :

Each one of thus arranged nine samples was first consolidated in the oedometer. But the above stated preconsolidation pressures were not applied directly. The loading was increased gradually as the consolidation of the specimen achieved under each pressure increment. After these steps were completed, the specified preconsolidation load was applied and the strain dial was attached. From the strain dial readings taken at specified time intervals, H vs log t curves were plotted (see appendix).

The preliminary loading steps before the application of the preconsolidation load were :

when $P_c = 1.0$ kg/cm^2; 0.1 kg/cm^2, 0.2 kg/cm^2, 0.4 kg/cm^2.

when $P_c = 2.0$ kg/cm^2; 0.1 kg/cm^2, 0.2 kg/cm^2, 0.4 kg/cm^2, 0.8 kg/cm^2.

when $P_c = 4.0$ kg/cm^2; 0.1 kg/cm^2, 0.2 kg/cm^2, 0.5 kg/cm^2, 1.2 kg/cm^2.

Consolidation :

Thus preconsolidated samples were consolidated in the testing cell of the GEONOR permeameter under the loading conditions specified by the model.

The loading steps were :

a. When $\Delta p/p = 0.5$, $P_1 = 0.5$ kg/cm^2, $P_2 = 0.75$ kg/cm^2,
$P_3 = 1.125$ kg/cm^2, $P_4 = 1.68$ kg/cm^2,
$P_5 = 2.52$ kg/cm^2, $P_6 = 3.78$ kg/cm^2,
$P_7 = 5.67$ kg/cm^2, $P_8 = 8.5$ kg/cm^2.

b. When $\Delta p/p = 1.0$, $P_1 = 0.5$ kg/cm^2, $P_2 = 1.0$ kg/cm^2,
$P_3 = 2.0$ kg/cm^2, $P_4 = 4.0$ kg/cm^2,
and finally $P_5 = 8.0$ kg/cm^2.

c. When $\Delta p/p = 2.0$, $P_1 = 0.9\ kg/cm^2$, $P_2 = 2.7\ kg/cm^2$, $P_3 = 8.1\ kg/cm^2$.

In each loading step, the change in the volume of the sample with respect to the elapsed time was recorded as the water level in the burette connected to the sample. With the points thus obtained, V vs log t diagrams were plotted (see appendix).

Permeability :

At the end of each loading step permeability value was measured from the GEONOR permeameter. In order to obtain the permeability value, recorded values of H, t, h, and L were substituted into the formula :

$$k = \frac{a\ h\ L}{A\ t\ H} \cdot \frac{\gamma_w}{\gamma_{Hg} - \gamma_w} \qquad (12)$$

in which, k = permeability,

a = area of the plastic tubing which contains the mercury column,

h = change in the elevation of the mercury column,

L = length of the soil sample,

A = cross-sectional area of the soil sample,

t = time interval,

H = height of the mercury column,

γ_w = unit weight of water,

γ_{Hg} = unit weight of mercury.

It could have been possible to calculate the permeability of each sample from its consolidation data and compare the results with the actually measured values. But this was not attempted because of experimental difficulties in achieving one directional water drainage. It was observed that although the surface of the soil sample was covered with vaseline, pore water had the tendency to escape from the side surfaces and drain between the sample walls and the rubber membrane covered around the sample.

Analysis :

The effects of the four independent factors on the permeability at different steps of consolidation were analized with a Greco-Latin matrix variance analysis computer program and the order of importance of these effects were determined. This computer program is given in the appendix. Pertinent information about the Greco-Latin matrix is given in Chapter 5.

CHAPTER IV

PROCEDURE

About 300 g. of dry soil was placed into a dish. With the addition of enough water, and by thoroughly mixing, a slurry with a water content of about 100% was prepared. For all three soils this represented a moisture content much in excess of liquid limit.

On the other hand, the consolidation mould was prepared for the experiment by covering its inner surface with vaseline, clamping it into a fixed position, and placing a porous stone at the bottom. The mould was covered with vaseline in order to prevent it from adhering to the soil and breaking it in the removal stage, and also to attempt prevent radial drainage in consolidation. It was also found to be efficient to wrap the portion where the mould and the collar parts were connected, with a skotch tape, to prevent any possible leakage.

Then, a filter paper was placed at the top of the porous stone and the slurry was poured into the mould. In this process special care was given not to leave any entrapped air bubbles in the slurry. When the soil reached a significant height inside the collar part, a second filter paper was placed on top of it and sand was poured onto that filter paper. Finally, the piston was placed at the top.

After the soil was placed into the mould in the above mentioned manner, it was placed in its position on the oedometer and the base was filled with water. By the use of the lever arms system, a considerably small load was applied on the soil first. When the rate of consolidation under this load slowed down, the load was increased and that process continued untill the soil has reached to a state firm enough not to ooze out under the actual preconsolidation load. Then, the strain dial was attached and preconsolidation load was applied.(Figure 8, Picture 5)

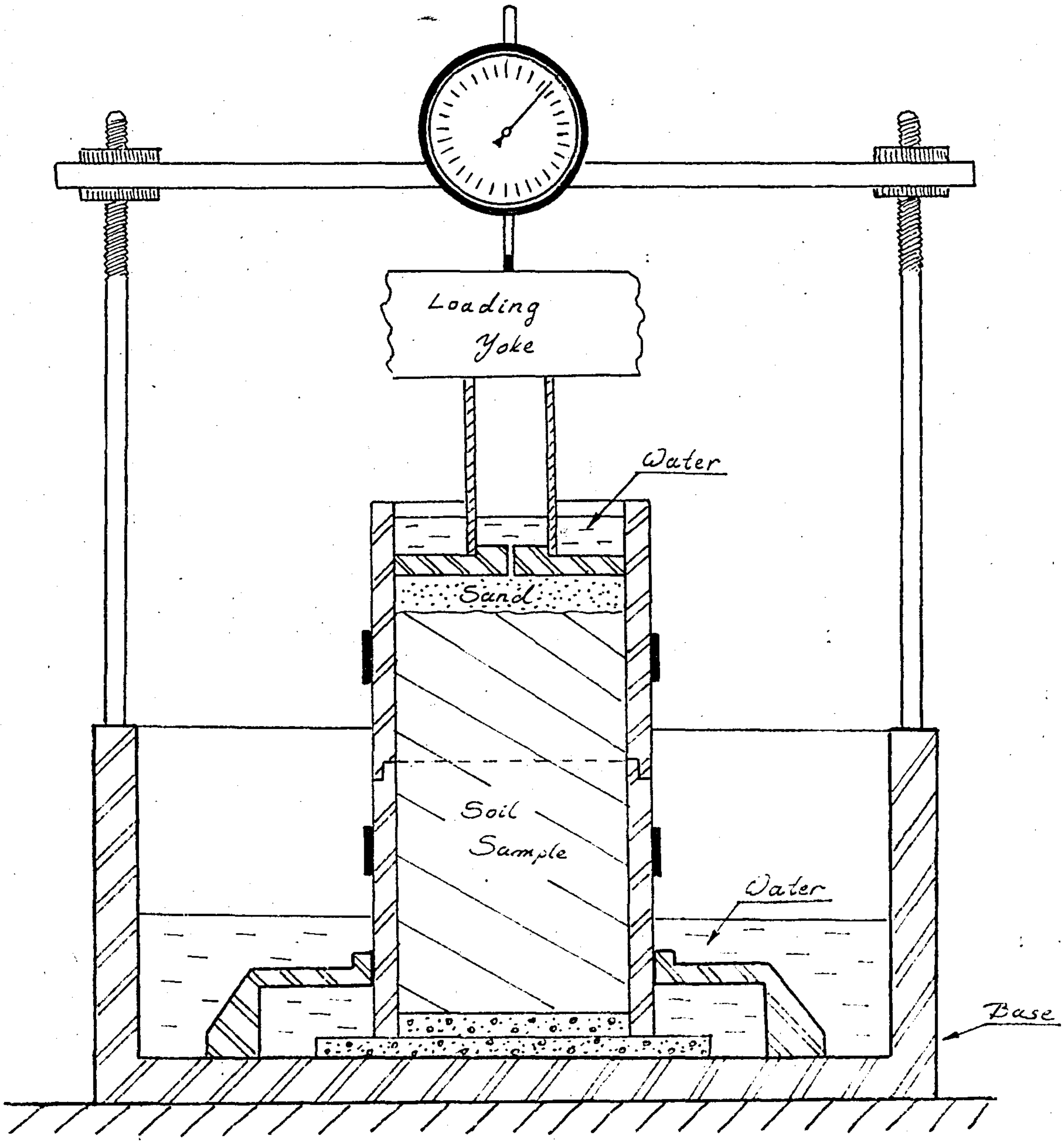
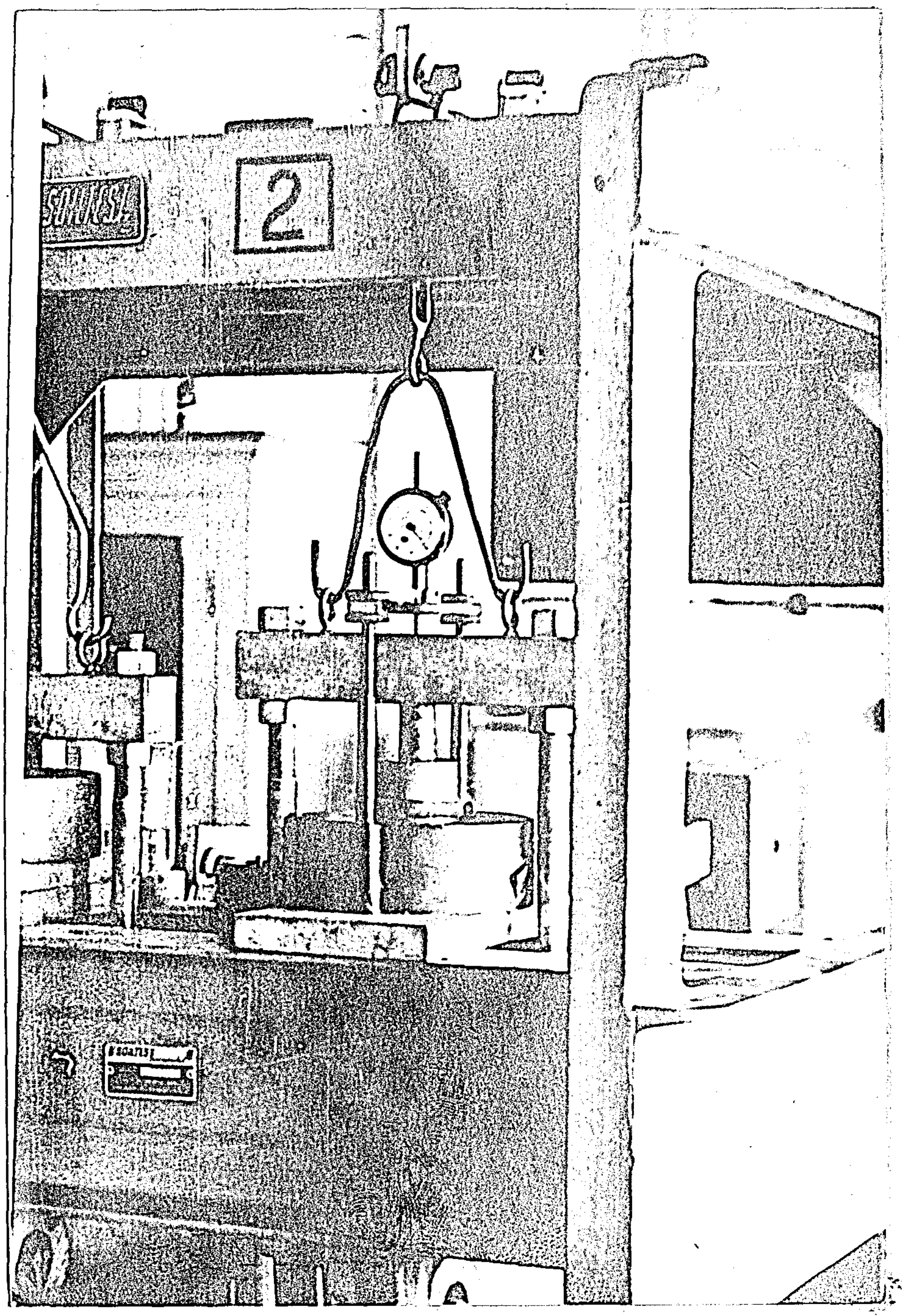


Fig. (8) - Preconsolidation set-up



Picture (5) - Preconsolidation set-up.

At that stage, strain dial readings were taken at total elapsed times of 0, 15", 30", 1', 2', 4', 8', 15', 30', 1 hr, 2 hr, ... until no considerable deflection was observed on the extensometer. Then the load was lifted, strain dial was disconnected and the mould was taken away from the consolidation machine.

To remove the sample from the mould, first the tape was torn off, then the metal ring around the collar portion was removed. The collar was taken off by sliding the two parts of the cylinder off carefully as shown in Figure 9 (Picture 6)

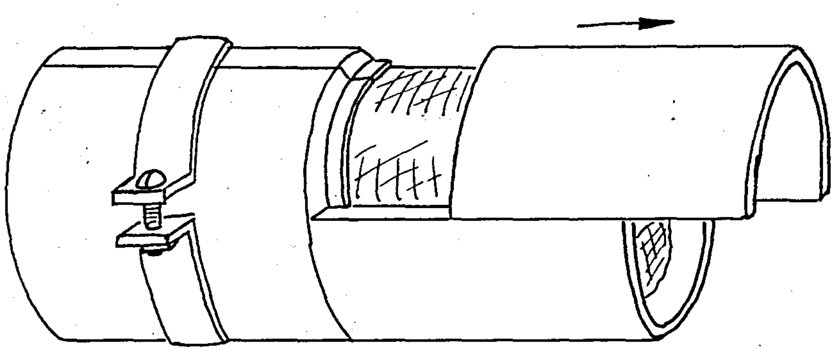
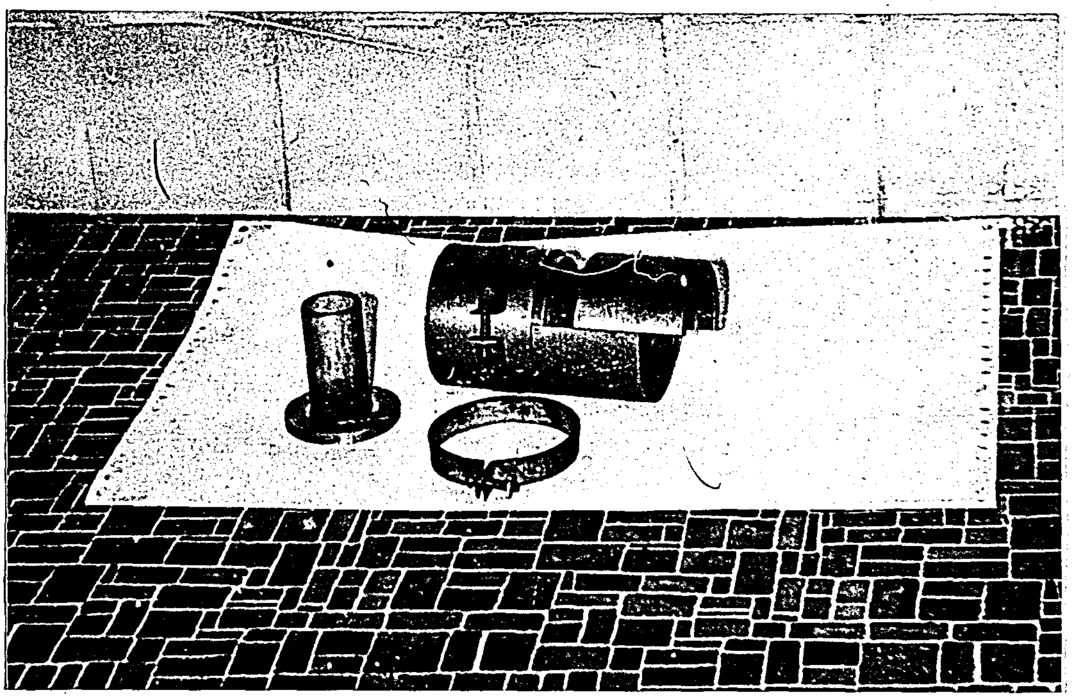


Figure 9

After the collar was removed, the top of the soil in the mould was trimmed smoothly and some part of the extra portion was taken for a moisture content determination (see preconsolidation data, m_f values).

The bottom clamp was then removed and the two parts of the cylinder was taken off in the above mentioned manner. The height of the sample was measured by a compass and it was transferred to the GEONOR permeameter.

Before the sample was placed into the GEONOR permeameter, this apparatus should have been prepared for the experiment. This was done by flushing the pipes with water, filling the plastic U tube with mercury, checking the constant pressure cells, and filling the pistons with water. The detailed procedure of these operations is given by Süha Uluçay in his Master of Science thesis. (12)



Picture (6)

The process of placing the sample into the permeameter should start with valves 3, 6, 5, 10, 14, 13, 16 open and valves 6, 11, 12, 2, 9, 1, 4, 7, 18 closed. The pedestal of the testing cell was covered with a cylindrical rubber tube in such a way that when the porous stone was placed on the pedestal, the rubber collar was to cover its sides and prevent it from cutting the rubber membrane which was going to be placed around the sample and the pedestal. The cylindrical portion which acted as a cap on top of the sample was also covered with a similar rubber tube in the same way (Figure 10).

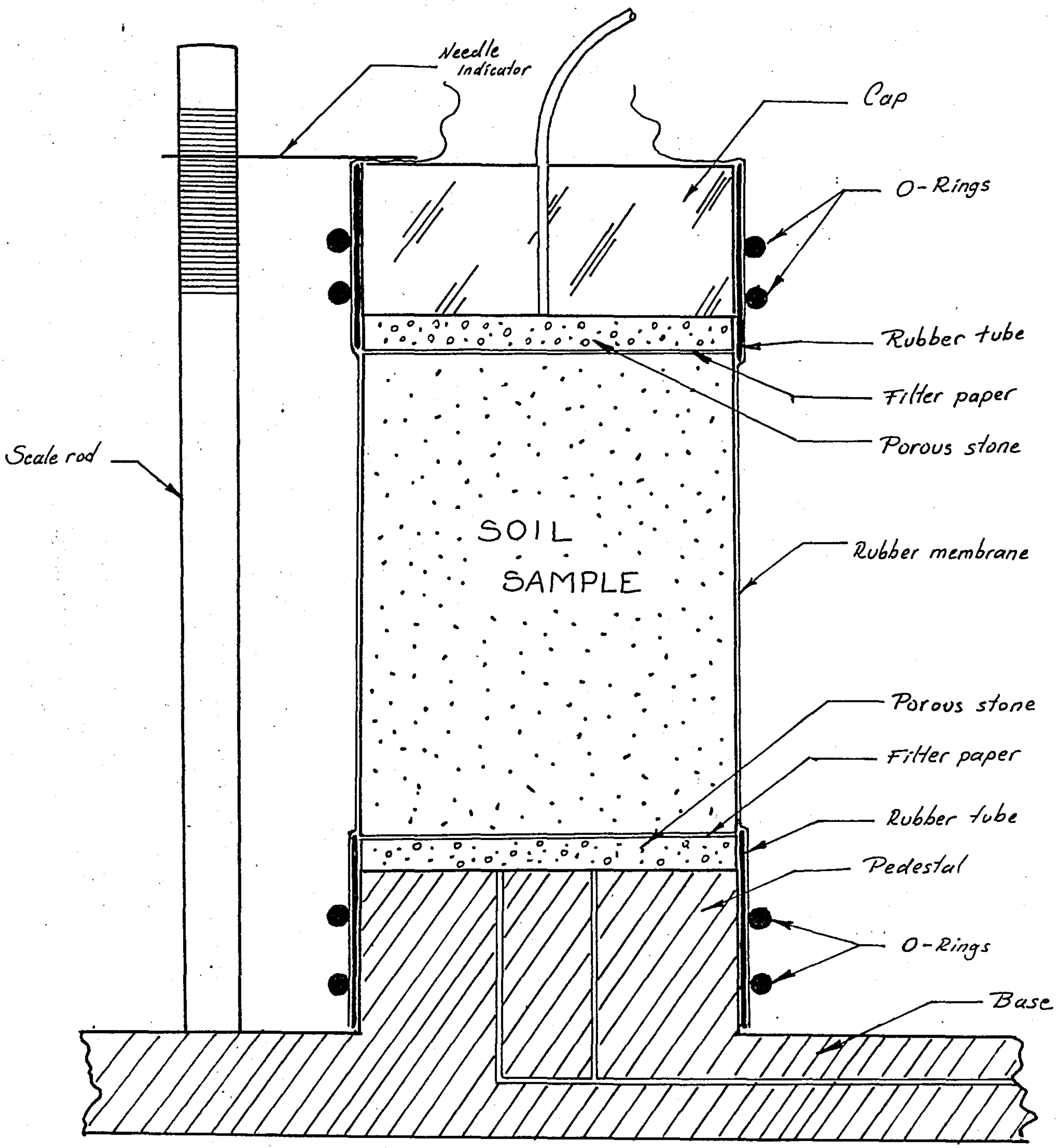


Fig (10) - Sample in GEONOR testing cell.

The pedestal wasconnected to the system simply by connecting the thin plastic tube coming from valve 17 to the base of the testing cell. The cap was first connected to the base with a short thin plastic tube which was to stay in the testing cell during the experiment. The plastic tube coming from valve 15 was connected to its special place in the base, and the connection of the cap to the system was accomplished through those two tubes.

After the porous stones were attached to the cap and the pedestal by means of the above mentioned rubber tubes, valve 17 was opened and the porous stone on the pedestal was saturated.

Then, a filter paper was put on the bottom porous stone and the sample was placed on it. Another filter paper was put on top of the sample.

A special hollow cylinder was used to mount a rubber membrane around the sample. That cylinder had a small hole on its wall to which a rubber tube was attached. When a membrane was placed into the cylinder with two free ends strached over the two ends of the cylinder, and the air between the membrane and the cylinder walls was sucked through the above mentioned rubber tube, the membrane was strached all over the inner surface of the cylinder. Then the cylinder with the rubber membrane was lowered around the soil sample. The cap piece was placed on top of the sample and the rubber membrane was released to cover the sample, the pedestal and the top. The cap was connected to the base with the short plastic tube and valve 15 was opened. The water filled the tube and saturated the porous stone attached to the cap. During this operation, the rubber membrane was separated from the cap by pulling its sides and the air was let out from between the cap and the membrane. Then, valve 15 was closed and the rubber membrane was released. The short plastic tube was disconnected from the base, staying filled with water.

The cylinder used in placing the rubber membrane was taken out and four O-rings were fastened around the rubber membrane. Two of the O-rings were fastened around the pedestal at the bottom of the sample and two of them around the cap. The O-rings were placed with the help of a split-cylinder and were efficient in preventing any leakage from the ends of the membrane. Then the short plastic tube was connected to the base. By this method no entrapped air was left in the top porous stone and in the plastic tube (Figure 10).

Finally, the scale rod was screwed into the base, a needle indicator was placed at the top of the cap and fastened with a rubber band. Then the testing cell was closed (Picture 7). The air vent at the top was opened, and by opening valve 1, water was let to fill the testing cell. When the cell was completely filled with water, it was tilted sideways to let all the air bubbles out. When no more air bubbles were observed in the cell, air vent was closed together with valve 1.

To start the consolidation process, the contact of the system with the reservoir was cut by closing valves 3, 10 and 14. Valves 15 and 17 were opened and valves 16 and 18 were checked to be open. Valve 4 was opened and the necessary amount of dead weights were placed onto the pan of the left constant pressure cell to apply the necessary pressure onto the sample when valve 1 was opened. The position of the piston was adjusted by screwing in the left pressure control screw. The temperature of the system was recorded, and the water level in the burette was recorded as the initial value. The level of the needle indicator on the scale rod was also recorded.

Consolidation pressure was applied on the sample by opening valve 1. At the same time a stop watch was started and readings were taken from the burette at total elapsed times of 15", 30", 1', 2', 4', 8', 15', 30', 1 hr, 2 hr, ... until no change of the water level was observed. Then the level of the needle on the scale rod was recorded and the permeability was measured.

To measure the permeability of the sample, valve 18 was opened together with valve 16 and the mercury column was pulled to one side of the U tube and was let to fall down for several hours. Then, its rate of fall was measured by means of a stop watch and when a consistant rate of fall was observed it was accepted as the final value.

Then valves 16 and 18 were opened, valve 1 was closed and necessary amount of dead weights were added to the pan of the constant pressure cell. Water level in the burette was recorded and by opening valve 1, the next step of consolidation was started.

After all the steps of consolidation with that specific sample were completed and all the permeability measurements were taken, the dead weights were removed and the testing cell was opened. The sample was taken out for moisture content determination (see consolidation and permeability data, m_e values) and the permeameter was prepared for the testing of the next sample.

Notes on the Procedure :

In the preconsolidation process, sand was used as the porous media on top of the soil instead of a porous stone. When sand is used the piston settles more easily and without tilting in the mould.

When a sample is consolidated in the testing cell of the GEONOR permeameter, the volume changes are directly measured. This is done by simply measuring the changes of the water level in a burette which is directly connected to the sample. For that measurement to be accurate, water temperature should be kept constant throughout the experiment, because any change in temperature causes the volume of water to increase, or to decrease, therefore effects the reliability of the measurement. To overcome that difficulty, the permeameter was heated by an infrared heater lamp, and arranging the distance of the lamp to the permeameter as the room temperature changed a constant temperature of 26°C is maintained during all experiments.

As it was stated above, permeability was obtained by substituting the measured values into the equation :

$$k = \frac{a\ L\ h}{H\ t\ A}\ \frac{\gamma_\omega}{\gamma_{Hg} - \gamma_\omega}$$

But it was impossible to take the sample out and measure its height (L) and its cross-sectional area (A), for the intermediate steps of consolidation. Therefore, a scale rod was placed into the testing cell and the decrease in the height of the sample was approximately measured on that rod. In order to obtain the cross-sectional area, the volume of the sample (obtained by subtracting the change in volume, as measured from the burette, from the initial volume) was divided by the sample height. In doing that it was assumed that the sample was in a perfect cylindrical shape although its actual shape was as shown in Figure 11, due to the confinements at the two ends. (The measurements taken by a compass at the end of the last consolidation steps showed that the error introduced by the above mentioned assumption was not more than 1-2 % in the diameter.)

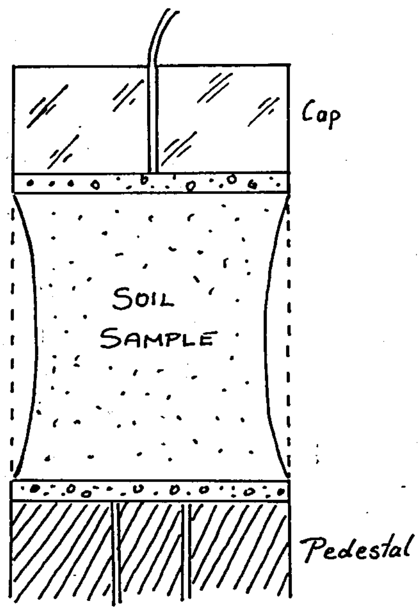


Figure 11

CHAPTER V

DATA and ANALYSIS

Preconsolidation Data

m_o = Initial water content,

m_f = Final water content,

e_f = Final void ratio,

S = Saturation.

Consolidation and Permeability Data

H = Height of mercury column,

h = Distance of fall,

t = Time interval,

L_i = Initial length of sample,

L_f = Final length of sample,

A_i = Initial area of the sample,

A_f = Final area of the sample,

e_i = Initial void ratio,

e_f = Final void ratio,

k = Coefficient of permeability,

m_o = Initial moisture content = m_f of preconsolidation data (see first data sheet of each sample),

e_o = Initial void ratio of sample before consolidation (see first data sheet of each sample),

m_e = Final moisture content (see last data sheet of each sample).

Sample No.	1
Soil type	PAŞABAHÇE
Granulometry	-40
Pc. Load	1.0 Kg/cm²

Date	Time	Tl.El.Time	Reading	Remarks
20-8-1969	13.19	0	0/ 0	Dial scale .001"
		15"	39.4	
		30"	42.0	$m_o \cong 100$ %
		1'	46.6	$m_f = 28.5$ %
		2'	51.8	
		4'	61.1	$e_f = .848$
		8'	73.8	S= 93.083
		15'	90.1	
		30'	1/ 18.2	
		60'	62.9	
	14.19	120'	2/ 25.0	
	17.24	245'	99.2	
	19.19	360'	3/ 30.0	
	21.19	480'	42.3	
21-8-1969	15.19	1560'	50.7	
22-8-1969	16.19	3060'	52.0	
23-8-1969	11.29	4390'	52.6	

Sample No.	2
Soil type	PAŞABAHÇE
Granulometry	-100
Pc. Load	2.0 Kg/cm²

Date	Time	Tl.El. Time	Reading	Remarks
28-8-1969	11.18	0	0 / 0	Dial scale .001"
		15"	92.5	
		30"	99.0	$m_o \cong 100\%$
		1'	1 / 5.9	$m_f = 24.0\%$
		2'	18.3	
		5'	36.0	$e_f = .747$
		8'	50.0	S = 88.907
		15'	72.9	
		30'	2 / 11.2	
	12.18	60'	56.9	
	13.18	120'	3 / 2.3	
	16.05	287'	36.4	
29-8-1969	11.58	1480'	41.0	
	17.04	1906'	41.2	
30-8-1969	10.53	2865'	42.0	
31-8-1969	13.18	4440'	42.9	

Sample No.	3
Soil type	PAŞABAHÇE
Granulometry	-200
Pc. Load	4.0 Kg/cm²

Date	Time	Tl.El. Time	Reading	Remarks
2-8-1969	10.17	0	0/ 0.0	Dial scale .001"
		15"	25.4	
		30"	27.9	$m_0 \cong 100$ %
		1'	31.2	$m_f = 28.5$ %
		2'	35.9	
		4'	42.0	$e_f = .785$
		8'	50.8	S = 100.00
		15'	61.5	
		30'	76.9	
	11.17	60'	97.0	
	12.17	120'	1/ 16.2	
	14.17	240'	26.1	
3-8-1969	15.47	1770'	30.1	
4-8-1969	14.38	3141'	30.6	

Sample No.	4
Soil type	TOPSER
Granulometry	− 40
Pc. Load	2.0 Kg/cm²

Date	Time	T.E. Time	Reading	Remarks
5-8-1969	11.13	0	0/ 0	Dial Scale .001"
		15"	30.0	
		30"	33.5	$m_o \cong 100$ %
		1'	38.2	$m_f = 27.7$ %
		2'	44.9	
		4'	54.9	$e_f = .714$
		8'	67.3	S = 94.158
		15'	84.0	
		30'	1/ 9.0	
	12.13	60'	41.9	
	13.13	120'	72.0	
	15.13	240'	86.0	
	20.13	540'	89.8	
6-8-1969	12.13	1500'	90.5	
7-8-1969	12.30	2957'	90.9	

Sample No.	5
Soil type	TOPSER
Granulometry	− 100
Pc. Load	4.0 Kg/cm²

Date	Time	T.E. Time	Reading	Remarks
8-8-1969	14.40	0	0 / 0	Dial Scale .001"
		15"	35.2	
		30"	40.1	$m_o \cong 100$ %
		1'	46.9	$m_f = 24.4$ %
		2'	55.7	
		4'	67.8	$e_f = .709$
		8'	85.6	S = 93.367
		15'	1 / 6.4	
		30'	37.7	
	15.40	60'	75.9	
	16.40	120'	2 / 6.9	
	18.40	240'	17.0	
	22.40	480'	20.0	
	14.40	1440'	20.9	
	14.40	2880'	21.3	

Sample No.	6
Soil type	TOPSER
Granulometry	-200
Pc. Load	1.0 Kg/cm²

Date	Time	Tl.El.Time	Reading	Remarks
16-8-1969	12.04	0	0/ 0	Dial Scale .001"
		15"	29.4	
		30"	33.5	$m_o \cong 100$ %
		1'	39.5	$m_f = 41.0$ %
		2'	46.7	
		4'	61.6	$e_f = 1.175$
		8'	80.7	S = 94.886
		15'	1/ 5.0	
		30'	44.8	
	13.04	60'	2/ 9.1	
	14.04	120'	86.0	
	16.04	240'	3/ 26.3	
17-8-1969	11.04	1380'	44.8	
	00.24	2160'	45.1	

Sample No.	7
Soil type	KILYOS
Granulometry	−40
Pc. Load	4.0 Kg/cm²

Date	Time	T. E. Time	Reading	Remarks
3-9-1969	11.30	0	0 / 0	Dial scale .001"
		15"	46.2	
		30"	49.0	$m_o \cong 100$ %
		1'	52.2	$m_f = 41.1$ %
		2'	56.0	
		4'	60.2	$e_f = 1.264$
		8'	65.7	S = 91.350
		15'	72.0	
		30'	82.5	
	12.30	60'	96.8	
	13.30	120'	1 / 17.1	
	17.05	315'	65.1	
4-9-1969	00.50	800'	3.0	
	12.12	1482'	22.2	
	16.25	1735'	27.0	
5-9-1969	01.55	2305'	32.0	
	12.45	2955'	34.7	

Sample No.	8
Soil type	KILYOS
Granulometry	-100
Pc. Load	1.0 Kg/cm²

Date	Time	T.E. Time	Reading	Remarks
21-7-1969	12.04	0	0/ 0	Dial scale .001"
		15"	27.9	
		30"	32.3	$m_o \cong 100\%$
		1'	38.8	$m_f = 55.7\%$
		2'	47.1	
		4'	58.4	$e_f = 1.751$
		8'	75.4	S = 89.354
		15'	96.3	
		30'	1/ 26.5	
	13.04	60'	60.4	
	14.07	123'	90.1	
	15.27	203'	2/ 7.8	
	18.04	360'	22.0	
	23.34	690'	29.2	
22-7-1969	16.33	1709'	35.3	
23-7-1969	16.04	3120'	38.6	
24-7-1969	19.57	4793'	40.1	
25-7-1969	11.20	5696'	40.8	

Sample No.	9
Soil type	KILYOS
Granulometry	- 200
Pc. Load	2.0 Kg/cm²

Date	Time	T.E. Time	Reading	Remarks
24-6-1969	16.22	0	0 / 0	Dial scale .001"
		15"	72.0	
		30"	77.0	$m_o \cong 100\%$
		1'	83.1	$m_f = 56.9\%$
		2'	90.0	
		4'	1 / 00.3	$e_f = 1.599$
		8'	12.8	S = 99.949
		15'	29.8	
		30'	56.3	
	17.25	63'	93.0	
	18.22	120'	2 / 29.7	
	20.22	240'	71.0	
25-6-1969	00.22	480'	94.4	
	11.22	1140'	3 / 06.2	
26-6-1969	00.00	1900'	09.1	
	9.05	2380'	11.4	
	15.00	2800'	13.0	
27-6-1969	00.00	3340'	14.5	
	21.25	5625'	15.0	

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	- 40

Pc.	1.0 Kg/cm²
P.	0.5 Kg/cm²
ΔP/P.	0.5

Date	Time	T.E.Time	Reading.
23-8-1969	13.00	0	17.12
		15"	16.60
		30"	16.50
		1'	16.40
		2'	16.29
		4'	16.10
		8'	15.87
		15'	15.50
		30'	15.01
	14.00	60'	14.39
	15.00	120'	13.65
	17.00	240'	13.14
	21.00	480'	12.85
24-8-1969	10.30	1290'	12.78

H	64.19 cm
h	2.18 cm
t	10 min
L_i	4.82 cm
L_f	4.79 cm
A_i	20.65 cm²
A_f	19.96 cm²

$e_i = .848$

$e_f = .767$

$k = 37.41 \times 10^{-9}$ cm/sec

$e_o = e_i = .848$

$m_o = 28.5\ \%$

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	-40

Pc.	1.0 Kg/cm^2
P.	0.75 Kg/cm^2
$\Delta P/P$	0.5

Date	Time	T.E. Time	Reading
24-8-1969	11.46	0	16.69
		15"	16.65
		30"	16.60
		1'	16.60
		2'	16.59
		4'	16.52
		8'	16.48
		15'	16.41
		30'	16.28
	12.46	60'	16.02
	13.46	120'	15.80
	15.46	240'	15.69
	20.46	540'	15.55
25-8-1969	10.21	1355'	15.50

H	64.19 cm
h	1.82 cm
t	10 min
L_i	4.79 cm
L_f	4.76 cm
A_i	19.96 cm^2
A_f	19.81 cm^2

$e_i = .767$

$e_f = .745$

$k = 31.23 \times 10^{-9}$ cm/sec

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry.	−40

Pc.	1.0 Kg/cm²
P.	1.125 Kg/cm²
ΔP/p	0.5

Date	Time	T.E. Time	Reading
25-8-1969	12.15	0	18.68
		15"	18.62
		30"	18.59
		1'	18.55
		2'	18.50
		4'	18.45
		8'	18.30
		15'	18.20
		30'	18.08
	13.15	60'	17.80
	14.15	120'	17.53
	16.40	265'	17.20
	20.55	520'	17.00
26-8-1969	9.40	1285'	16.90

H	64.19 cm
h	1.50 cm
t	10 min
L_i	4.76 cm
L_f	4.74 cm
A_i	19.81 cm²
A_f	19.54 cm²

$e_i = .745$

$e_f = .712$

$k = 25.98 \times 10^{-9}$ cm/sec

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	- 40

Pc.	1.0 Kg/cm²
P.	1.68 Kg/cm²
ΔP/p	0.5

Date	Time	T.E.Time	Reading
26-8-1969	11.25	0	16.60
		15"	16.60
		30"	16.59
		1'	16.54
		2'	16.52
		4'	16.51
		8'	16.50
		15'	16.37
		30'	16.18
	12.25	60'	15.63
	13.25	120'	15.40
	15.25	240'	15.01
	19.25	480'	14.83
	22.25	660'	14.80
27-8-1969	9.30	1325'	14.72

H	64.19 cm
h	1.14 cm
t	10 min
L_i	4.74 cm
L_f	4.72 cm
A_i	19.54 cm²
A_f	19.22 cm²

$e_i = .712$

$e_f = .677$

$k = 20.00 \times 10^{-9}$ cm/sec

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	-40

Pc.	1.0 Kg/cm²
P.	2.52 Kg/cm²
ΔP/p	0.5

Date	Time	T.E.Time	Reading
27-8-1969	11.39	0	16.29
		15"	16.28
		30"	16.27
		1'	16.26
		2'	16.22
		4'	16.21
		8'	16.19
		15'	16.09
		30'	15.91
	12.39	60'	15.62
	13.39	120'	15.20
	15.39	240'	14.92
	18.10	391'	14.71
28-8-1969	01.00	801'	14.54
	10.15	1356'	14.50

H	64.19 cm
h	0.89 cm
t	10 min
L_i	4.72 cm
L_f	4.67 cm
A_i	19.22 cm²
A_f	19.06 cm²

$e_i = .677$

$e_f = .644$

$k = 15.59 \times 10^{-9}$ cm/sec.

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	-40

Pc.	1.0 kg/cm²
P.	3.78 kg/cm²
ΔP/P	0.5

Date	Time	T.E. Time	Reading
28-8-1969	12.32	0	15.49
		15"	15.40
		30"	15.39
		1'	15.31
		2'	15.28
		4'	15.19
		8'	15.05
		15'	14.89
		30'	14.54
	13.32	60'	14.19
	14.32	120'	13.79
	16.32	240'	13.50
	18.21	349'	13.39
29-8-1969	9.00	1188'	13.25

H	64.19 cm
h	1.04 cm
t	15 min
L_i	4.67 cm
L_f	4.65 cm
A_i	19.06 cm²
A_f	18.66 cm²

$e_i = .644$

$e_f = .602$

$k = 12.35 \times 10^{-9}$ cm/sec.

Sample No.	1
Soil Type	PAŞABAHÇE
Granulometry	-40

Pc.	1.0 Kg/cm²
P.	5.67 Kg/cm²
ΔP/P	0.5

Date	Time	T.E. Time	Reading
29-8-1969	12.46	0	14.42
		15"	14.40
		30"	14.38
		1'	14.30
		2'	14.20
		4'	14.09
		8'	13.90
		15'	13.78
		30'	13.49
	13.46	60'	13.20
	14.46	120'	12.98
	16.56	250'	12.70
30-8-1969	11.00	1334'	12.55

H	64.19 cm
h	0.85 cm
t	15 min
L_i	4.65 cm
L_f	4.62 cm
A_i	18.66 cm²
A_f	18.37 cm²

$e_i = .602$

$e_f = .567$

$k = 10.19 \times 10^{-9}$ cm/sec.

Sample No.	1
Soil Type.	PAŞABAHÇE
Granulometry	−40

Pc.	1.0 Kg/cm²
P.	8.5 Kg/cm²
ΔP/p.	0.5

Date	Time	T.E. Time	Reading
30-8-1969	12.43	0	14.70
		15"	14.69
		30"	14.62
		1'	14.57
		2'	14.50
		4'	14.41
		8'	14.20
		15'	14.00
		30'	13.75
	13.43	60'	13.46
	14.43	120'	13.25
	16.43	240'	13.11
31-8-1969	11.18	1355'	13.02

H	64.19 cm.
h	0.84 cm.
t	20 min.
L_i	4.62 cm
L_f	4.57 cm
A_i	18.37 cm²
A_f	18.20 cm²

$e_i = .567$

$e_f = .544$

$k = 7.54 \times 10^{-9}$ cm/sec.

$m_e = 18.96$ %

Sample No.	2
Soil Type	PASABAHCE
Granulometry	-100

Pc.	2.0 Kg/cm^2
P.	0.5 Kg/cm^2
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading
31-8-1969	13.58	0	16.89
		15"	16.81
		30"	16.76
		1'	16.67
		2'	16.54
		4'	16.41
		8'	16.24
		15'	16.06
		30'	15.75
	14.58	60'	15.47
	15.58	120'	15.09
	17.58	240'	14.79
	23.58	600'	14.62
1-9-1969	10.12	1210'	14.59

H	64.41 cm
h	2.01 cm
t	10 min
L_i	4.82 cm
L_f	4.80 cm
A_i	20.65 cm^2
A_f	20.17 cm^2

$e_i = .747$

$e_f = .707$

$k = 33.55 \times 10^{-9}$ cm/sec

$e_o = e_i = .747$

$m_o = 24.0\%$

Sample No.	2
Soil Type	PAŞABAHÇE
Granulometry	− 100

Pc	2.0 Kg/cm²
P	1.0 Kg/cm²
ΔP/P	1.0

Date	Time	T-E-Time	Reading
1-9-1969	12.09	0	17.19
		15"	17.12
		30"	17.09
		1'	17.07
		2'	16.99
		4'	16.92
		8'	16.89
		15'	16.80
		30'	16.60
	13.09	60'	16.31
	14.09	120'	16.07
	17.09	300'	15.80
2-9-1969	9.09	1260'	15.79

H	64.41 cm
h_1	1.70 cm
t	10 min
L_i	4.80 cm
L_f	4.80 cm
A_i	20.17 cm²
A_f	19.96 cm²

$e_i = .707$

$e_f = .682$

$k = 28.67 \times 10^{-9}$ cm/sec

Sample No.	2
Soil Type	PAŞABAHÇE
Granulometry	−100

P_c.	2.0 kg/cm²
P.	2.0 kg/cm²
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading
2-9-1969	10.49	0	18.70
"		15"	18.58
		30"	18.51
		1'	18.43
		2'	18.34
		4'	18.21
		8'	18.07
		15'	17.81
		30'	17.48
	11.49	60'	16.85
	12.49	120'	16.49
	14.49	240'	16.23
	18.49	480'	16.09
3-9-1969	10.54	1445'	15.97

H	64.41 cm
h	1.18 cm
t	10 min
L_i	4.80 cm
L_f	4.79 cm
A_i	19.96 cm²
A_f	19.45 cm²

$e_i = .682$

$e_f = .634$

$k = 20.38 \times 10^{-9}$ cm/sec

Sample No.	2
Soil Type	PAŞABAHÇE
Granulometry	-100

P_c.	2.0 kg/cm²
P.	4.0 kg/cm²
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading
3-9-1969	12.53	0	17.88
		15"	17.70
		30"	17.62
		1'	17.54
		2'	17.41
		4'	17.25
		8'	16.99
		15'	16.71
		30'	16.27
	13.53	60'	15.77
	14.53	120'	15.30
	16.58	245'	14.85
	20.45	472'	14.72
4-9-1969	10.38	1315'	14.65

H	64.41 cm
h	1.15 cm
t	15 min
L_i	4.79 cm
L_f	4.72 cm
A_i	19.45 cm²
A_f	19.04 cm²

$e_i = .634$

$e_f = .578$

$k = 13.32 \times 10^{-9}$ cm/sec.

Sample No.	2
Soil Type	PAŞABAHÇE
Granulometry	-100

Pc	2.0 Kg/cm²
P	8.0 Kg/cm²
ΔP/p	1.0

Date	Time	T-E-Time	Readings
4-9-1969	13.52	0	17.67
		15"	17.50
		30"	17.40
		1'	17.30
		2'	17.17
		4'	16.94
		8'	16.70
		15'	16.32
		30'	15.81
	14.52	60'	15.30
	15.52	120'	15.00
	17.52	240'	14.70
	23.52	540'	14.55
5-9-1969	9.52	1200'	14.52

H	64.41 cm
h	0.95 cm
t	20 min
L_i	4.72 cm
L_f	4.63 cm
A_i	19.04 cm²
A_f	18.72 cm²

$e_i = .578$

$e_f = .522$

$k = 8.25 \times 10^{-9}$ cm/sec

$m_e = 18.30$ %

Sample No.	3
Soil Type	PAŞABAHÇE
Granulometry	-200

Pc.	4.0 Kg/cm^2
P.	0.9 Kg/cm^2
$\Delta P/P$	2.0

Date	Time	T.E.Time	Reading
4-8-1969	16.35	0	19.30
		15"	19.10
		30"	19.01
		1'	18.94
		2'	18.80
		4'	18.69
		8'	18.51
		15'	18.36
		30'	18.06
	17.35	60'	17.75
	18.35	120'	17.60
	20.35	240'	17.51
5-8-1969	00.35	480'	17.49
	8.35	960'	17.49

H	64.23 cm
h	3.26 cm
t	20 min
L_i	4.90 cm
L_f	4.85 cm
A_i	20.65 cm^2
A_f	20.48 cm^2

$e_i = .785$

$e_f = .753$

$K = 27.10 \times 10^{-9}\ cm/sec$

$e_o = e_i = .785$

$m_o = 28.5\ \%$

Sample No.	3
Soil Type	PAŞABAHÇE
Granulometry	-200

Pc.	4.0 Kg/cm²
P.	2.7 Kg/cm²
ΔP/p	2.0

Date	Time	T.E.Time	Reading
5-8-1969	12.11	0	19.28
		15"	19.05
		30"	18.91
		1'	18.80
		2'	18.67
		4'	18.46
		8'	18.20
		15'	17.85
		30'	17.36
	13.11	60'	16.71
	14.11	120'	16.27
	16.11	240'	15.79
	20.11	480'	15.50
6-8-1969	10.11	1380'	15.40
	12.11	1440'	15.40

H	64.23 cm
h	2.20 cm
t	20 min.
L_i	4.85 cm
L_f	4.78 cm
A_i	20.48 cm²
A_f	19.98 cm²

$e_i = .753$

$e_f = .685$

$K = 18.52 \times 10^{-9}$ cm/sec

Sample No.	3
Soil Type	PAŞABAHÇE
Granulometry	−200

Pc.	4.0 Kg/cm²
P.	8.1 Kg/cm²
ΔP/p	2.0

Date	Time	T.E.Time	Reading.
6-8-1969	13.56	0	18.60
		15"	18.32
		30"	18.20
		1'	18.01
		2'	17.76
		4'	17.39
		8'	16.90
		15'	16.30
		30'	15.30
	14.56	60'	14.32
	15.56	120'	13.60
	19.41	345'	13.10
7-8-1969	01.21	685'	12.92
	10.00	1204'	12.92

H	64.23 cm
h	0.61 cm
t	20 min
L_i	4.78 cm
L_f	4.70 cm
A_i	19.98 cm²
A_f	19.13 cm²

$e_i = .685$

$e_f = .584$

$K = 5.27 \times 10^{-9}$ cm/sec.

$m_e = 20.17$ %

Sample No.	4
Soil Type.	TOPSER
Granulometry	-40

Pc.	2.0 Kg/cm²
P.	0.9 Kg/cm²
$\Delta P/P$	2.0

Date	Time	T.E.Time	Reading.
7-8-1969	14.25	0	19.30
		15"	19.21
		30"	19.18
		1'	19.09
		2'	18.93
		4'	18.70
		8'	18.46
		15'	18.10
		30'	17.63
	15.25	60'	17.18
	16.25	120'	16.80
	18.25	240'	16.69
	22.25	480'	16.63
8-8-1969	9.25	1140'	16.63

H	64.23 cm
h	2.52 cm
t	10 min.
L_i	4.83 cm
L_f	4.80 cm
A_i	20.65 cm²
A_f	20.22 cm²

$e_i = .714$

$e_f = .668$

$K = 42.04 \times 10^{-9}$ cm/sec.

$e_o = e_i = .714$

$m_o = 27.7\ \%$

Sample No.	4
Soil Type	TOPSER
Granulometry	-40

Pc.	2.0 Kg/cm²
P.	2.7 Kg/cm²
ΔP/p	2.0

Date	Time	T.E.Time	Reading.
8-8-1969	12.29	0	18.39
		15"	18.15
		30"	18.02
		1'	17.90
		2'	17.70
		4'	17.48
		8'	17.04
		15'	16.59
		30'	15.92
	13.29	60'	15.17
	14.39	130'	14.61
	16.29	240'	14.20
	20.29	480'	14.06
9-8-1969	9.29	1260'	13.80

H	64.23 cm
h	1.53 cm
t	10 min
L_i	4.80 cm
L_f	4.76 cm
A_i	20.22 cm²
A_f	19.40 cm²

$e_i = .668$

$e_f = .589$

$K = 26.41 \times 10^{-9}$ cm/sec.

Sample No.	4
Soil Type	TOPSER
Granulometry	- 40

Pc.	2.0 Kg/cm²
P.	8.1 Kg/cm²
ΔP/p	2.0

Date	Time	T-E. Time	Reading
9-8-1969	11.15	0	18.11
		15"	17.81
		30"	17.61
		1'	17.45
		2'	17.13
		4'	16.71
		8'	16.20
		15'	15.50
		30'	14.58
	12.15	60'	13.74
	13.15	120'	13.10
	15.15	240'	12.81
10-8-1969	10.45	1420'	12.49

H	64.23 cm
h	1.47 cm
t	20 min
L_i	4.76 cm
L_f	4.69 cm
A_i	19.40 cm²
A_f	18.51 cm²

$e_i = .589$

$e_f = .493$

$K = 12.90 \times 10^{-9}$ cm/sec.

$m_e = 18.25$ %

Sample No.	5
Soil Type.	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	0.5 Kg/cm²
ΔP/p	0.5

Date	Time	T.E. Time	Reading
10-8-1969	15.25	0	18.60
		15"	18.42
		30"	18.37
		1'	18.29
		2'	18.20
		4'	18.12
		8'	18.00
		15'	17.94
		30'	17.81
	16.25	60'	17.70
	17.25	120'	17.61
	19.25	240'	17.57
	23.25	480'	17.56
11-8-1969	9.00	1055'	17.56

H	64.19 cm
h	1.90 cm
t	10 min
L_i	5.00 cm
L_f	4.99 cm
A_i	20.65 cm²
A_f	20.49 cm²

$e_i = .709$

$e_f = .692$

$K = 32.45 \times 10^{-9}$ cm/sec.

$e_o = e_i = .709$

$m_o = 24.4\ \%$

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	0.75 Kg/cm²
ΔP/P	0.5

Date	Time	T.E.Time	Reading
11-8-1969	11.38	0	18.90
		15"	18.89
		30"	18.88
		1'	18.86
		2'	18.82
		4'	18.80
		8'	18.77
		15'	18.71
		30'	18.65
	12.38	60'	18.57
	13.38	120'	18.50
	15.38	240'	18.45
	19.38	480'	18.42
12-8-1969	9.40	1324'	18.42

H	64.19 cm
h	1.81 cm
t	10 min
L_i	4.99 cm
L_f	4.99 cm
A_i	20.49 cm²
A_f	20.36 cm²

$e_i = .692$

$e_f = .684$

$K = 31.10 \times 10^{-9}$ cm/sec.

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	1.125 Kg/cm²
ΔP/p	0.5

Date	Time	T.E.Time	Reading
12-8-1969	12.00	0	19.08
		15"	19.00
		30"	18.99
		1'	18.96
		2'	18.92
		4'	18.87
		8'	18.80
		15'	18.70
		30'	18.59
	13.00	60'	18.40
	14.05	125'	18.27
	16.00	240'	18.21
13-8-1969	11.00	1380'	18.19

H	64.19 cm
h	1.59 cm
t	10 min.
L_i	4.99 cm
L_f	4.98 cm
A_i	20.36 cm²
A_f	20.21 cm²

$e_i = .684$

$e_f = .669$

$K = 27.46 \times 10^{-9}$ cm/sec.

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	1.68 Kg/cm²
ΔP/P.	0.5

Date	Time	T.E. Time	Reading.
13-8-1969	13.57	0	18.30
		15"	18.25
		30"	18.23
		1'	18.20
		2'	18.17
		4'	18.10
		8'	18.06
		15'	18.00
		30'	17.90
	14.57	60'	17.79
	15.57	120'	17.70
	17.57	240'	17.64
	21.57	480'	17.60
14-8-1969	9.45	1188'	17.58

H	64.19 cm
h	1.51 cm
t	10 min
L_i	4.98 cm
L_f	4.97 cm
A_i	20.21 cm²
A_f	20.15 cm²

$e_i = .669$

$e_f = .657$

$K = 26.12 \times 10^{-9}$ cm/sec.

Sample No.	5
Soil Type.	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	2.52 Kg/cm²
ΔP/p	0.5

Date	Time	T.E. Time	Reading.
14-8-1969	11.25	0	17.59
		15"	17.57
		30"	17.51
		1'	17.49
		2'	17.41
		4'	17.33
		8'	17.20
		15'	17.04
		30'	16.85
	12.25	60'	16.61
	13.25	120'	16.41
	15.33	248'	16.23
	20.25	540'	16.00
15-8-1969	00.30	665'	15.94
	10.00	1235'	15.90

H	64.19 cm
h	1.33 cm
t	10 min
L_i	4.97 cm
L_f	4.96 cm
A_i	20.15 cm²
A_f	20.05 cm²

$e_i = .657$

$e_f = .629$

$K = 22.54 \times 10^{-9}$ cm/sec.

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	3.78 Kg/cm²
ΔP/p	0.5

Date	Time	T.E. Time	Reading.
15-8-1969	12.20	0	18.69
		15"	18.67
		30"	18.62
		1'	18.59
		2'	18.50
		4'	18.40
		8'	18.25
		15'	18.06
		30'	17.79
	13.20	60'	17.58
	14.20	120'	17.32
	15.40	200'	17.20
	17.45	325'	17.05
16-8-1969	00.05	705'	16.85
	9.10	1250'	16.80

H	64.19 cm
h	1.08 cm
t	10 min
L_i	4.96 cm
L_f	4.95 cm
A_i	20.05 cm²
A_f	19.71 cm²

$e_i = .629$

$e_f = .598$

$K \doteq 19.06 \times 10^{-9}$ cm/sec

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	5.67 Kg/cm²
ΔP/p	0.5

Date	Time	T.E.Time	Reading
16-8-1969	11.47	0	16.80
		15"	16.80
		30"	16.79
		1'	16.71
		2'	16.63
		4'	16.50
		8'	16.32
		15'	16.13
		30'	15.81
	12.47	60'	15.49
	13.47	120'	15.19
	15.47	240'	14.97
17-8-1969	10.47	1380'	14.85

H	64.19 cm
h	1.27 cm
t	15 min
L_i	4.95 cm
L_f	4.94 cm
A_i	19.71 cm²
A_f	19.46 cm²

$e_i = .598$

$e_f = .565$

$K = 14.86 \times 10^{-9}$ cm/sec.

Sample No.	5
Soil Type	TOPSER
Granulometry	-100

Pc.	4.0 Kg/cm²
P.	8.5 Kg/cm²
ΔP/P	0.5

Date	Time	T.E. Time	Reading
17-8-1969	13.33	0	14.78
		15"	14.74
		30"	14.72
		1'	14.70
		2'	14.60
		4'	14.45
		8'	14.20
		15'	14.00
		30'	13.69
	14.33	60'	13.24
	15.33	120'	13.00
	17.33	240'	12.80
	21.33	480'	12.65
18-8-1969	10.33	1260'	12.62

H	64.19 cm
h	1.33 cm
t	20 min
L_i	4.94 cm
L_f	4.93 cm
A_i	19.46 cm²
A_f	18.94 cm²

$e_i = .565$

$e_f = .546$

$K = 12.15 \times 10^{-9}$ cm/sec.

$m_e = 20.85\%$

Sample No.	6
Soil Type.	TOPSER
Granulometry	−200

Pc.	1.0 Kg/cm²
P.	0.5 Kg/cm²
ΔP/P.	1.0

Date	Time	T.E. Time	Reading
18-8-1969	15.33	0	17.60
		15"	17.45
		30"	17.30
		1'	17.00
		2'	16.78
		4'	16.42
		8'	15.97
		15'	15.40
		30'	14.50
	16.33	60'	13.57
	17.33	120'	12.95
	19.33	240'	12.42
	23.48	495'	12.25
19-8-1969	10.58	1165'	12.20

H	64.28 cm
h	2.65 cm
t	5 min.
L_i	4.86 cm
L_f	4.79 cm
A_i	20.65 cm²
A_f	19.72 cm²

$e_i = 1.175$

$e_f = 1.058$

$K = 90.5 \times 10^{-9}$ cm/sec.

$e_o = e_i = 1.175$

$m_o = 41.0$ %

Sample No.	6
Soil Type.	TOPSER
Granulometry	-200

Pc.	1.0 Kg/cm²
P.	1.0 Kg/cm²
ΔP/P	1.0

Date	Time	T.E. Time	Reading
19-8-1969	11.17	0	16.20
		15"	16.17
		30"	16.10
		1'	16.01
		2'	15.95
		4'	15.86
		8'	15.61
		15'	15.27
		30'	14.81
	12.17	60'	14.31
	13.17	120'	13.95
	15.17	240'	13.70
20-8-1969	11.17	1440'	13.45

H	64.28 cm
h	1.98 cm
t	5 min.
L_i	4.79 cm
L_f	4.78 cm
A_i	19.72 cm²
A_f	19.20 cm²

$e_i = 1.058$

$e_f = .998$

$K = 69.4 \times 10^{-9}$ cm/sec.

Sample No.	6
Soil Type.	TOPSER
Granulometry	-200

Pc.	1.0 Kg/cm²
P.	2.0 Kg/cm²
ΔP/p	1.0

Date	Time	T.E.Time	Reading.
20-8-1969	12.09	0	17.79
		15"	17.60
		30"	17.50
		1'	17.38
		2'	17.20
		4'	16.96
		8'	16.60
		15'	16.20
		30'	15.65
	13.09	60'	15.05
	14.09	120'	14.62
	17.25	316'	14.29
	21.09	540'	14.17
21-8-1969	10.09	1320'	14.15

H	64.28 cm
h	2.60 cm
t	10 min.
L_i	4.78 cm
L_f	4.72 cm
A_i	19.20 cm²
A_f	18.66 cm²

$e_i = .998$

$e_f = .919$

$K = 46.25 \times 10^{-9}$ cm/sec.

Sample No.	6
Soil Type.	TOPSER
Granulometry	-200

Pc.	1.0 Kg/cm²
P.	4.0 Kg/cm²
ΔP/p	1.0

Date	Time	T.E.Time	Reading
21-8-1969	12.20	0	16.75
		15"	16.50
		30"	16.40
		1'	16.29
		2'	16.10
		4'	15.86
		8'	15.40
		15'	14.92
		30'	14.24
	13.20	60'	13.69
	14.25	125'	13.17
	20.20	480'	12.70
22-8-1969	8.50	1230'	12.65

H	64.28 cm
h	2.32 cm
t	15 min
L_i	4.72 cm
L_f	4.66 cm
A_i	18.66 cm²
A_f	17.93 cm²

$e_i = .919$

$e_f = .830$

$K = 28.13 \times 10^{-9}$ cm/sec.

Sample No.	6
Soil Type	TOPSER
Granulometry	-200

Pc.	1.0 Kg/cm²
P.	8.0 Kg/cm²
ΔP/p.	1.0

Date	Time	T.E.Time	Reading
22-8-1969	11.56	0	16.90
		15"	16.70
		30"	16.58
		1'	16.41
		2'	16.18
		4'	15.90
		8'	15.34
		15'	14.88
		30'	14.15
	12.56	60'	13.50
	13.56	120'	13.21
	15.56	240'	13.10
23-8-1969	8.56	1260'	12.70

H	64.28 cm
h	1.39 cm
t	15 min
L_i	4.66 cm
L_f	4.49 cm
A_i	17.99 cm²
A_f	17.74 cm²

$e_i = .830$

$e_f = .735$

$K = 16.50 \times 10^{-9}$ cm/sec.

$m_e = 25.57\%$

Sample No.	7
Soil Type.	KILYOS
Granulometry.	-40

Pc	4.0 Kg/cm²
P.	0.5 Kg/cm²
ΔP/P	1.0

Date	Time	T.E. Time	Reading
5-9-1969	14.23	0	16.04
		15"	15.38
		30"	15.30
		1'	15.28
		2'	15.24
		4'	15.19
		8'	15.14
		15'	15.11
		30'	15.10
	15.23	60'	15.09

H	64.40 cm
h	1.43 cm
t	20 min
L_i	4.82 cm
L_f	4.82 cm
A_i	20.65 cm²
A_f	20.46 cm²

$e_i = 1.264$

$e_f = 1.242$

$k = 11.79 \times 10^{-9}$ cm/sec

$e_o = e_i = 1.264$

$m_o = 41.1\ \%$

Sample No.	7
Soil Type	KILYOS
Granulometry	-40

P_c	4.0 Kg/cm²
P	1.0 Kg/cm²
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading
5-9-1969	19.30	0	15.40
		15"	15.39
		30"	15.37
		1'	15.31
		2'	15.29
		4'	15.25
		8'	15.21
		15'	15.17
		30'	15.13
	20.30	60'	15.02
	21.30	120'	14.90
	23.30	240'	14.75
6-9-1969	8.40	790'	14.55
	11.30	970'	14.55

H	64.40 cm
h	0.89 cm
t	20 min
L_i	4.82 cm
L_f	4.81 cm
A_i	20.46 cm²
A_f	20.31 cm²

$e_i = 1.242$

$e_f = 1.223$

$k = 7.39 \times 10^{-9}$ cm/sec

Sample No.	7
Soil Type	KILYOS
Granulometry	-40

P_c	4.0 Kg/cm²
P	2.0 Kg/cm²
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading
6-9-1969	14.14	0	16.86
		15"	16.79
		30"	16.76
		1'	16.71
		2'	16.78
		4'	16.60
		8'	16.55
		15'	16.50
		30'	16.39
	15.14	60'	16.19
	16.14	120'	16.00
	18.04	230'	15.70
7-9-1969	10.14	1200'	14.51
	15.14	1500'	14.30
	19.49	1775'	14.19
8-9-1969	00.34	2055'	14.10
	10.00	2621'	14.08

H	64.40 cm
h	0.79 cm
t	30 min
L_i	4.81 cm
L_f	4.78 cm
A_i	20.31 cm²
A_f	19.86 cm²

$e_i = 1.223$

$e_f = 1.160$

$k = 4.10 \times 10^{-9}$ cm/sec

Sample No	7
Soil Type	KILYOS
Granulometry.	-40

Pc	4.0 Kg/cm²
P	4.0 Kg/cm²
ΔP/p.	1.0

Date	Time	T.E. Time	Reading.
8-9-1969	15.23	0	16.51
		15"	16.43
		30"	16.40
		1'	16.37
		2'	16.34
		4'	16.30
		8'	16.21
		15'	16.14
		30'	15.93
	16.23	60'	15.68
	19.13	220'	14.79
9-9-1969	00.13	520'	14.01
	11.18	1185'	13.41
	23.55	1942'	13.00
10-9-1969	11.13	2620'	12.90
	19.00	3087'	12.69
11-9-1969	12.13	4120'	12.55
	23.43	4810'	12.55

H	64.40 cm
h	0.52 cm
t	60 min
L_i	4.78 cm
L_f	4.72 cm
A_i	19.86 cm²
A_f	19.27 cm²

$e_i = 1.160$

$e_f = 1.069$

$k \doteq 1.49 \times 10^{-9}$ cm/sec.

Sample No.	7
Soil Type	KILYOS
Granulometry	-40

P_c	4.0 kg/cm^2
P	8.0 kg/cm^2
$\Delta P/P$	1.0

Date	Time	T.E. Time	Reading.
12-9-1969	10.08	0	17.40
		15"	17.30
		30"	17.29
		1'	17.23
		2'	17.20
		4'	17.14
		8'	17.10
		15'	17.00
		30'	16.85
	11.08	60'	16.60
	12.08	120'	16.24
	14.08	240'	15.74
	18.08	480'	15.06
13-9-1969	11.08	1500'	13.60
14-9-1969	11.13	2945'	13.00
15-9-1969	10.53	4365'	12.67
16-9-1969	8.00	5632'	12.50
	23.00	6532	12.50

H	64.40 cm
h	0.22 cm
t	100 min
L_i	4.72 cm
L_f	4.67 cm
A_i	19.27 cm^2
A_f	18.44 cm^2

$e_i = 1.069$

$e_f = .958$

$k = 0.39 \times 10^{-9}$ cm/sec.

$m_e = 32.99$ %

Sample No.	8
Soil Type	KİLYOS
Granulometry	−100

Pc.	1.0 kg/cm²
P.	0.9 kg/cm²
ΔP/P	2.0

Date	Time	T.E.Time	Reading
25-7-1969	12.16	0	16.35
		15"	16.20
		30"	15.95
		1'	15.80
		2'	15.63
		4'	15.42
		8'	14.99
		15'	14.31
		30'	13.40
	13.16	60'	12.19
	14.16	120'	11.00
	16.16	240'	10.09
	20.24	488'	9.50
25-7-1969	24.00	704'	9.30
26-7-1969	11.27	1391'	8.95
27-7-1969	19.25	3309'	8.89

H	62.15 cm
h	3.0 cm
t	20 min
L_i	4.82 cm
L_f	4.71 cm
A_i	20.65 cm²
A_f	19.55 cm²

$e_i = 1.751$

$e_f = 1.545$

$K \doteq 26.27 \times 10^{-9}$ cm/sec

$e_o = e_i = 1.751$

$m_o = 55.7\ \%$

Sample No.	8
Soil Type	KILYOS
Granulometry	-100

P_c.	1.0 kg/cm²
P.	2.7 kg/cm²
$\Delta P/P$	2.0

Date	Time	T.E.Time	Reading
28-7-1969	11.10	0	19.70
		15"	19.50
		30"	19.41
		1'	19.30
		2'	19.18
		4'	19.00
		8'	18.70
		15'	18.39
		30'	17.81
	12.10	60'	17.04
	13.10	120'	16.01
	15.10	240'	14.71
	19.55	525'	13.30
29-7-1969	11.00	1430'	12.59
30-7-1969	13.30	3020'	11.98
31-7-1969	11.00	4310'	11.74
	16.00	4610'	11.71
1-8-1969	00.30	5120'	11.71

H	62.15 cm
h	1.57 cm
t	60 min.
L_i	4.71 cm
L_f	4.51 cm
A_i	19.55 cm²
A_f	18.64 cm²

$e_i = 1.545$

$e_f = 1.324$

$K = 4.595 \times 10^{-9}$ cm/sec.

Sample No.	8
Soil Type	KILYOS
Granulometry	-100

Pc.	1.0 Kg/cm²
P.	8.1 Kg/cm²
ΔP/p.	2.0

Date	Time	T.E.Time	Reading
1-8-1969	11.36	0	18.85
		15"	18.69
		30"	18.60
		1'	18.53
		2'	18.42
		4'	18.30
		8'	18.12
		15'	17.91
		30'	17.59
	12.36	60'	17.09
	13.36	120'	16.40
	15.36	240'	15.39
2-8-1969	02.00	864'	12.71
	13.26	1550'	11.95
3-8-1969	15.45	3129'	11.47
4-8-1969	9.20	4184'	11.43

H	62.15 cm
h	0.41 cm
t	60 min
L_i	4.51 cm
L_f	4.37 cm
A_i	18.64 cm²
A_f	17.54 cm²

$e_i = 1.324$

$e_f = 1.119$

$K = 1.236 \times 10^{-9}$ cm/sec.

$m_e = 34.57$ %

Sample No.	9
Soil Type	KILYOS
Granulometry	-200

Pc.	2.0 Kg/cm²
P.	0.5 Kg/cm²
ΔP/p	0.5

Date	Time	T.E. Time	Reading
27-6-1969	22.20	0	18.80
		15"	18.49
		30"	18.40
		1'	18.35
		2'	18.26
		4'	18.15
		8'	18.07
		15'	17.90
		30'	17.69
	23.20	60'	17.50
28-6-1969	01.25	185'	17.20
	09.05	645'	16.92
	13.55	935'	16.85
29-6-1969.	16.57	2557'	16.70
	19.00	2860'	16.70

H	62.25 cm
h	2.75 cm
t	20 min
L_i	4.82 cm
L_f	4.80 cm
A_i	20.65 cm²
A_f	20.28 cm²

$e_i = 1.599$

$e_f = 1.544$

$K = 23.58 \times 10^{-9}$ cm/sec.

$e_o = e_i = 1.599$

$m_o = 56.9$ %

Sample No.	9
Soil Type	KILYOS
Granulometry	−200

Pc.	2.0 Kg/cm²
P.	0.75 Kg/cm²
ΔP/p.	0.5

Date	Time	T.E. Time	Reading
29-6-1969	21-05	0	17.50
		15"	17.49
		30"	17.44
		1'	17.40
		2'	17.35
		4'	17.30
		8'	17.28
		15'	17.20
		30'	17.18
	22.05	60'	17.01
	23.05	120'	16.90
30-6-1969	01-05	240'	16.79
	08.45	700'	16.49
	15.55	1130'	16.40
1-7-1969	00.00	1605'	16.26
	09.00	2145'	16.20
	16.55	2620'	16.12
2-7-1969	00-25	3070'	16.12

H	62.25 cm
h	2.64 cm
t	20 min
L_i	4.80 cm
L_f	4.76 cm
A_i	20.28 cm²
A_f	20.19 cm²

$e_i = 1.544$

$e_f = 1.508$

$K = 22.59 \times 10^{-9}$ cm/sec.

Sample No.	9
Soil Type	KILYOS
Granulometry	-200

Pc.	2.0 Kg/cm^2
P.	1.125 Kg/cm^2
$\Delta P/p$.	0.5

Date	Time	T.E. Time	Reading
2-7-1969	17.51	0	18.62
		15"	18.61
		30"	18.61
		1'	18.60
		2'	18.59
		4'	18.50
		8'	18.44
		15'	18.36
		30'	18.30
	18.51	60'	18.04
	19.51	120'	17.84
	23.51	360'	17.39
3-7-1969	23.46	1795'	16.60
4-7-1969	17.14	2843'	16.45
	20.06	3015'	16.45

H	62.25 cm
h	1.66 cm
t	20 min
L_i	4.76 cm
L_f	4.70 cm
A_i	20.19 cm^2
A_f	19.95 cm^2

$e_i = 1.508$

$e_f = 1.449$

$K = 14.16 \times 10^{-9}$ cm/sec.

Sample No.	9
Soil Type	KILYOS
Granulometry	-200

Pc.	2.0 Kg/cm²
P.	1.68 Kg/cm²
ΔP/P.	0.5

Date	Time	T.E. Time	Reading
5-7-1969	00.28	0	19.00
		15"	19.00
		30"	18.99
		1'	18.98
		2'	18.98
		4'	18.91
		8'	18.87
		15'	18.80
		30'	18.60
	01.28	60'	18.44
	02.18	110'	18.29
	08.30	482'	17.55
	17.10	1002'	16.95
7-7-1969	19.22	3975'	16.16
8-7-1969	14.00	4495'	16.16

H	62.25 cm
h	1.12 cm
t	20 min.
L_i	4.70 cm
L_f	4.68 cm
A_i	19.95 cm²
A_f	19.41 cm²

$e_i = 1.449$

$e_f = 1.375$

$K = 9.79 \times 10^{-9}$ cm/sec

Sample No.	9
Soil Type	KILYOS
Granulometry	−200

Pc.	2.0 Kg/cm²
P.	2.52 Kg/cm²
ΔP/P.	0.5

Date	Time	T.E.Time	Reading
8-7-1969	16.32	0	18.20
		15″	18.15
		30″	18.11
		1′	18.09
		2′	18.06
		4′	18.01
		8′	17.98
		15′	17.90
		30′	17.78
	17.32	60′	17.58
	18.32	120′	17.29
	20.32	240′	16.70
9-7-1969	00.37	485′	16.10
	10.05	1053′	15.50
10-7-1969	18.05	2973′	14.50
11-7-1969	00.00	4768′	14.00
12-7-1969	09.00	5248′	13.90
13-7-1969	15.00	7048′	13.90

H	62.25 cm.
h	0.56 cm
t	20 min.
L_i	4.68 cm
L_f	4.63 cm
A_i	19.41 cm²
A_f	18.70 cm²

$e_i = 1.375$

$e_f = 1.263$

$K = 5.025 \times 10^{-9}$ cm/sec.

Sample No.	9
Soil Type	KILYOS
Granulometry	-200

P_c.	2.0 Kg/cm^2
P.	3.78 Kg/cm^2
$\Delta P/P$.	0.5

Date	Time	T.E. Time	Reading
13-7-1969	19.41	0	18.80
		15"	18.80
		30"	18.79
		1'	18.77
		2'	18.74
		4'	18.71
		8'	18.70
		15'	18.64
		30'	18.50
	20.41	60'	18.30
	21.41	120'	17.95
	23.41	240'	17.49
14-7-1969	9.56	855'	16.31
	19.41	1440'	15.90
15-7-1969	20.41	2940'	15.20
16-7-1969	20.40	4379'	14.90
17-7-1969	8.40	5099'	14.90

H	62.25 cm
h	0.46 cm
t	30 min.
L_i	4.63 cm
L_f	4.58 cm
A_i	18.70 cm^2
A_f	18.06 cm^2

$e_i = 1.263$

$e_f = 1,161$

$K = 2.82 \times 10^{-9}$ cm/sec.

Sample No.	9
Soil Type	KILYOS
Granulometry	-200

Pc.	2.0 Kg/cm^2
P.	5.67 Kg/cm^2
$\Delta P/P$.	0.5

Date	Time	T.E. Time	Reading
17-7-1969	11.35	0	
		15"	
		30"	
		1'	
		2'	
		4'	
		8'	
		15'	
		30'	
	12.35	60'	
	13.35	120'	
	14.24	169'	
18-7-1969	14.45	1630'	
	23.17	2082'	
19-7-1969	12.35	2940'	
20-7-1969	18.10	4715'	
	23.30	5035'	

H	62.25 cm
h	0.42 cm.
t	60 min.
L_i	4.58 cm.
L_f	4.53 cm.
A_i	18.06 cm^2
A_f	17.25 cm^2

$e_i = 1.161$

$e_f = 1.042$

$K = 1.332 \times 10^{-9}$ cm/sec

Sample No.	9
Soil Type	KILYOS
Granulometry	– 200

Pc.	2.0 Kg/cm²
P.	8.5 Kg/cm²
ΔP/p	0.5

Date	Time	T.E.Time	Reading.
21-7-1969	10.52	0	18.80
		15"	18.79
		30"	18.78
		1'	18.75
		2'	18.73
		4'	18.70
		15'	18.61
		32'	18.55
	11.52	60'	18.41
	12.52	120'	18.18
	14.52	240'	17.80
	18.02	430'	17.30
	23.57	975'	16.70
22-7-1969	16.34	1782'	16.30
23-7-1969	17.13	3261'	15.81
24-7-1969	10.20	4288'	15.80
	15.00	4528'	15.80

H	62.25 cm
h	0.46 cm
t	102 min
L_i	4.53 cm
L_f	4.47 cm
A_i	17.25 cm²
A_f	16.81 cm²

$e_i = 1.042$

$e_f = .962$

$K = 0.87 \times 10^{-9}$ cm/sec.

$m_e = 34.04$ %

<u>Analysis</u> :

For the statistical evaluations of the test results, a 3x3 Greco-Latin matrix was used with four variables. The distribution of variables in this matrix were planned as :

	I	II	III
1	Aα	Bβ	Cγ
2	Cβ	Aγ	Bα
3	Bγ	Cα	Aβ

the symbols standing for :

Soil type :

1. Paşabahçe
2. Topser
3. Kilyos

Granulometry :

I. - 40
II. -100
III. -200

Presonsolidation load :

α. 1.0 kg/cm^2
β. 2.0 kg/cm^2
γ. 4.0 kg/cm^2

Δp/p ratio :

A. 0.5
B. 1.0
C. 2.0

At the end of the preconsolidation steps, void ratios of the samples were determined (e_f on Preconsolidation Data sheets). These values were the initial void ratios of the samples (e_o on Consolidation and Permeability Data sheets) when the actual consolidation steps in the GEONOR apparatus were concerned. At the end of each step of consolidation, void ratios of the samples were also calculated (e_f on Consolidation and Permeability Data sheets). By dividing those intermediate void ratios to the corresponding initial void ratio of each sample, e/e_o values were obtained. Then, log k vs e/e_o curves were plotted for each sample (see Figures 12, 13, and 14).

To analyze the significances of the effects of each variable on the permeability value, several variance analysis were carried at different levels of e/e_o.

The matrices obtained by that way were (Figures 12, 13, and 14 were used for this purpose) :

$e/e_o = 0.95$ *

48.0	34.1	28.5
46.5	30.0	120.0
6.5	51.3	21.6

$e/e_o = 0.90$

36.0	26.0	18.5
36.5	23.5	95.0
3.3	29.0	13.8

$e/e_o = 0.85$

28.0	19.9	13.0
29.2	18.9	67.0
1.6	15.7	8.8

$e/e_o = 0.80$

20.1	15.0	8.7
23.0	14.7	51.0
0.76	8.7	5.5

$e/e_o = 0.75$

15.0	11.3	5.9
18.3	11.6	36.8
0.4	4.8	3.4

$e/e_o = 0.70$

11.2	8.7	4.1
14.4	9.2	27.2
0.18	2.6	2.15

* All permeability values are given in 10^{-9} cm/sec.

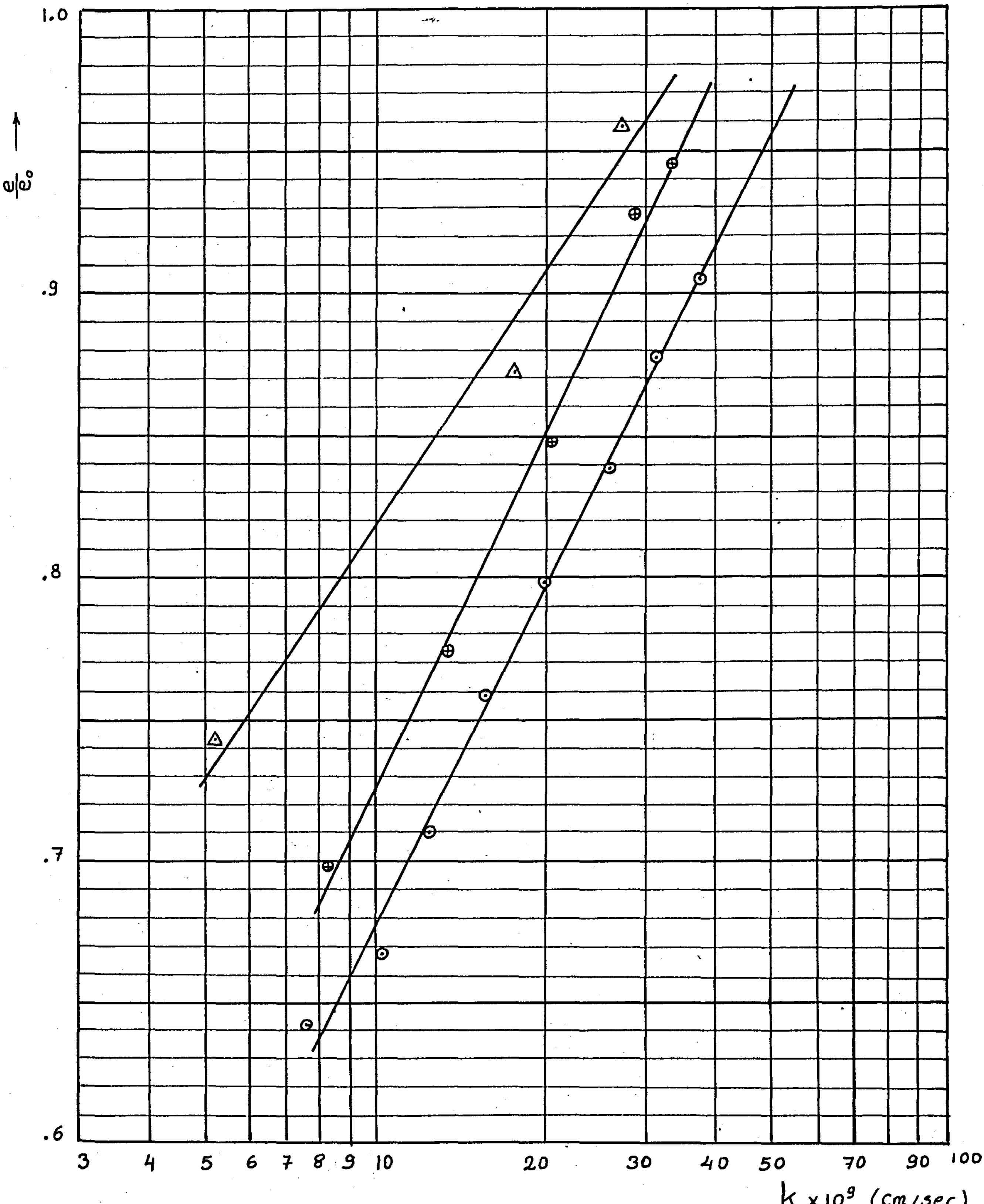
$e/e_o = 0.65$

8.4	6.6	2.7
11.3	7.3	20.0
0.09	1.4	1.33

These matrices were analized by a computer program and the significance levels of each variable at the different stages of consolidation were obtained.

Another statistical analysis was performed in order to investigate a regression between permeability and several physical properties of soils. These properties were chosen as : Activity ($\frac{PI}{\%\ 0.002\ mm}$), PI, e, D_{10} and $\frac{e}{1+e^3}$.

This analysis was done by a computer program (programmed by Dr. M. A. Efroymson, Esso Mathematics and Systems Inc. and modified by M. T. Tümay for IBM 1620) and was repeated for three different values of e/e_o ratio. Log k was used as the dependent variable in this analysis. Then, γ_{dry} was added to the above mentioned variables and the analysis was repeated at the same e/e_o levels, this time by using $k \times 10^9$ as the dependent variable.

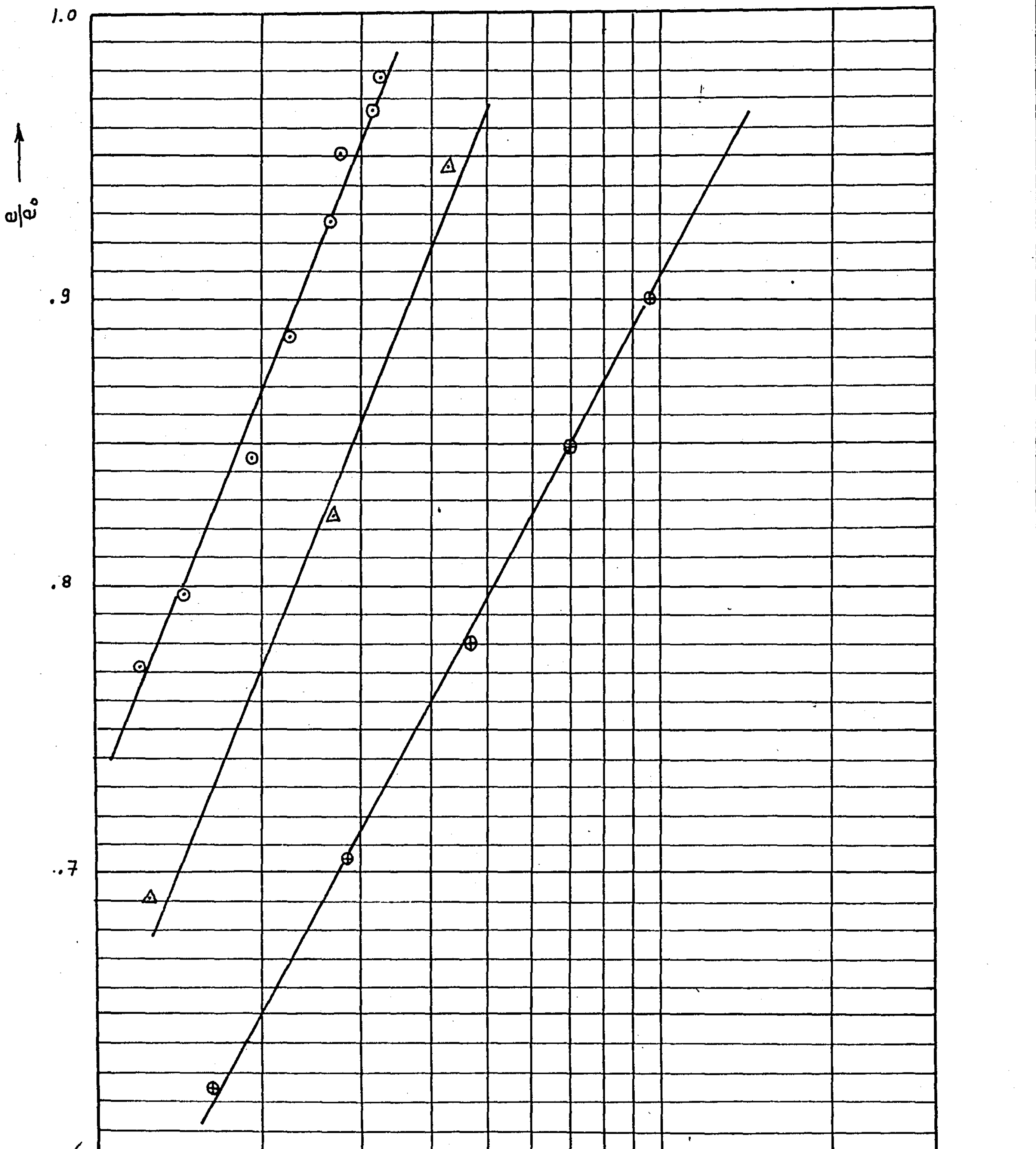


⊙ Sample No. 1, Paşabahçe, $P_c = 1.0$, $\frac{\Delta P}{P} = .5$, – 40

⊕ Sample No. 2, Paşabahçe, $P_c = 2.0$, $\frac{\Delta P}{P} = 1.0$, –100

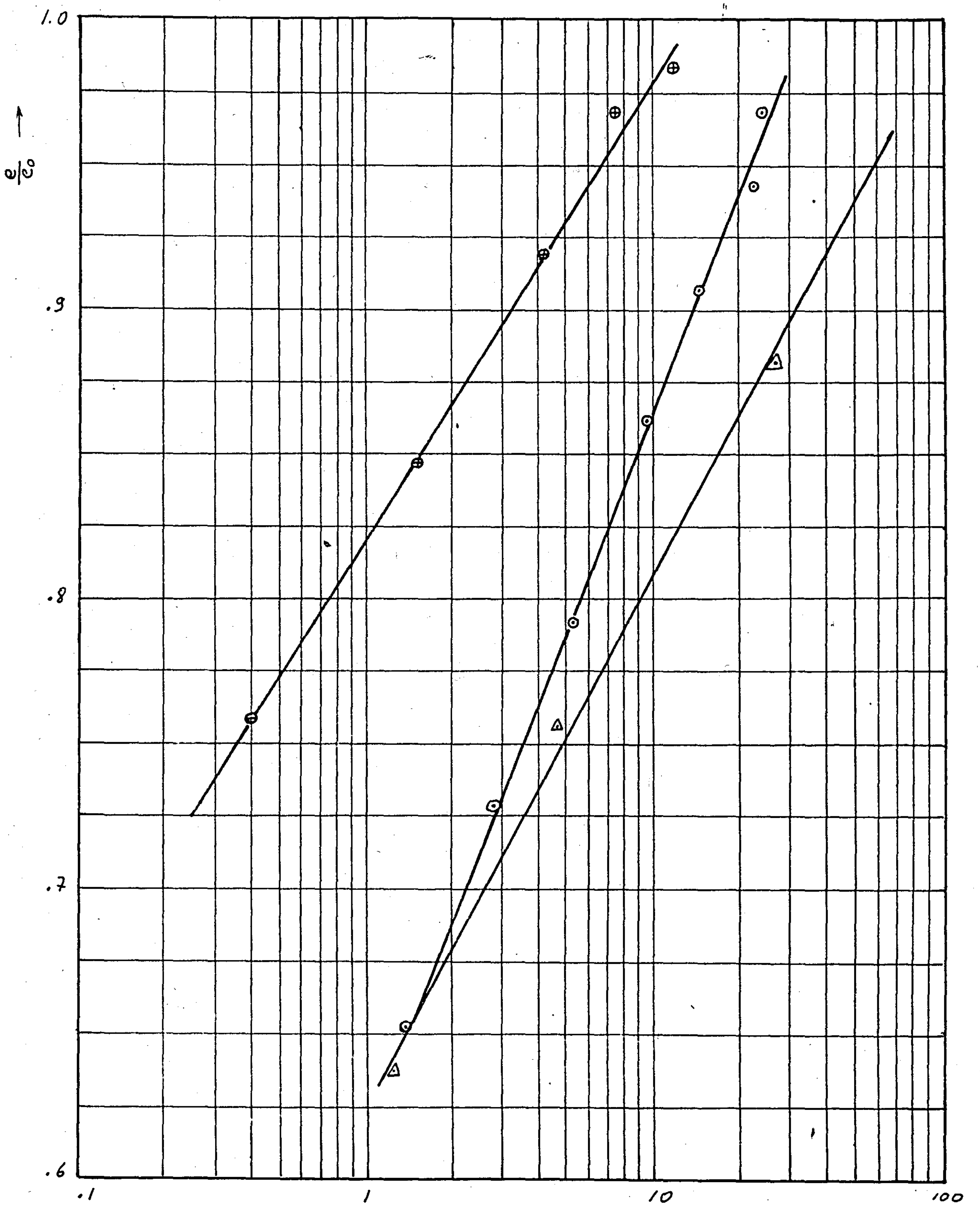
△ Sample No. 3, Paşabahçe, $P_c = 4.0$, $\frac{\Delta P}{P} = 2.0$, –200

Fig (12)



△ Sample No. 4 , Topser, $P_c = 2.0$, $\frac{\Delta p}{p} = 2.0$, -40
⊙ Sample No. 5 , Topser, $P_c = 4.0$, $\frac{\Delta p}{p} = 0.5$, -100
⊕ Sample No. 6 , Topser, $P_c = 1.0$, $\frac{\Delta p}{p} = 1.0$, -200

Fig (13)



⊕ Sample No. 7, Kilyos, $P_c = 4.0$, $\frac{\Delta p}{p} = 1.0$, −40

△ Sample No. 8, Kilyos, $P_c = 1.0$, $\frac{\Delta p}{p} = 2.0$, −100

⊙ Sample No. 9, Kilyos, $P_c = 2.0$, $\frac{\Delta p}{p} = 0.5$, −200

Fig (14)

CHAPTER VI

RESULTS, DISCUSSIONS and CONCLUSIONS

Results :

The changes in the permeability values of each sample with the increasing consolidation pressures were obtained. These curves are given in the following page (Figures 15, 16, and 17), together with e vs log P curves (Figures 18, 19, and 20).

F values, that is the significance levels of each variable at different stages of consolidation were obtained as :

e/e_o / Variable	0.95	0.90	0.85	0.80	0.75	0.70	0.65
Soil type	3.93	4.28	5.98	6.88	9.69	12.52	16.95
Granulometry	1.42	1.16	1.03				
Preconsolidation load	6.93	4.86	4.63	3.97	4.32	4.49	5.10
$\Delta p/p$				1.15	1.36	1.60	1.95

These results are also shown on a F versus e/e_o curve (Figure 21) to demonstrate their relative effects on permeability at different stages of consolidation. On that graph percentage evidence levels (2) are also indicated.

As it is seen from this diagram, the effects of the variables are in the following order in the final stage :

1. Soil type
2. Preconsolidation load
3. $\Delta p/p$

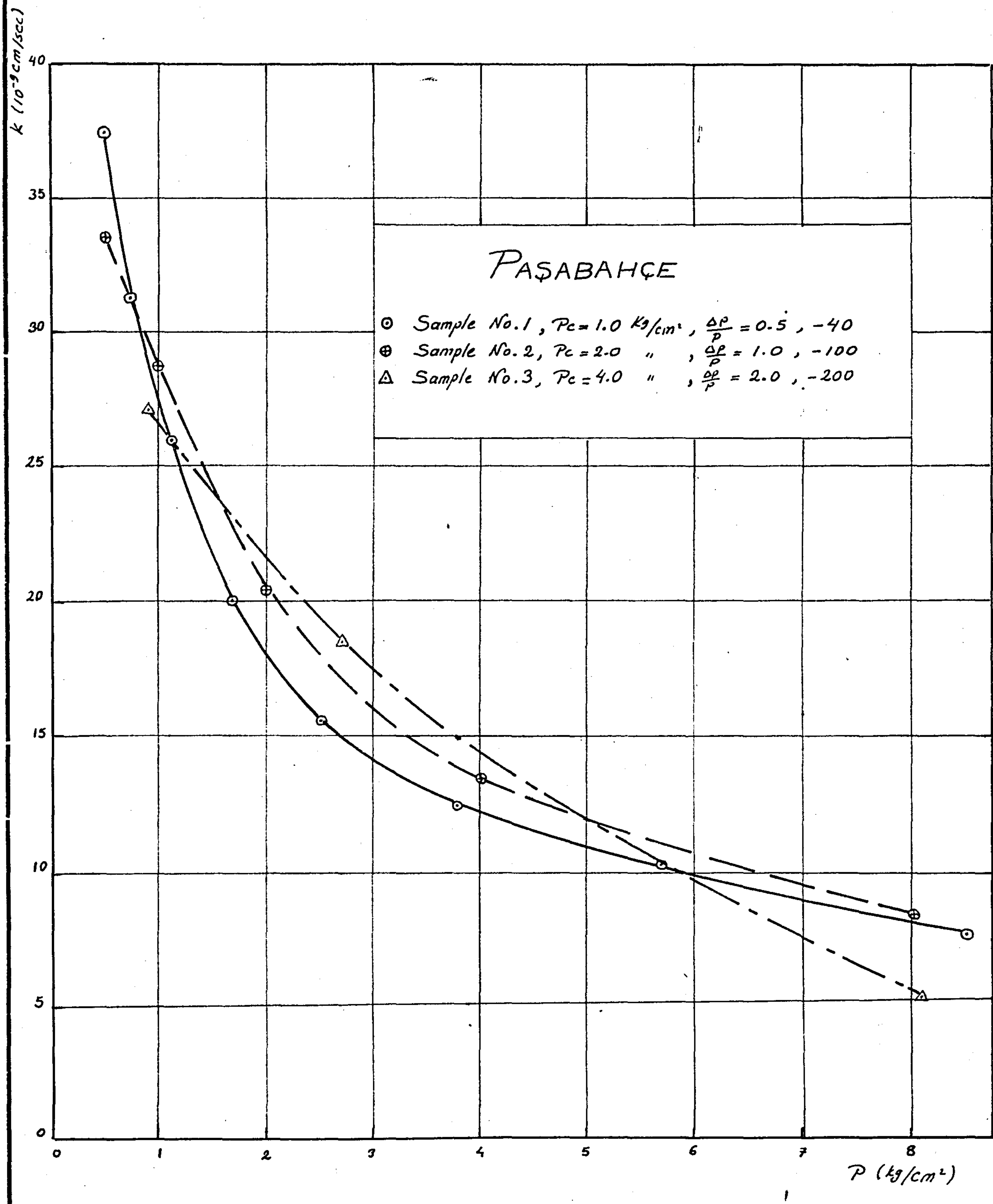


Fig (15) Permeability vs Consolidation pressure.

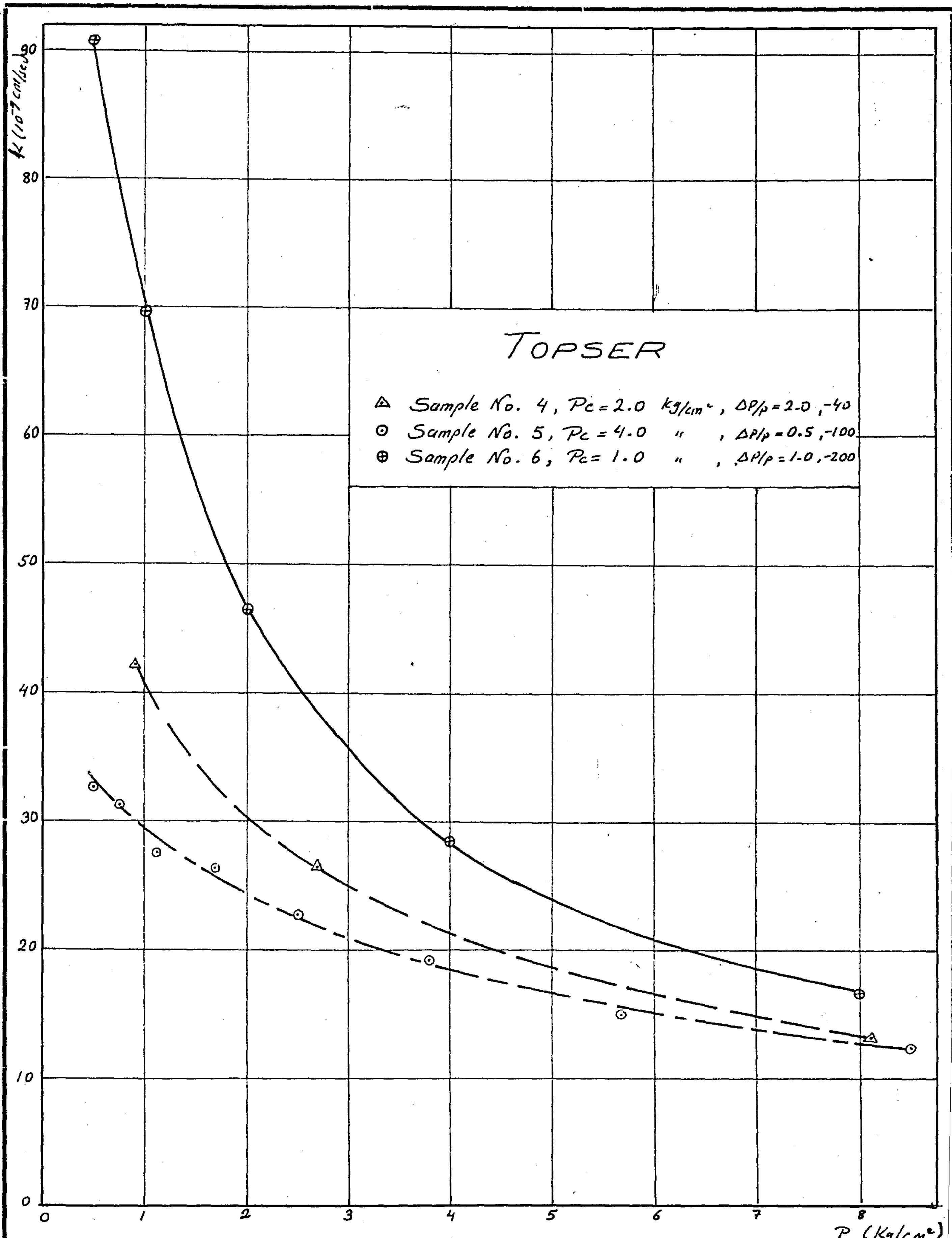


Fig. (16) Permeability vs. Consolidation pressure.

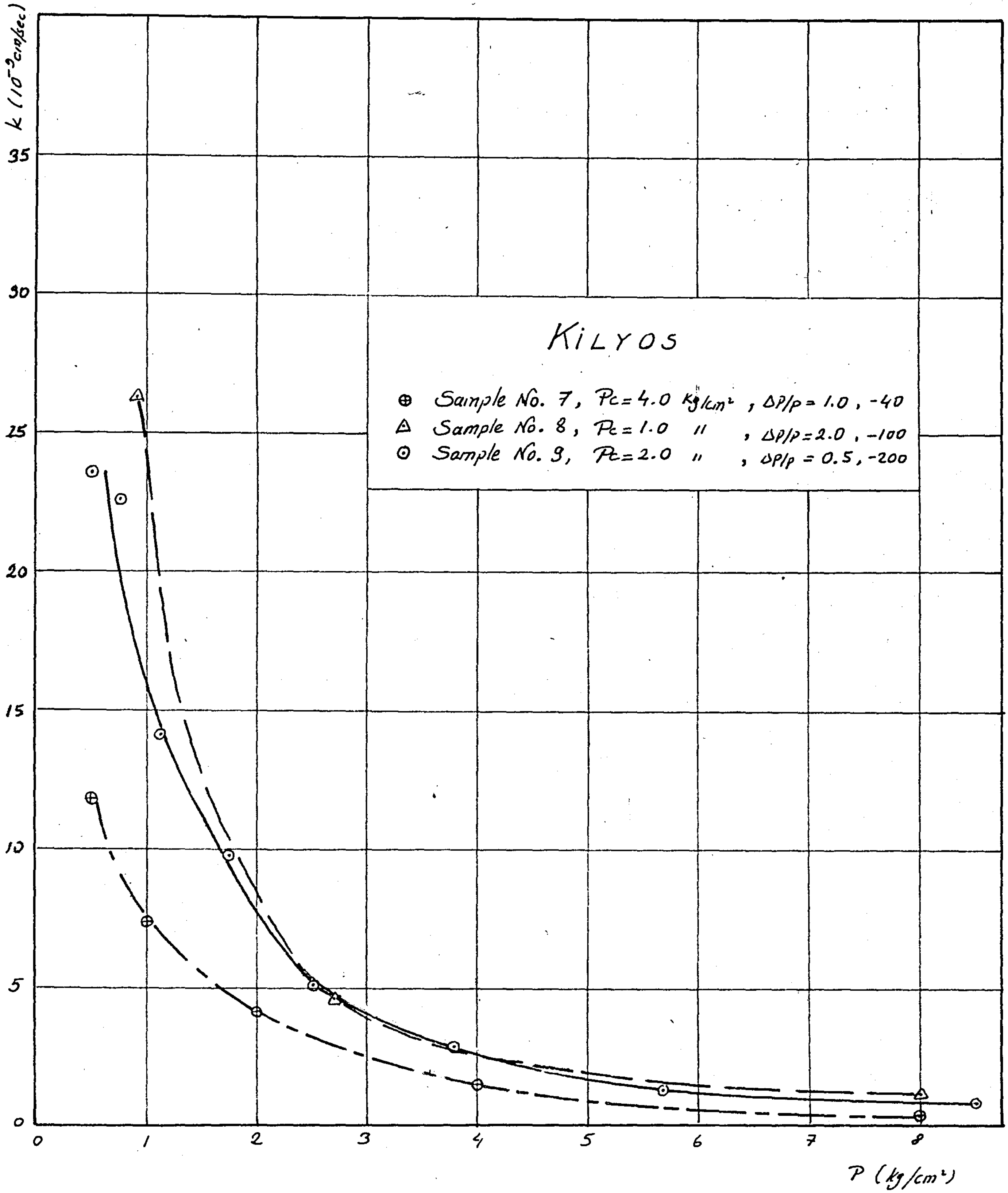


Fig.(17) Permeability vs Consolidation pressure.

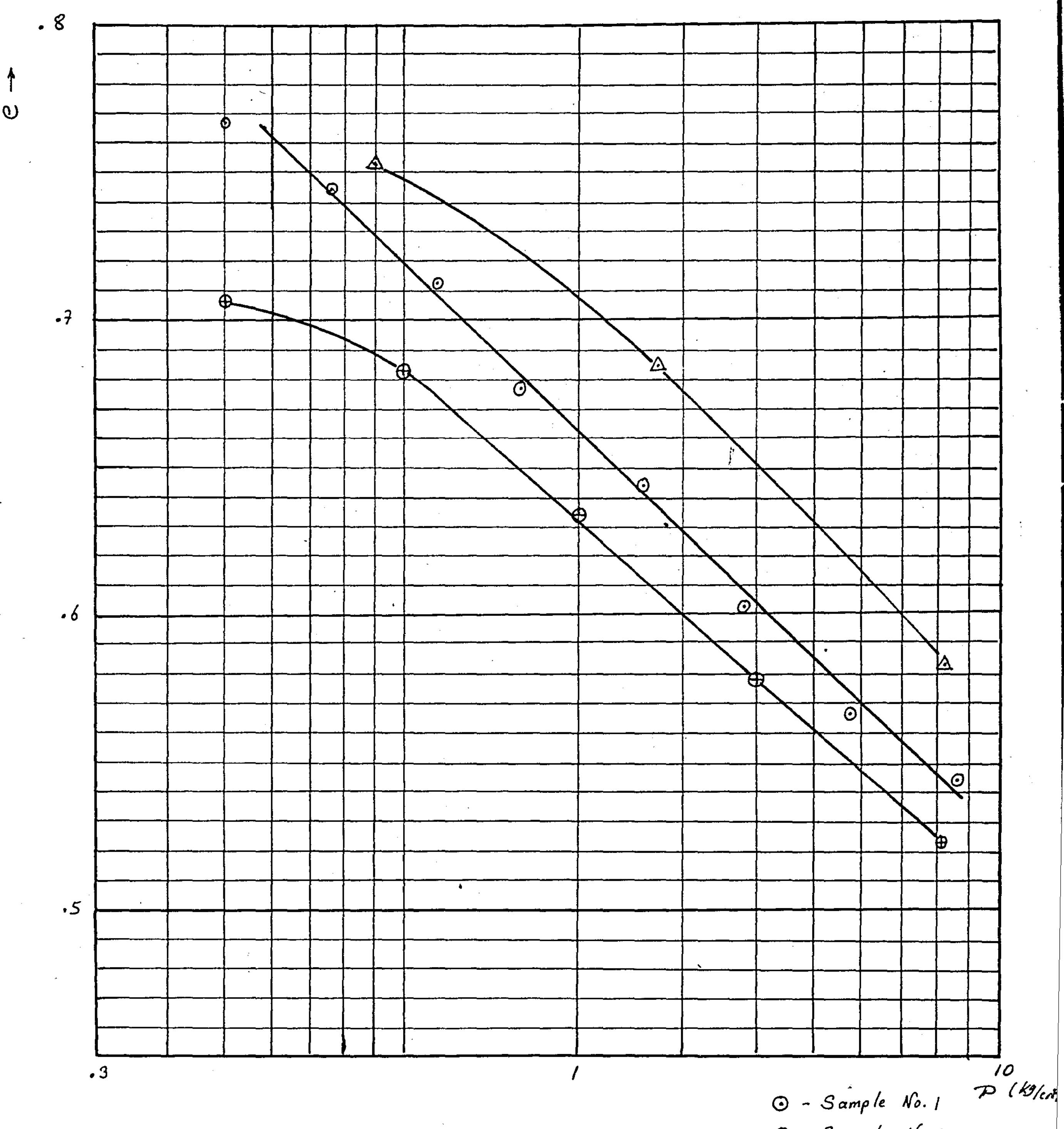


Fig (18)

e vs log P

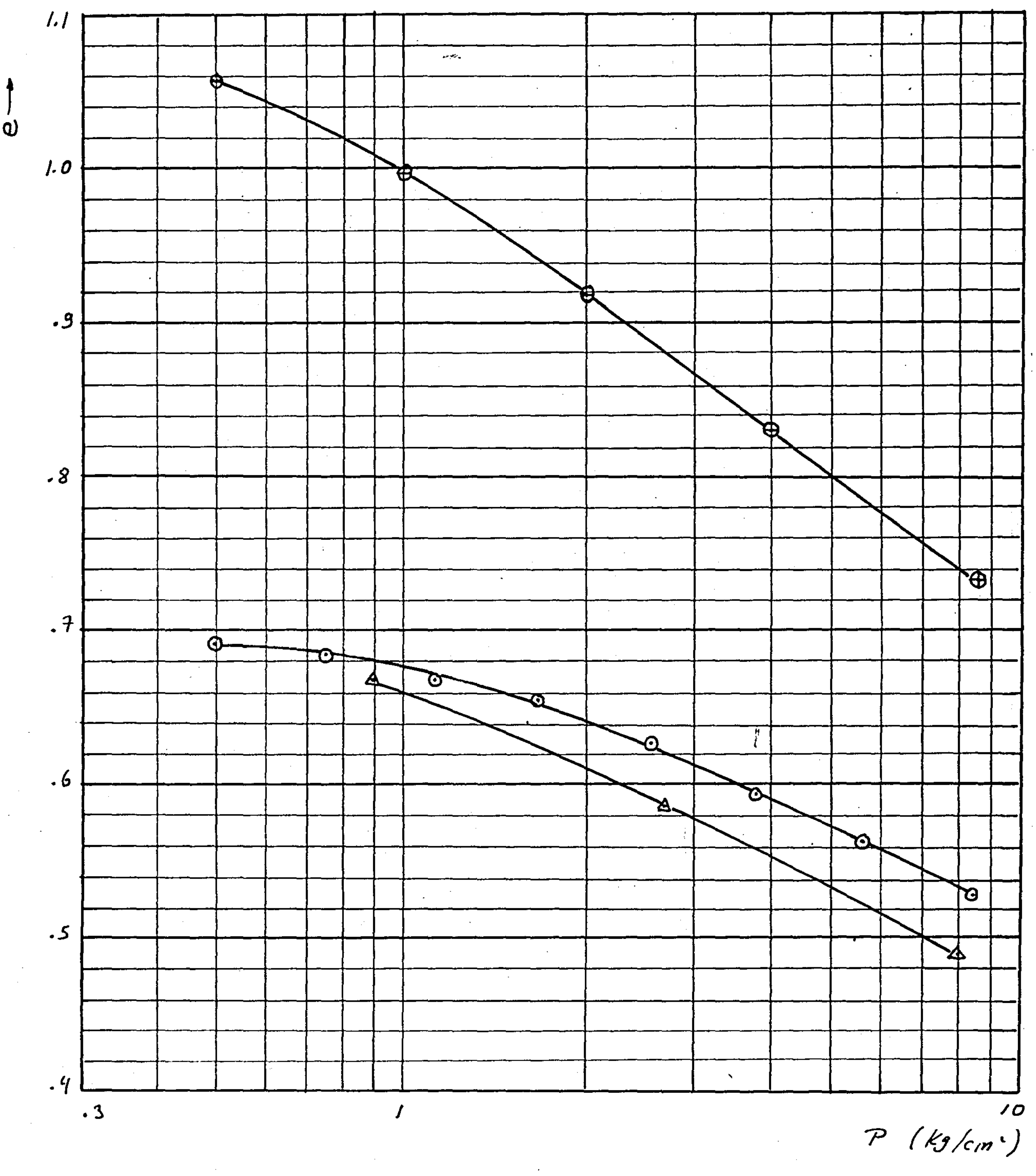


Fig (19)

e vs log P

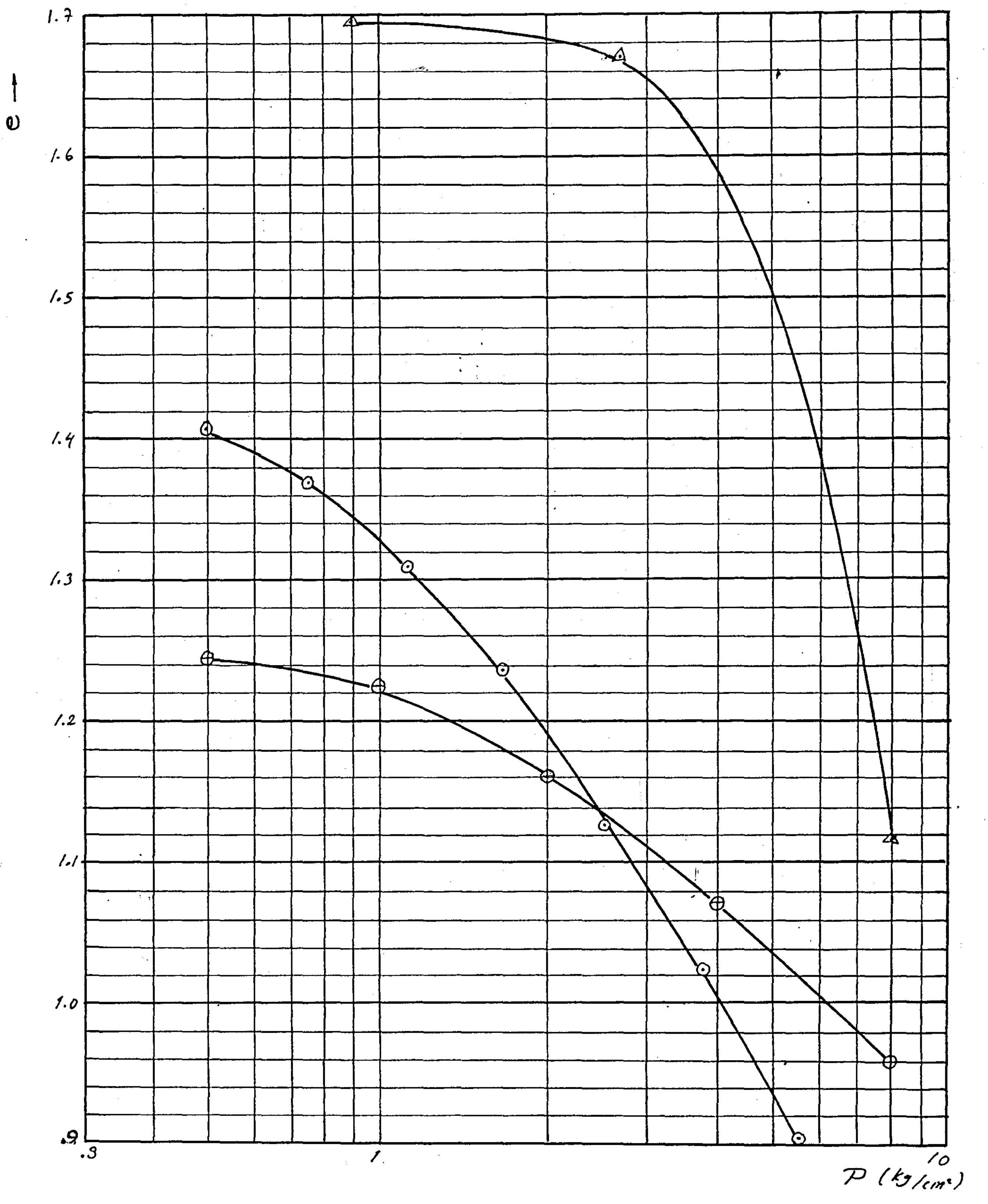


Fig (20)

e vs log P

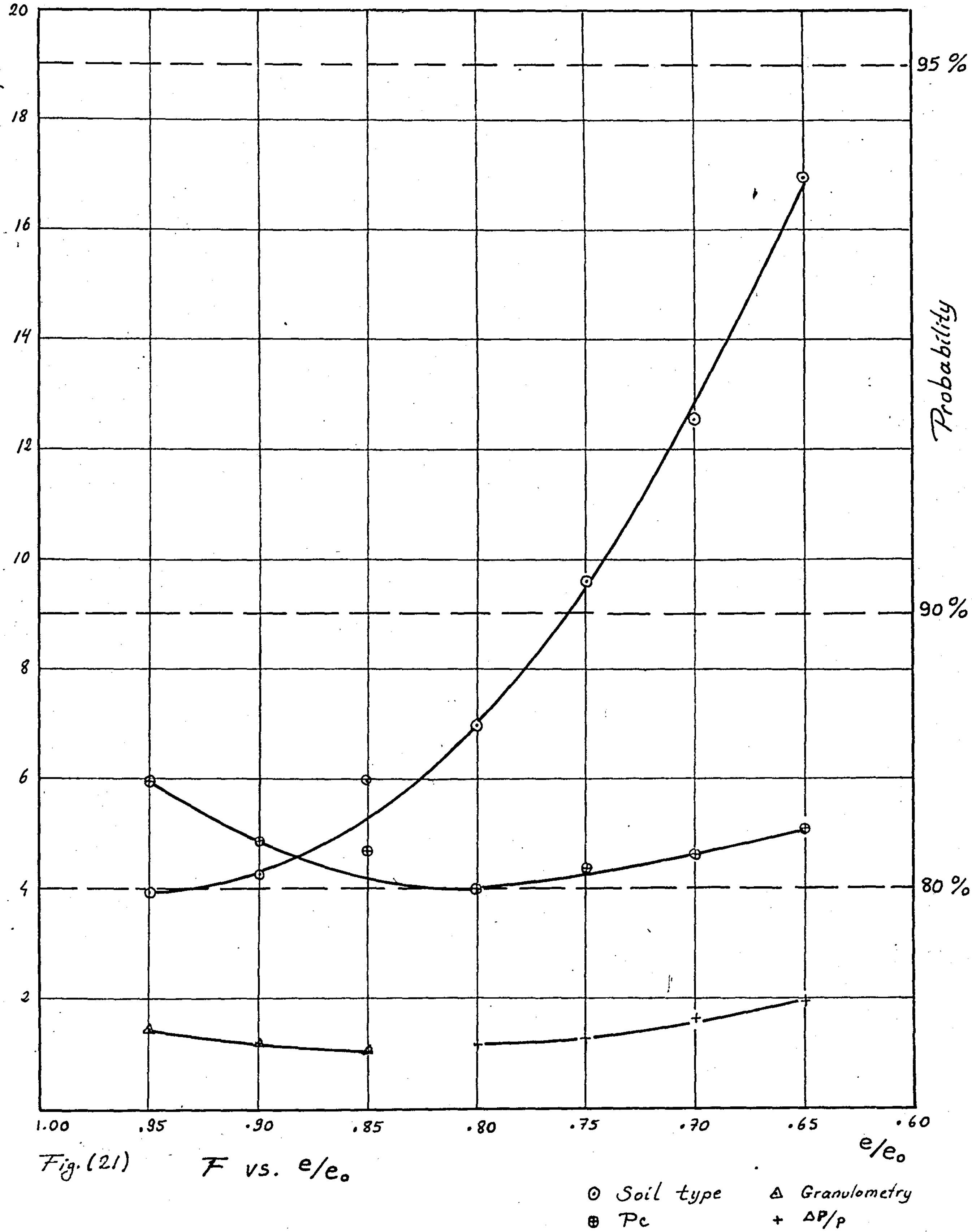


Fig. (21) F vs. e/eo

4. Granulometry.

In the regression analysis, correlation coefficients of each variable with respect to log k and k were obtained at three different levels of e/e_o. These values and these changes with e/e_o ratio are given in two "correlation coefficient vs e/e_o" graphs (Figures 22 and 23).

Variables with significance levels greater than 2.50 were taken into the second step of regression analysis and regression coefficients were calculated. Thus, the following equations were obtained for $e/e_o = 0.70$ and $e/e_o = 0.80$ levels respectively.

$$\log k = -9.38157 - (0.26261)(\text{Activity}) + (3.30844)\left(\frac{e}{1+e}\right) \qquad (e/e_o = 0.70)$$

$$\log k = -9.44871 - (0.03025)(\text{PI}) + (1.03160)(e) + (3.04016)\left(\frac{e}{1+e}\right) \qquad (e/e_o = 0.80)$$

$$k \times 10^9 = -27.906 - 13800.353\,(D_{10}) + 96.436\left(\frac{e}{1+e}\right) \qquad (e/e_o = 0.70)$$

$$k \times 10^9 = 10.106 - 32.297\,(\text{Activity}) + 43.839\,(e) \qquad (e/e_o = 0.80)$$

Log k equations give better results.

No variable with an F value of greater than 2.50 were found for $e/e_o = 0.90$ cases.

The values of log k calculated from the first two equations are given below together with the experimentally found values :

$e/e_o = 0.70$:

Calculated	Measured	Difference
-7.96803	-7.95078	-0.01725
-8.05977	-8.06048	0.00071
-7.95495	-8.38721	0.43226
-8.02236	-7.84163	-0.18073
-8.02831	-8.03621	0.00790
-7.70866	-7.56543	-0.14323
-8.08873	-8.06048	-0.02825
-8.47474	-8.58502	0.11028
-8.41758	-8.25963	-0.15795

$e/e_o = 0.80$

Calculated	Measured	Difference
-7.72368	-7.69680	-0.02688
-7.88385	-7.82390	-0.05995
-7.81818	-7.06048	-0.75770
-7.78641	-7.63827	-0.14814
-7.79601	-7.83268	0.03667
-7.30813	-7.29243	-0.01570
-8.33476	-8.06048	-0.27428
-8.12600	-8.06048	-0.06552
-8.13025	-8.25963	0.12938

The results obtained from the last two equations are given in appendix E as computer outputs.

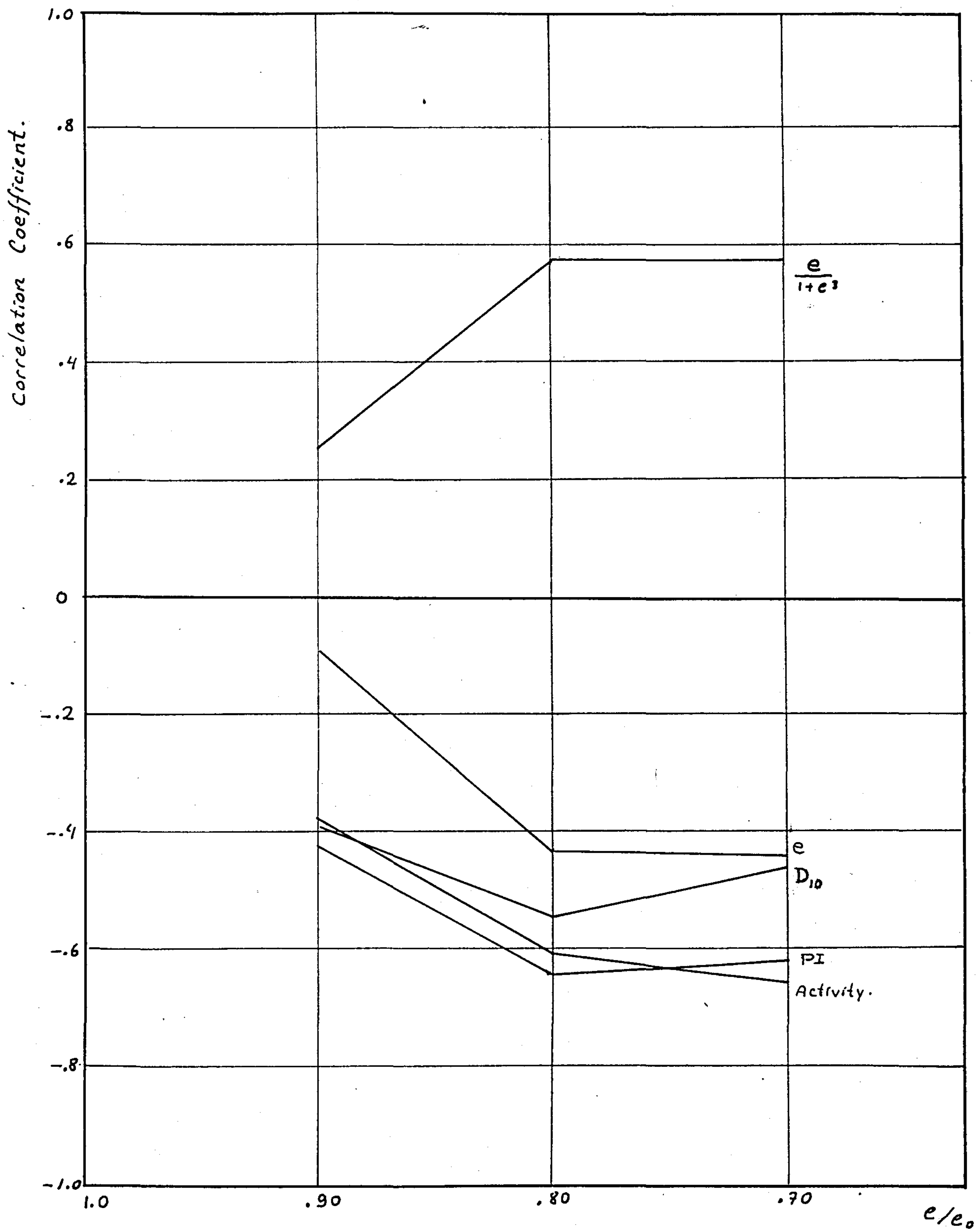


Fig. (22) Correlations with log k.

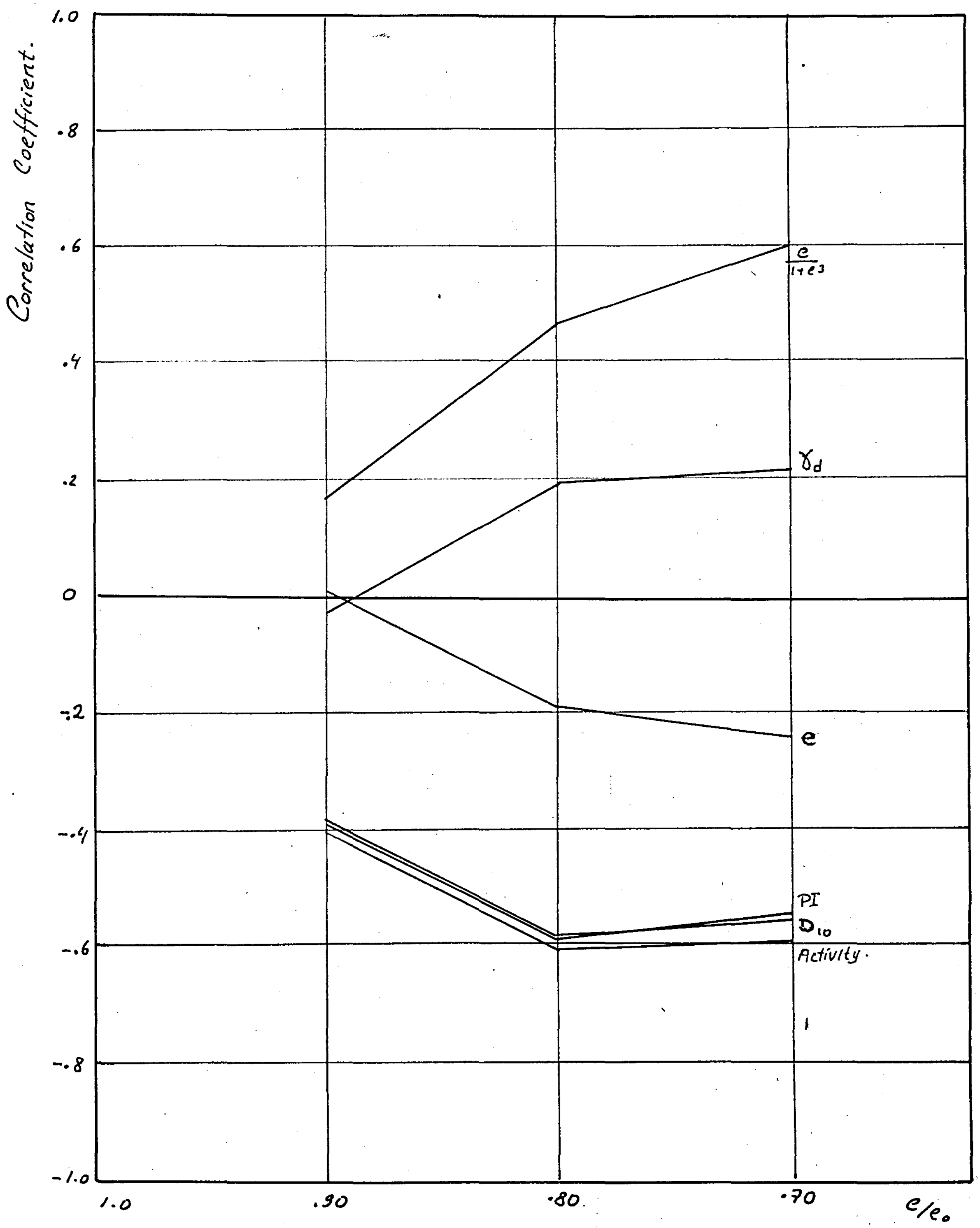


Fig (23) Correlations with k

Discussion of Results :

The order of importance of four variables are in the expected manner with the exception of the effect of granulometry.

The analysis results show that granulometry has an unimportant effect on permeability. But it is a well known fact granulometry is one of the most important factors. But this does not mean that the test results are in contradiction with this fact. Because, the sieving operation was done on dry soils when the test samples were prepared. And since it is almost impossible to break a clayey soil to its individual particles by mechanical means, actually the lumps of soil were taken as soil particles. This was confirmed when wet analysis of these samples were made in order to find their activity and Hazen's coefficient, D_{10} values. As it will be seen from the gradation curves obtained from wet analysis which are given in appendix, about 60-70 % of +100 portions were found to be passing No.200 sieve. Therefore, all the samples were almost of same granulometry, and a granulometry effect on permeability should not be expected. Since the effect of granulometry was found to be insignificant, this confirms the validity of the variance analysis.

Soil type is found to be the most important factor. And this may be attributed to the properties of predominant clay minerals in the soil. The thickness of water film around the soil particles are affected by the clay mineral. And since this nonflowing film of water blocks the movement of free water, permeability is affected by the type of soil.

In this set of experiments, soil type had another important effect. The lumps of soil were taken in preparing the samples as the actual grains. And the actual grain size distribution of the samples were much related to the distribution of individual particles in those lumps. Since each soil had a different grain size distribution in the lumps, actual granulometry of the samples were also affected by the soil type.

As it is seen from F versus e/e_0 graph, the importance of soil type increases as the consolidation proceeds. This fact is in agreement with Terzaghi's theory that when soils are excessively consolidated, permeability is affected only by the mineral structure regardless of the other factors.

Preconsolidation load is found to be the second important factor. In fact, in the early stages of consolidation it is the most important one. This is the expected result because the arrangement of soil particles is related to the preconsolidation. And in the early stages void ratio is also dependent on the preconsolidation load.

Although it shows an increase as the consolidation steps increase, p/p is still the less important one of the above mentioned factors.

The results of regression analysis show that permeability is significantly related to activity (the ratio of plasticity index to percentage weight of grains smaller than 2 microns size), $\frac{e}{1+e}$) and plasticity index itself. Especially the relation between permeability and activity is highly significant. This result also confirms the great importance of soil type on permeability.

Also, the correlation coefficients are determined between each pair of variables entering into the regression analysis.

Conclusions :

At the end of this set of experiments, soil type is found to be the most important factor in permeability. Preconsolidation load also turned out to be an important factor in permeability of consolidated clays. The effects of the rate at which the consolidation load is increased and granulometry are less significant. The result related to the effect of granulometry is due to the deficiency of dry sieving.

It may also be concluded that there is a significant correlation between the activity of a soil and its permeability. Similar correlations are also found between permeability and plasticity index and $\frac{e}{1+e^3}$ values of soils.

Although the experiments were run only with nine samples, the results are reliable. The experiments were carefully planned beforehand according to statistical rules. That made it possible to obtain quite satisfactory results even with nine samples. The probability levels are rather high in spite of the few number of experiments (80-90 %). If a more extensive experimentation will be run with a greater number of samples in the same statistical model, it may be possible to obtain results with almost 100% significance.

The formulas relating permeability to activity, $\frac{e}{1+e^3}$ and Plasticity Index derived with calculations based on statistical methods, may be considered the most important achievement of this experimentation. Those equations make it possible to determine permeability which require difficult experimentation itself, by the use of relatively easily found soil properties.

As a further research on this subject, to run another statistically predetermin set of experiments with a greater number of samples (e.g. 4x4 or 5x5 Greco-Latin models) may be suggested. It may be possible to obtain more accurate formulas to relate permeability to soil properties as a result of this research. It may also be possible to determine the actual effect of granulometry by using wet sieving in preparation of the samples for that set of experiments.

Another important achievement of such a research, provided that radial drainage is prohibited, may be the comparison of permeability values which will be calculated from consolidation data, with the experimental permeability measurements. That comparison may test the validity of theoretical values at different stages of consolidation.

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APPENDICES

A. Preconsolidation Curves

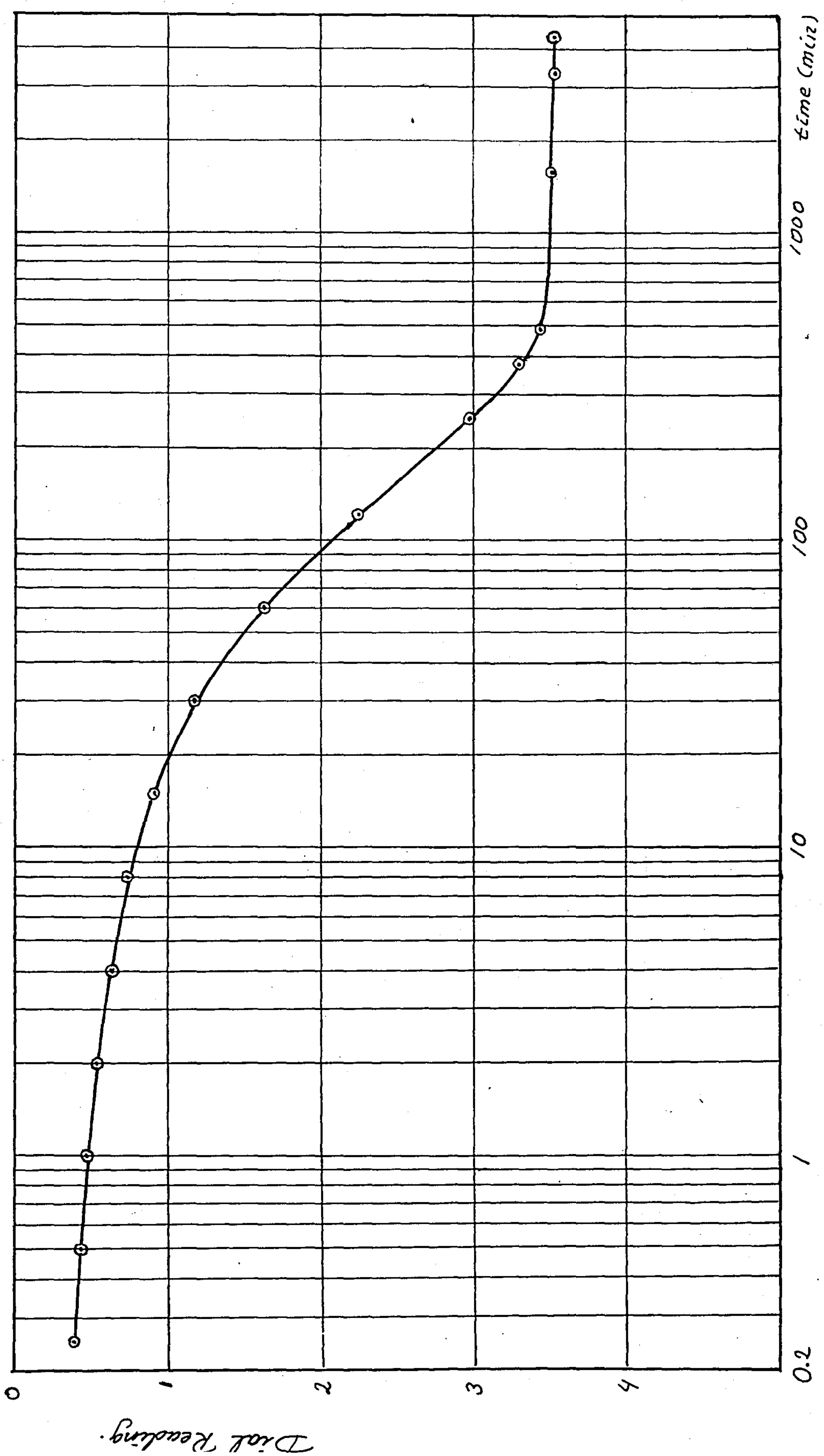
B. Consolidation Curves

C. Calculations

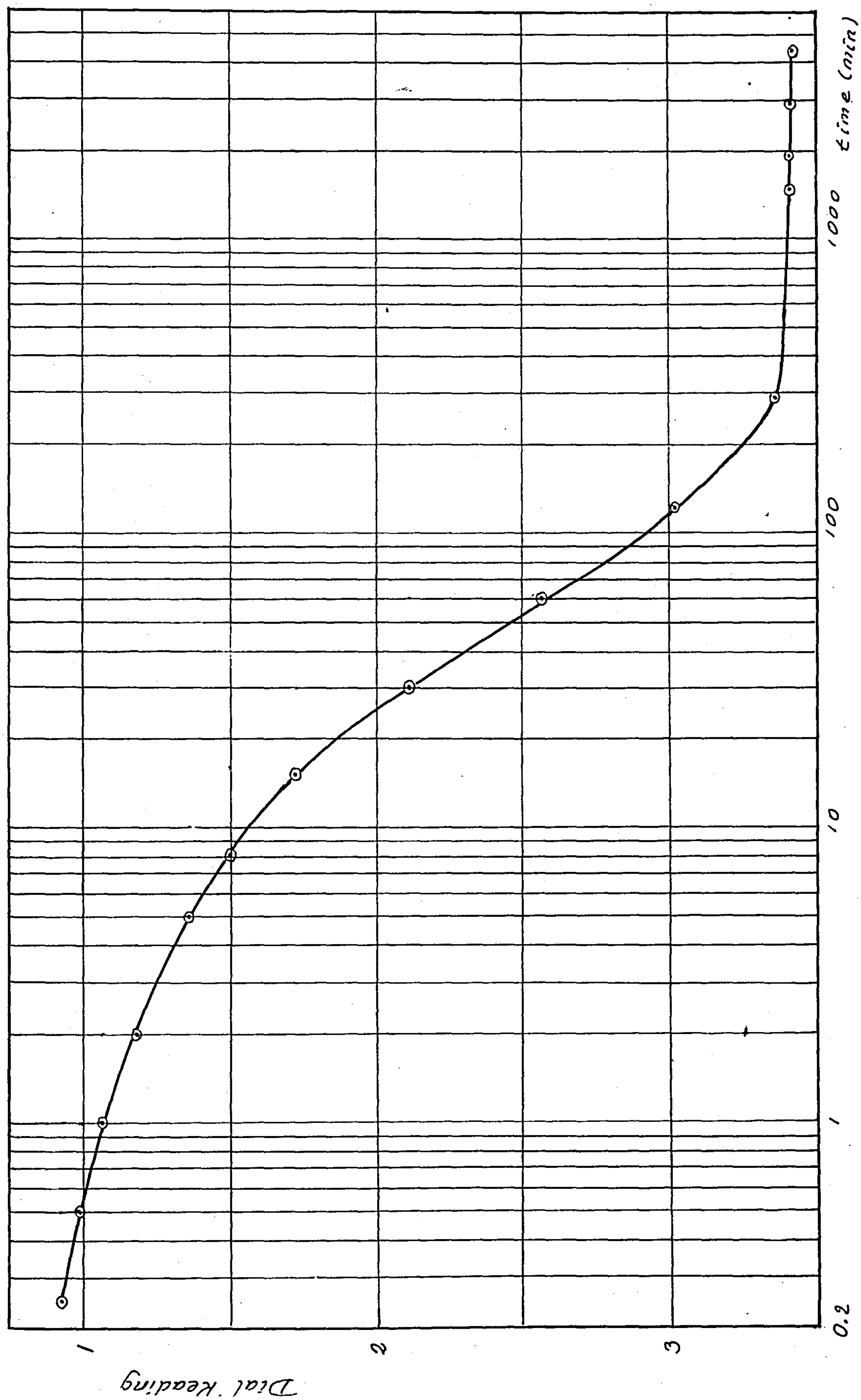
D. Gradation Curves

E. Computer Programs and Results.

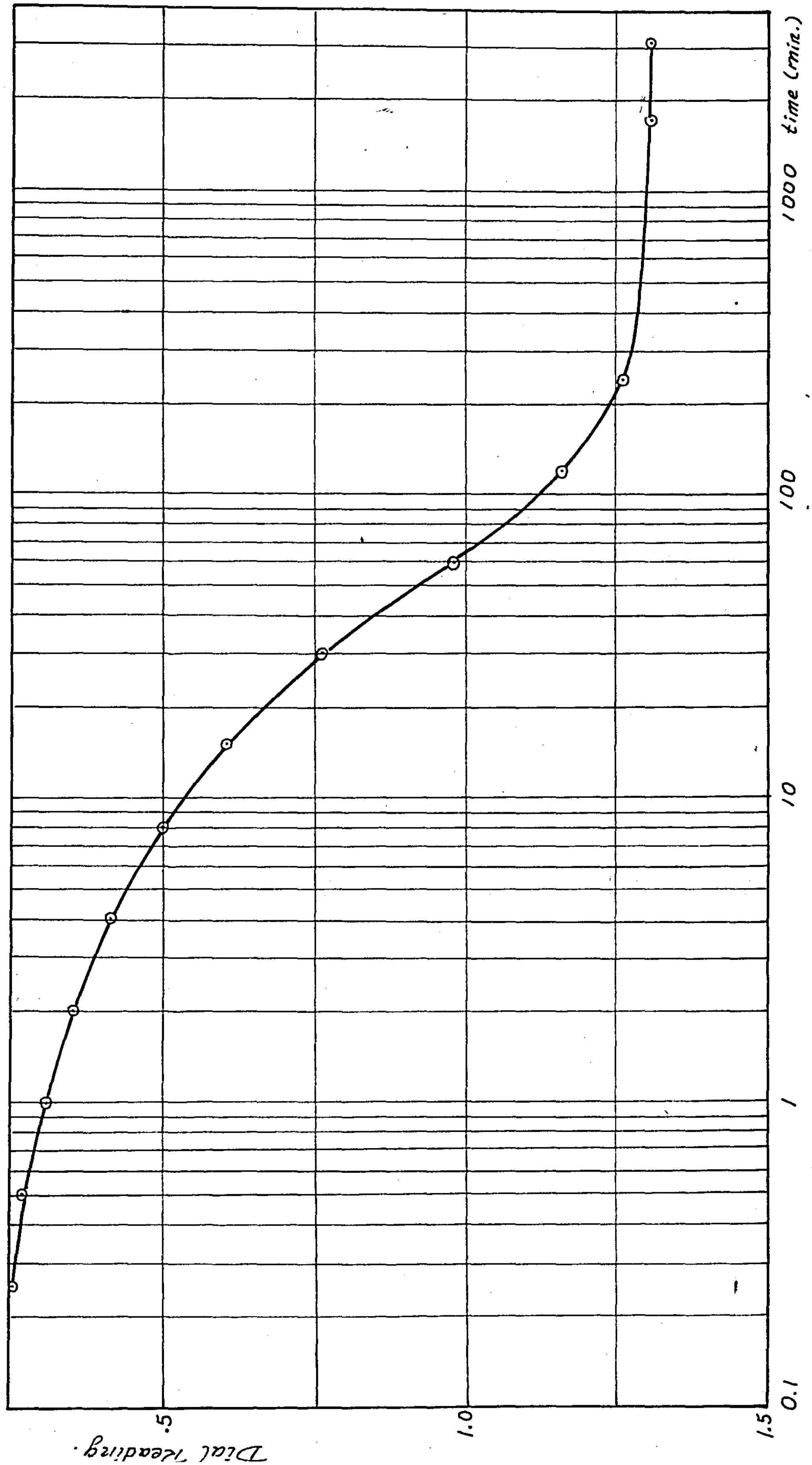
A. Preconsolidation Curves



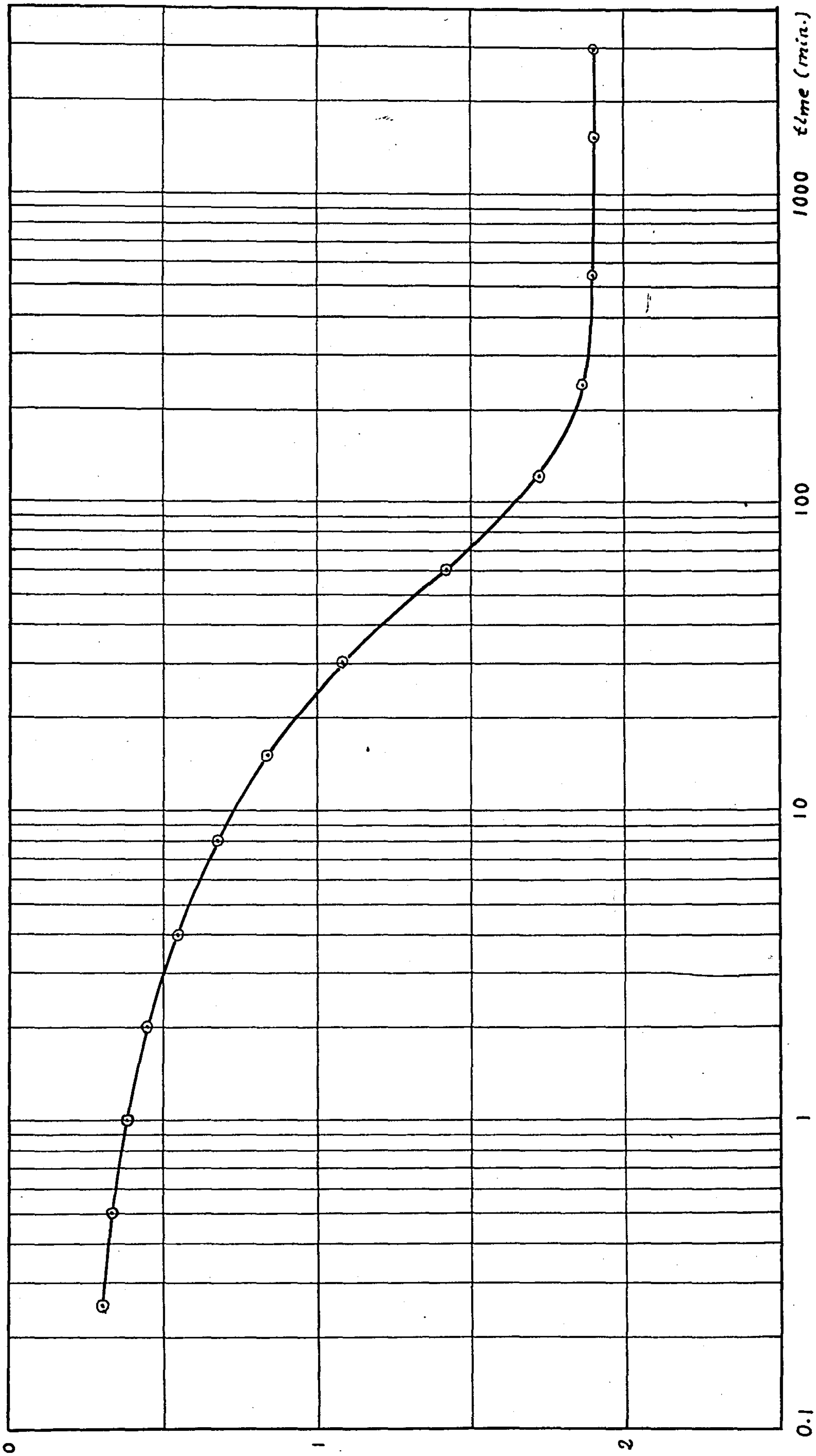
Sample No. 1 - $P_c = 1.0$ Kg/cm²



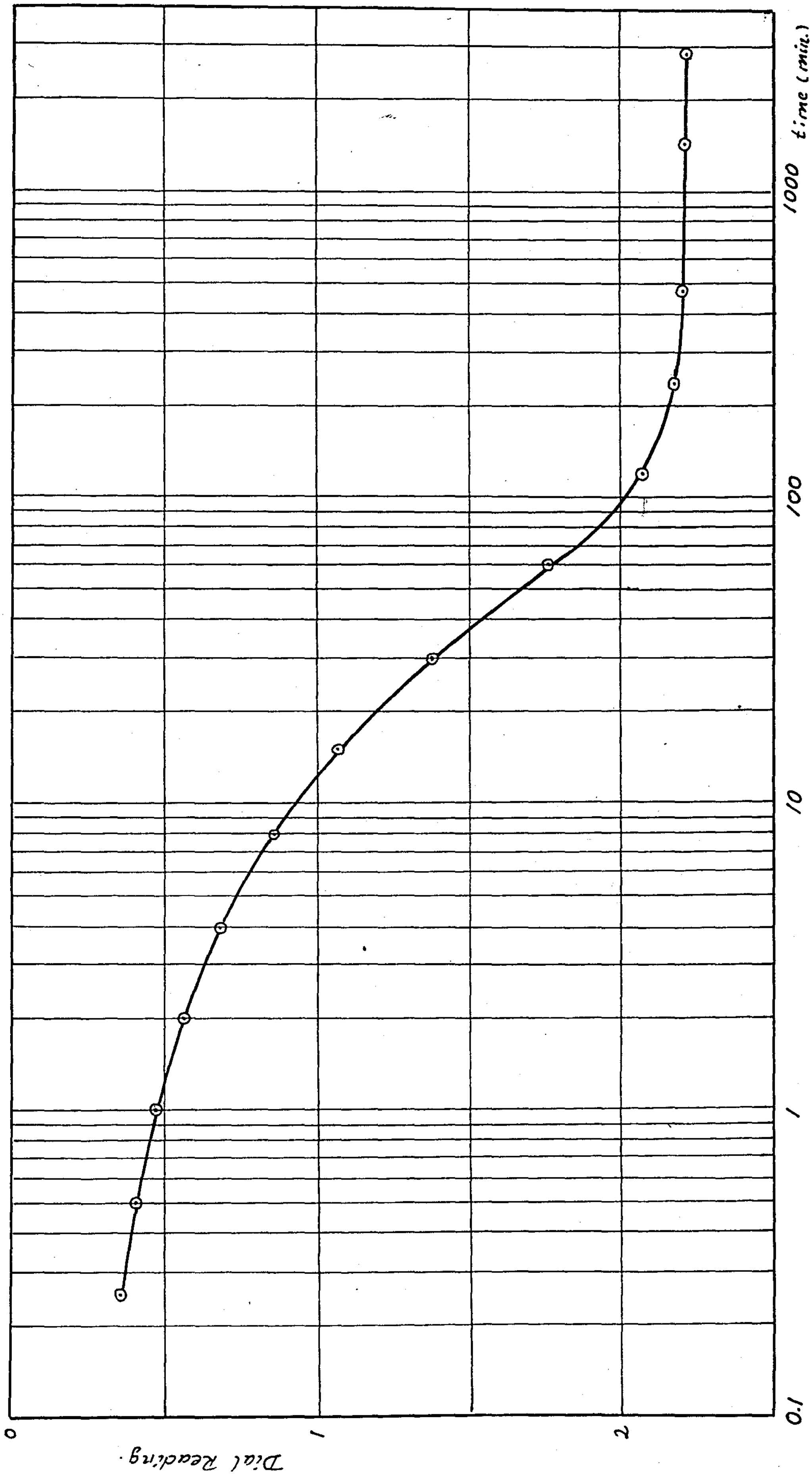
Sample No. 2 - Pc. = 2.0 Kg/cm²



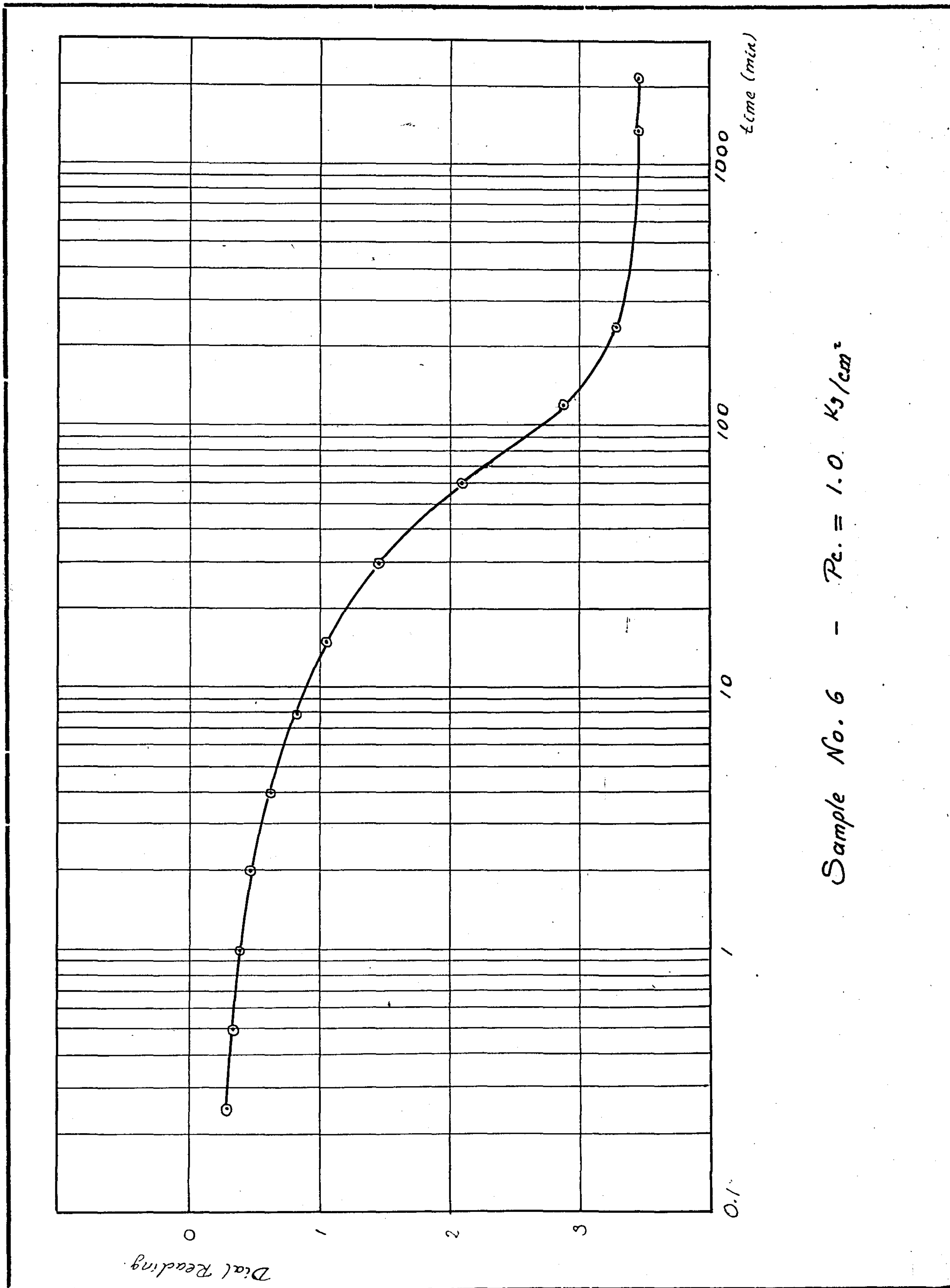
Sample No. 3 - $P_c = 4.0$ Kg/cm²

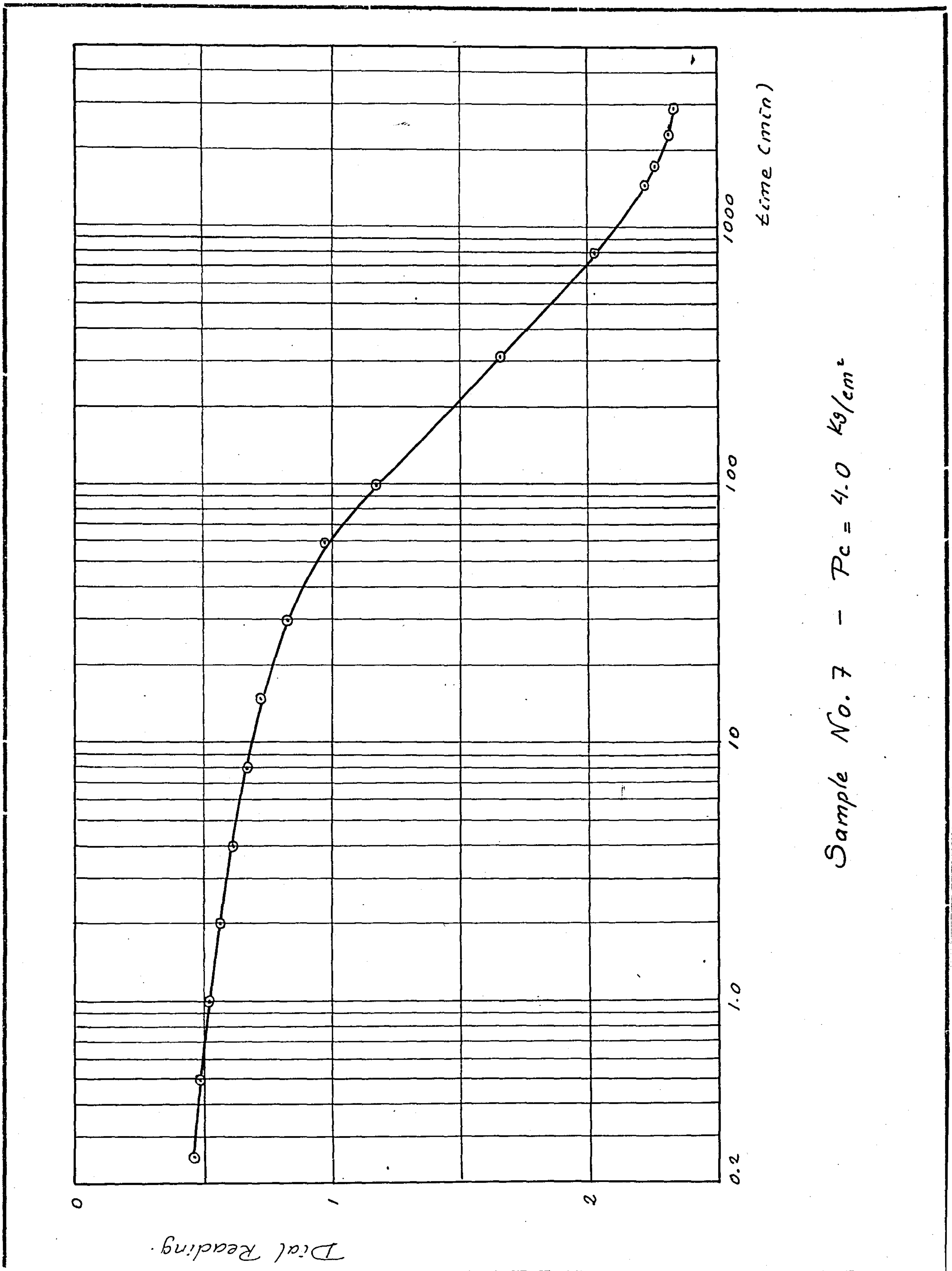


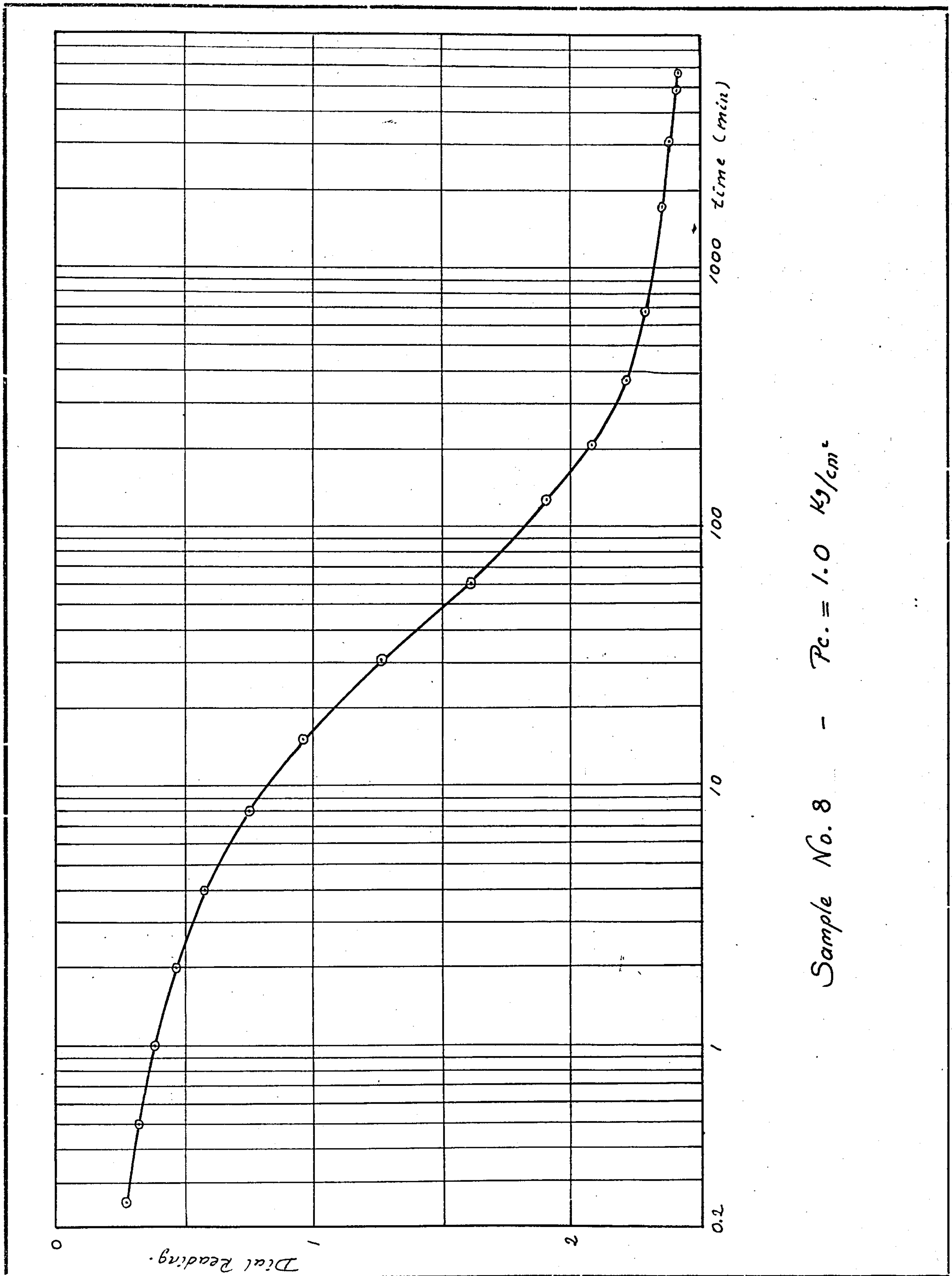
Sample No. 4 - $P_c = 2.0$ Kg/cm²

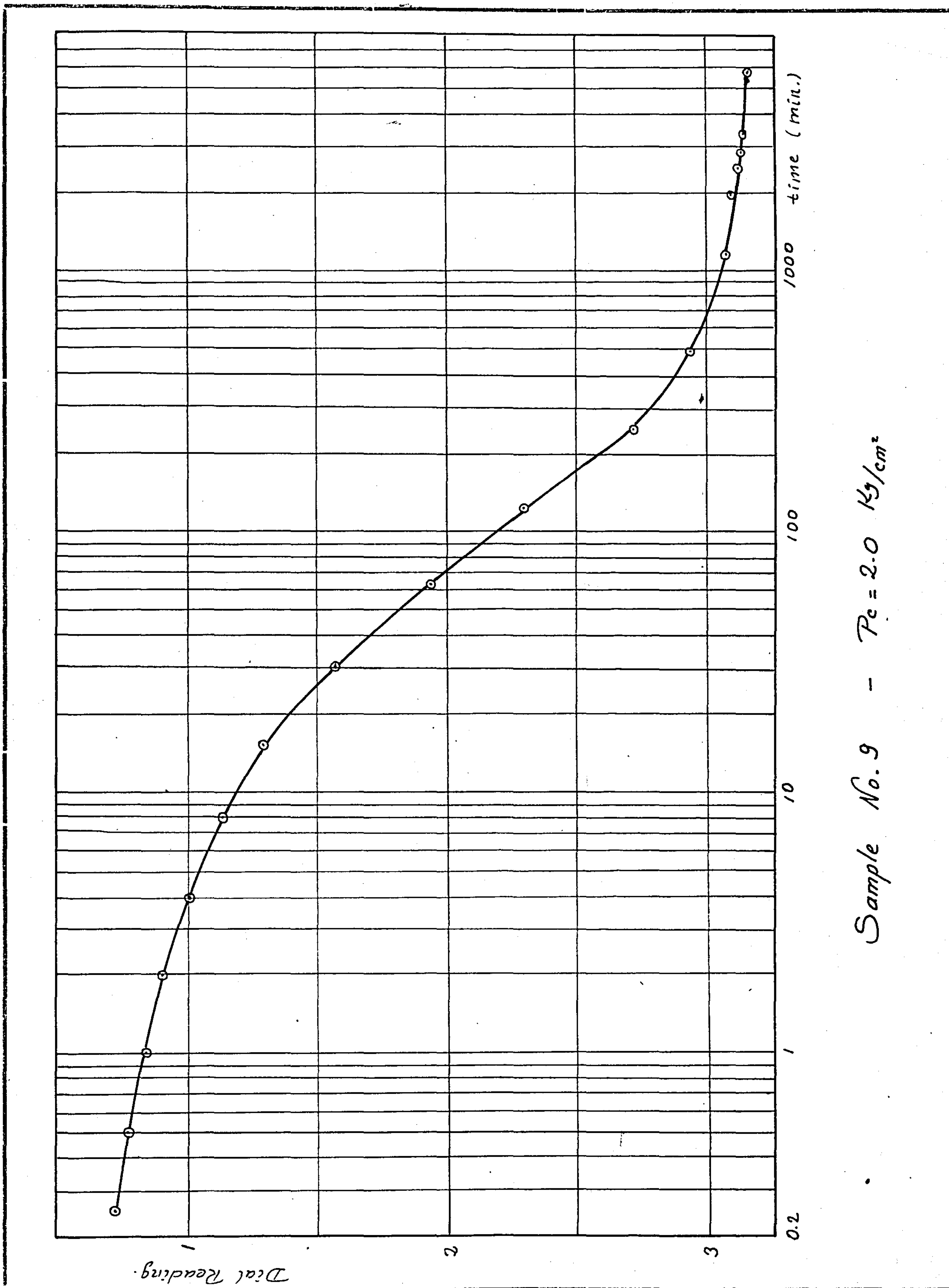


Sample No. 5 - P_c. = 4.0 Kg/cm^2

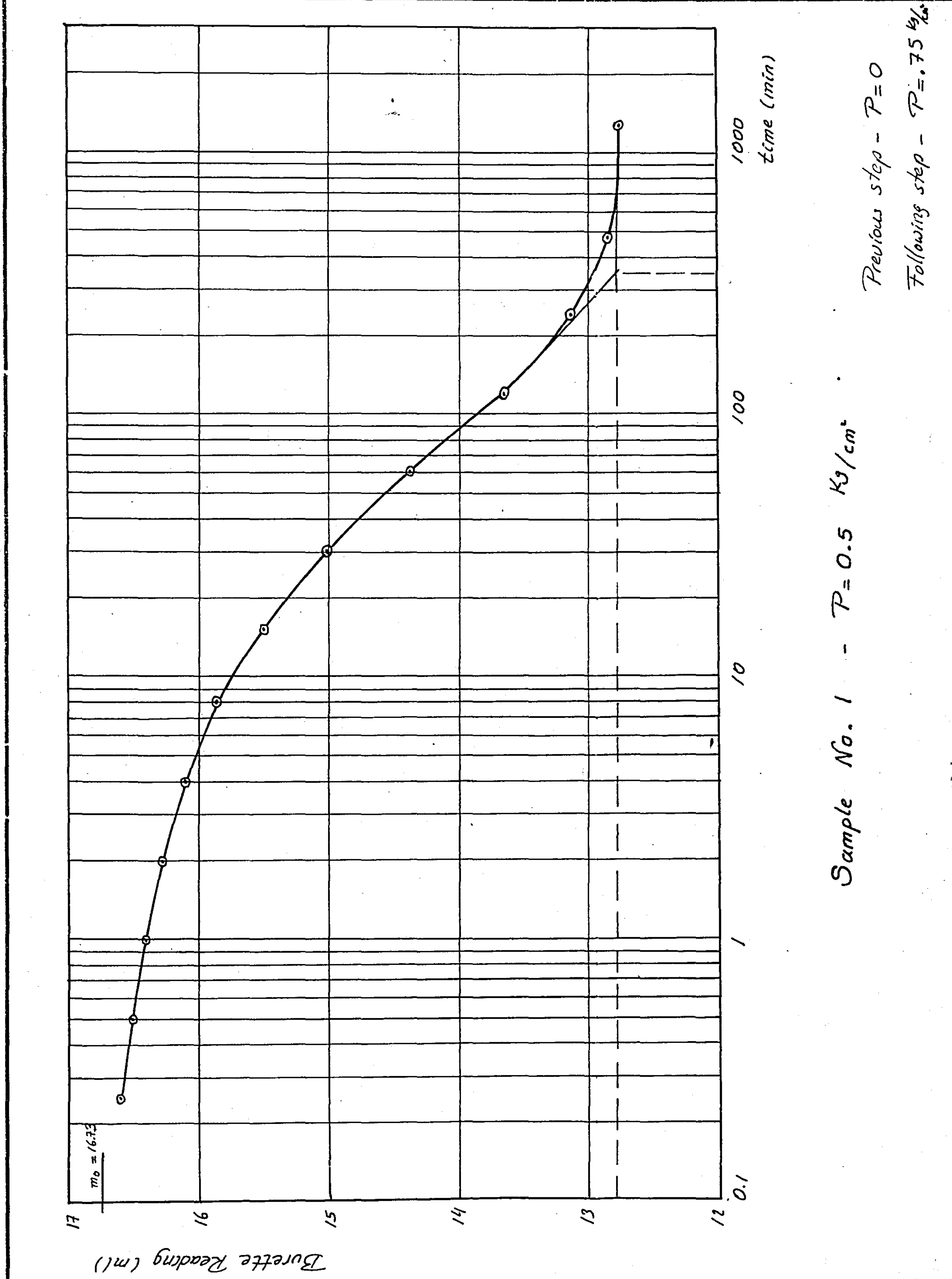

time (min)
1000
100
10
1
0.1
0
1
2
3
Dial Reading
Sample No. 6 - Pc. = 1.0 Kg/cm²

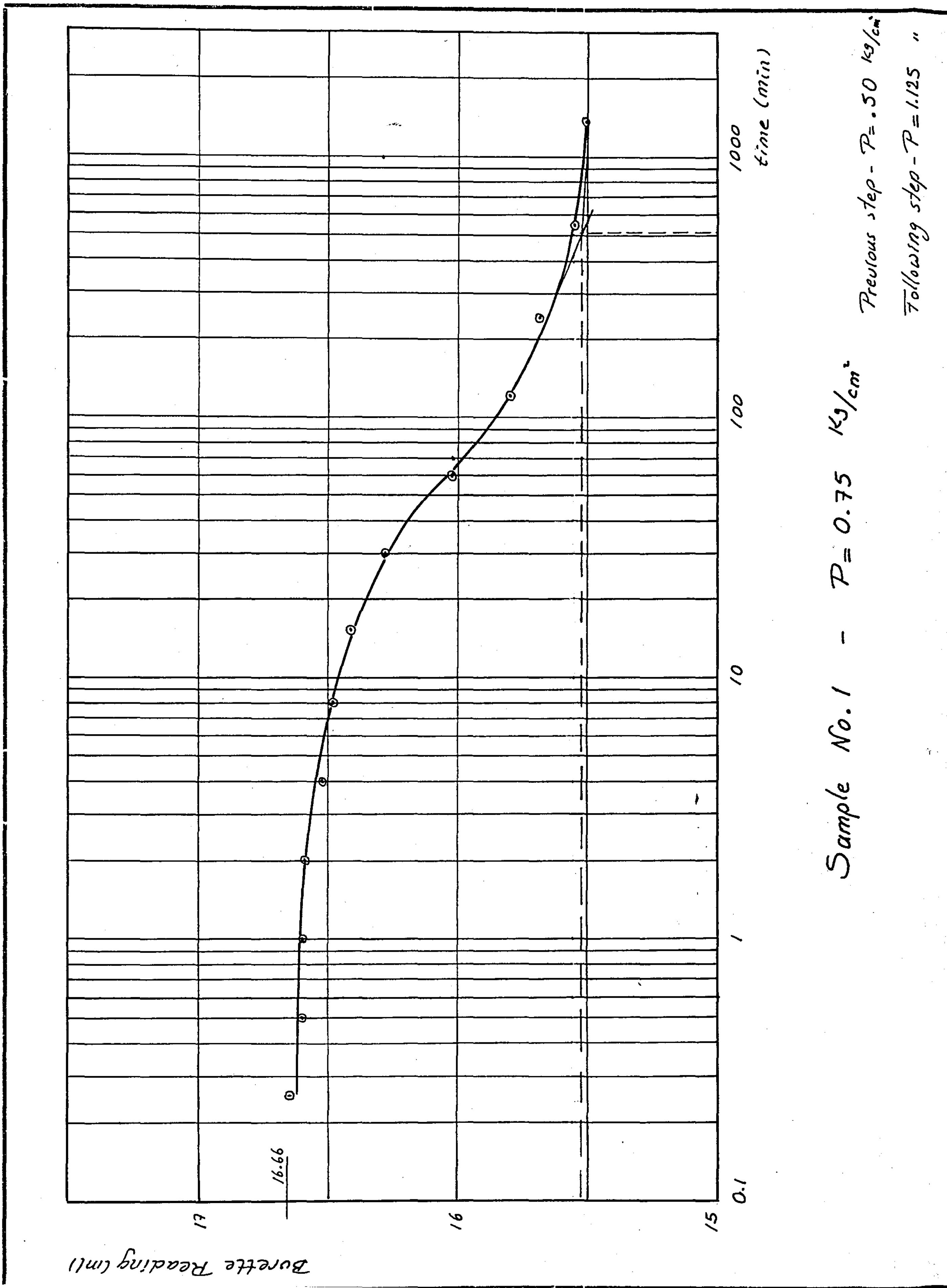

Sample No. 7 - Pc = 4.0 kg/cm²
time (min)
0.2
1.0
10
100
1000
Dial Reading.
0
1
2


time (min)
0.2
1
10
100
1000
0
1
2
Dial Reading.
Sample No. 8 - Pc. = 1.0 Kg/cm²

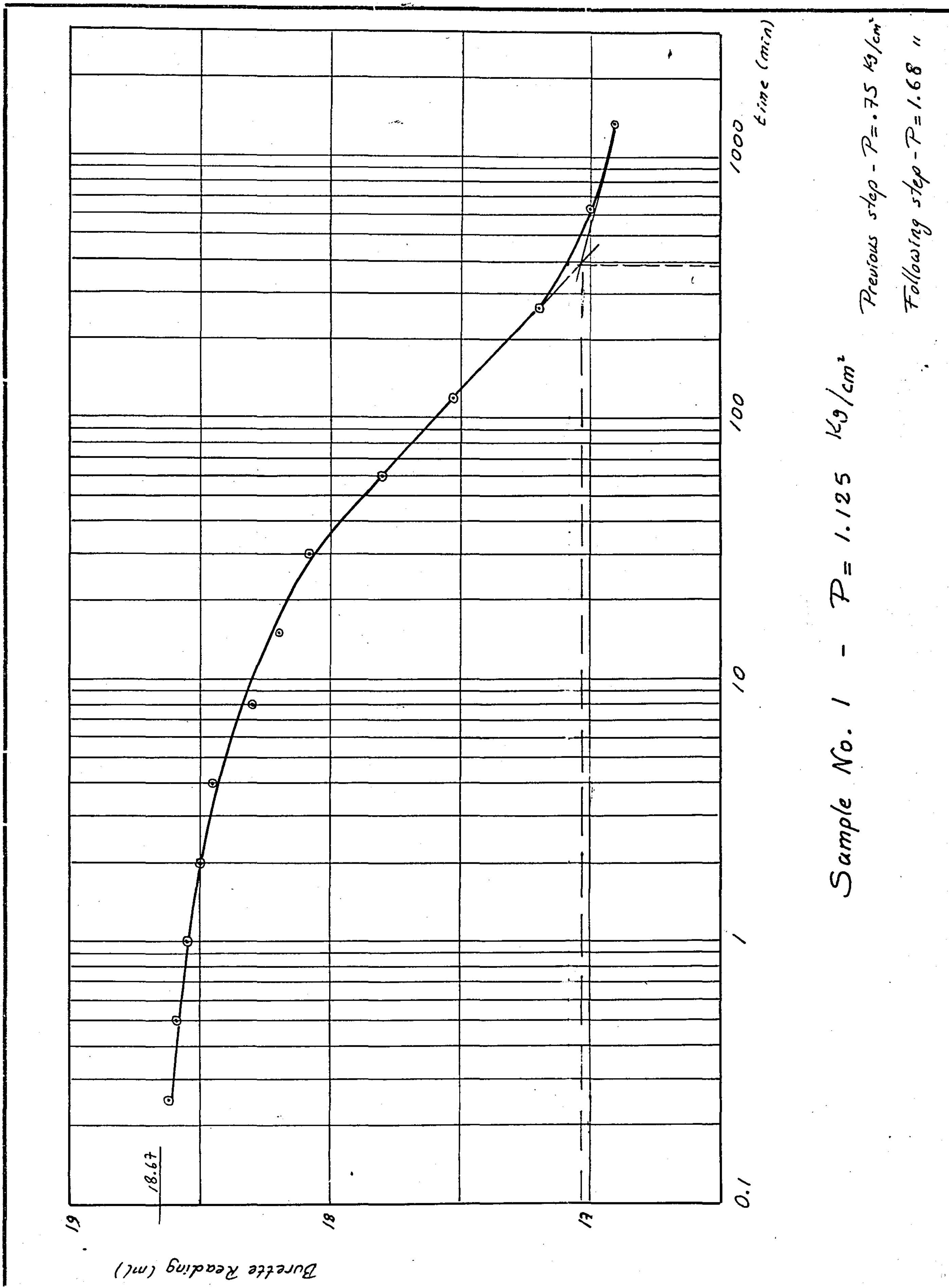

time (min.)
0.2
1
10
100
1000
1
2
3
Dial Reading
Sample No. 9 - Pc = 2.0 Kg/cm²

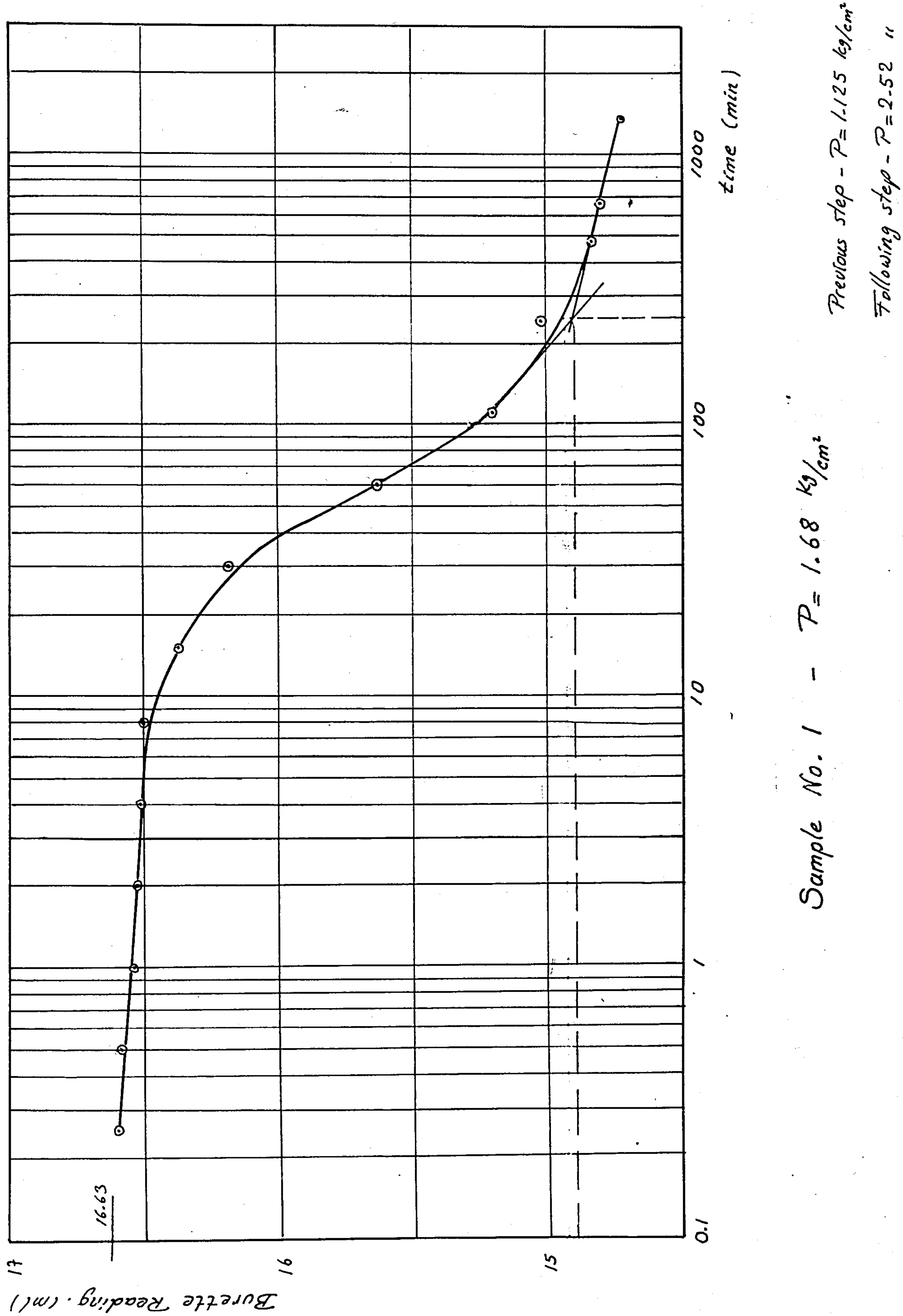
B. Consolidation Curves

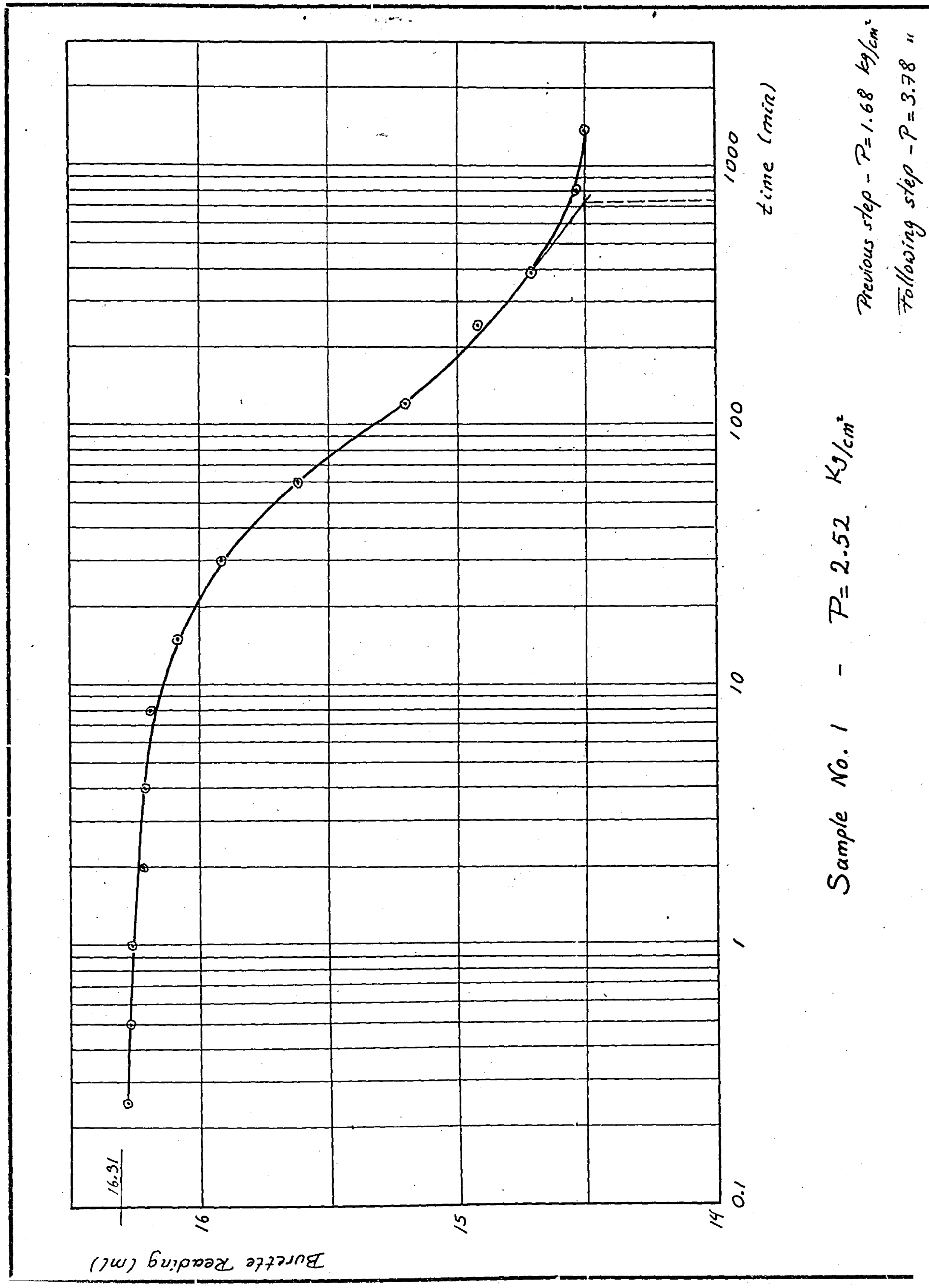

time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17
16
15
14
13
12
$m_o = 16.73$
Sample No. 1 - P = 0.5 Kg/cm²
Previous step - P = 0
Following step - P = .75 Kg/cm²

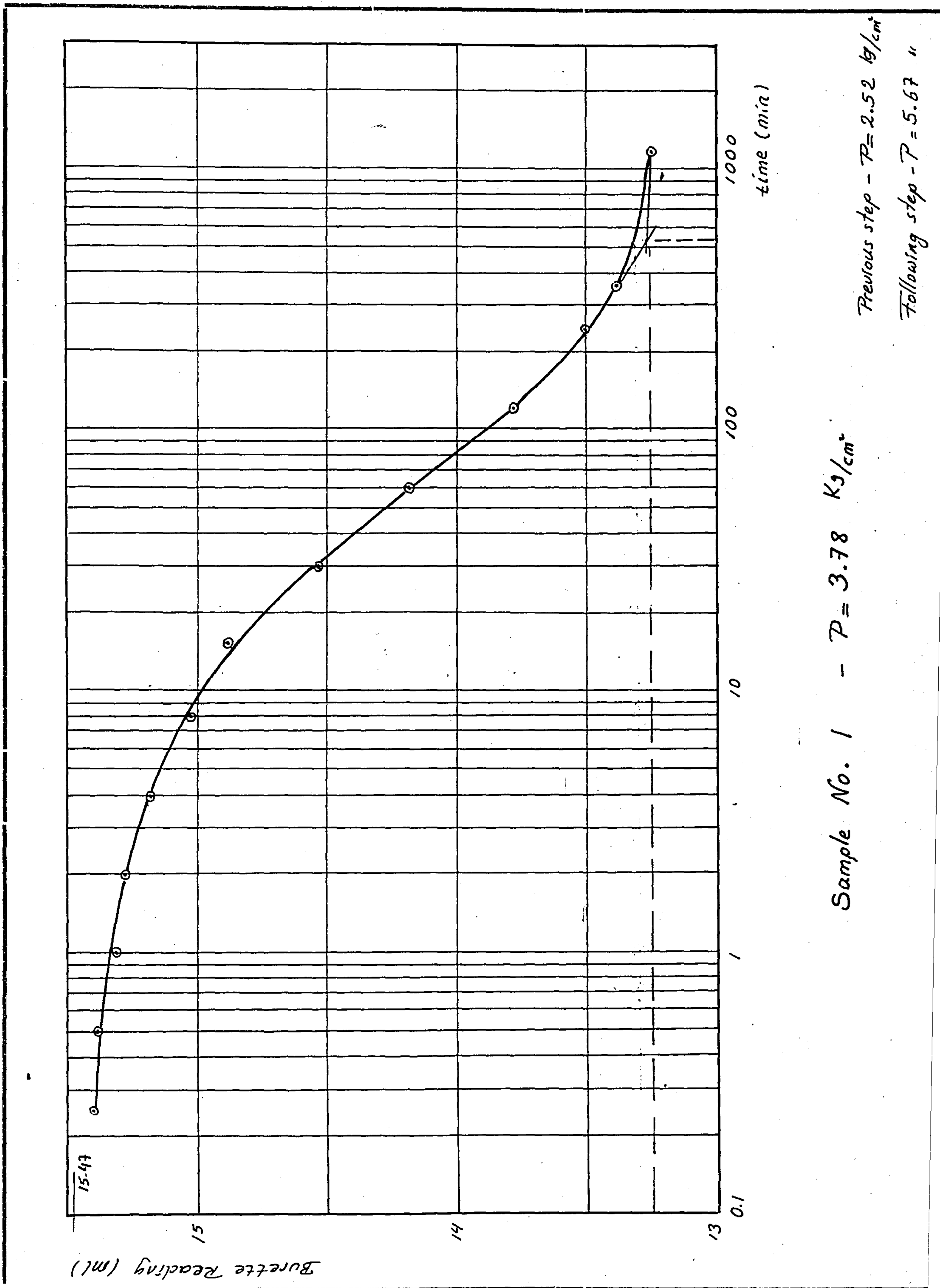


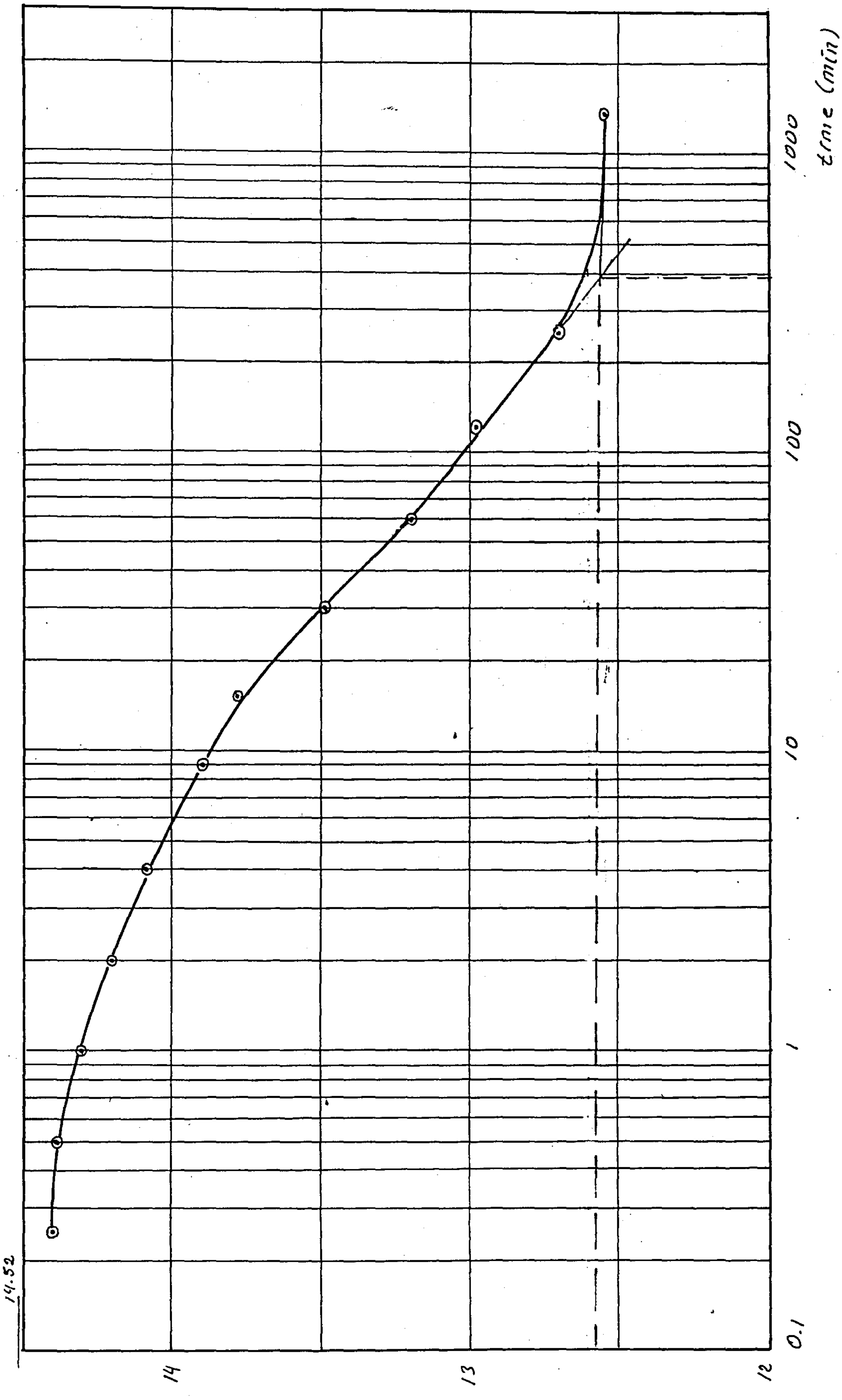
time (min)
1000
100
10
1
0.1
17
16
15
16.66
Burette Reading (ml)
Sample No. 1 - P= 0.75 Kg/cm²
Previous step - P= .50 Kg/cm²
Following step - P= 1.125 "


Sample No. 1 - P = 1.125 Kg/cm²
Previous step - P = .75 Kg/cm²
Following step - P = 1.68 "
time (min)
0.1
1
10
100
1000
19
18
17
18.67
Burette Reading (ml)


time (min)
1000
100
10
1
0.1
17
16
15
16.63
Burette Reading (ml)
Sample No. 1 - P= 1.68 kg/cm²
Previous step - P= 1.125 kg/cm²
Following step - P= 2.52 "

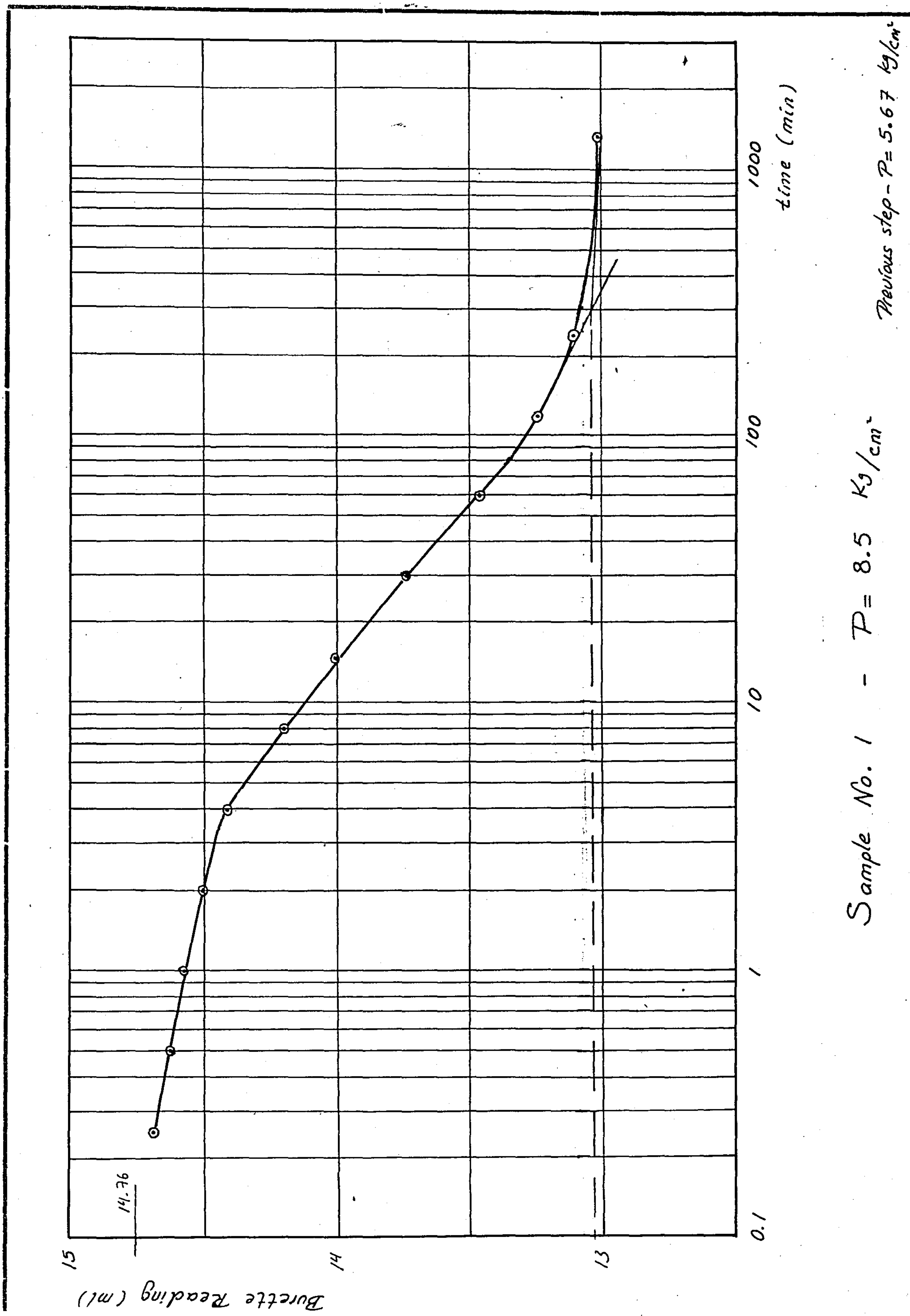

time (min)
1000
100
10
1
0.1
16.31
16
15
14
Burette Reading (ml)
Sample No. 1 - P= 2.52 Kg/cm²
Previous step - P=1.68 kg/cm²
Following step - P=3.78 "


Previous step - P = 2.52 kg/cm²
Following step - P = 5.67 "
Sample No. 1 - P = 3.78 Kg/cm²
time (min)
1000
100
10
1
0.1
15.47
15
14
13
Burette Reading (ml)

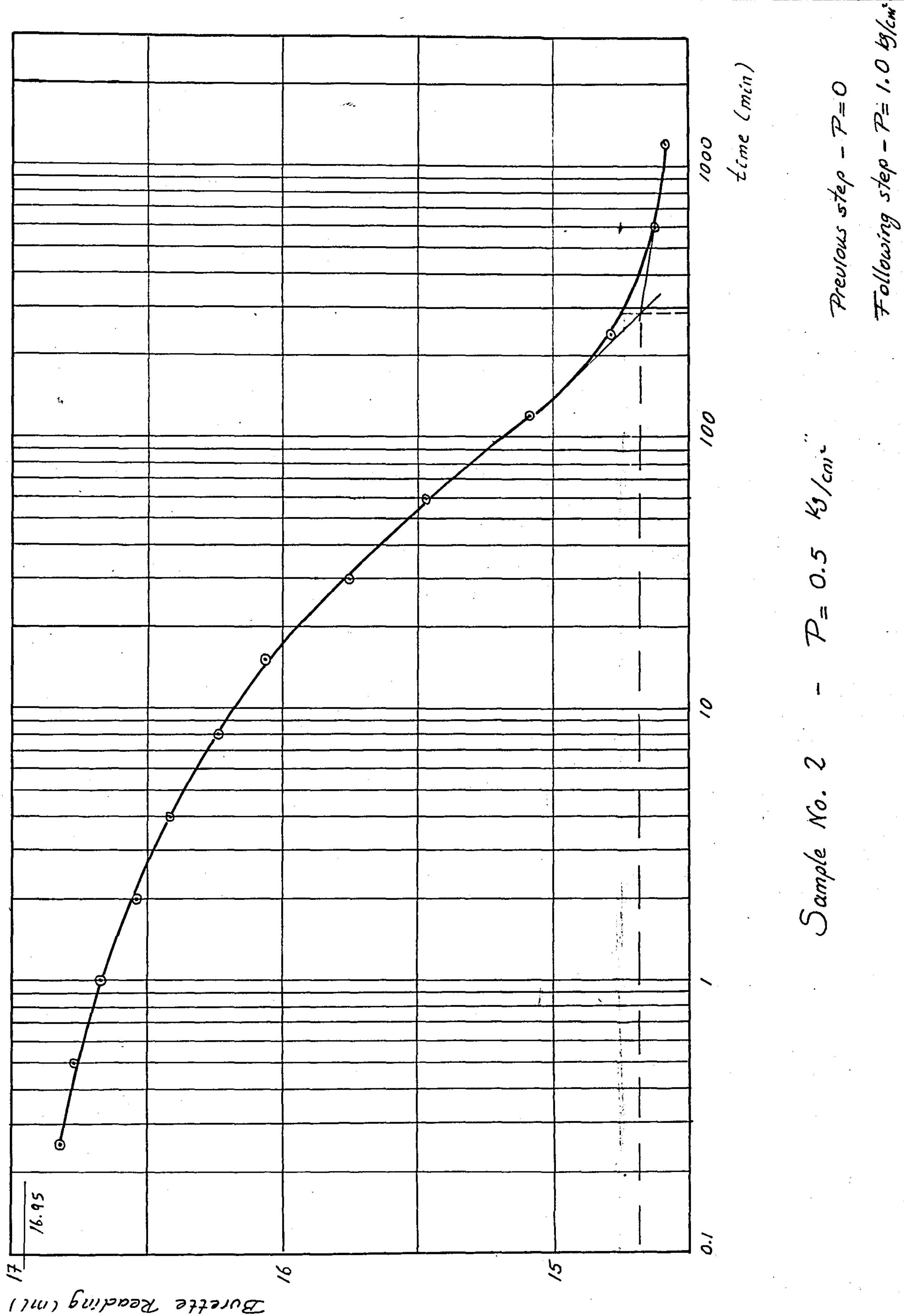


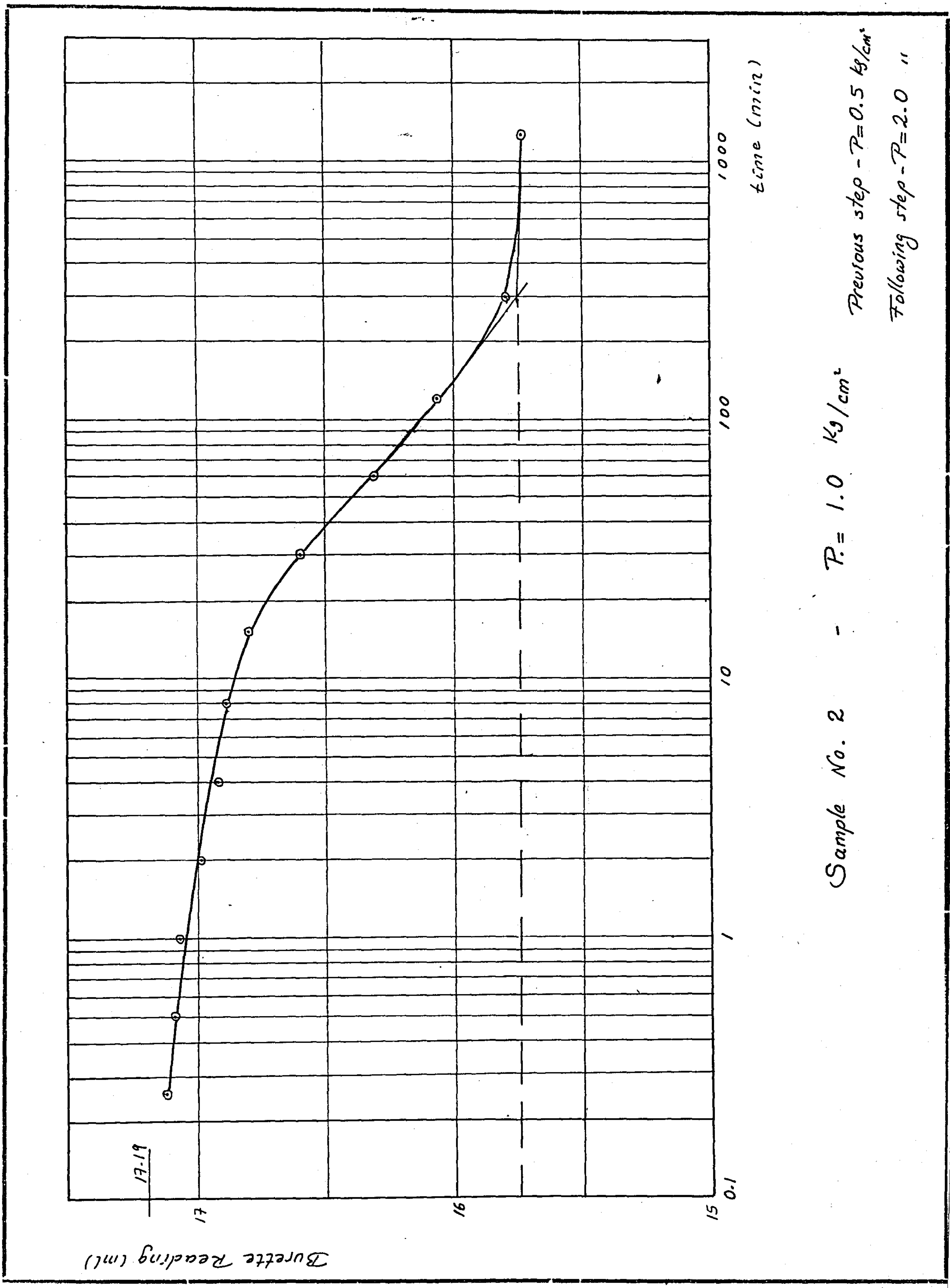
Sample No. 1 - P = 5.67 Kg/cm²

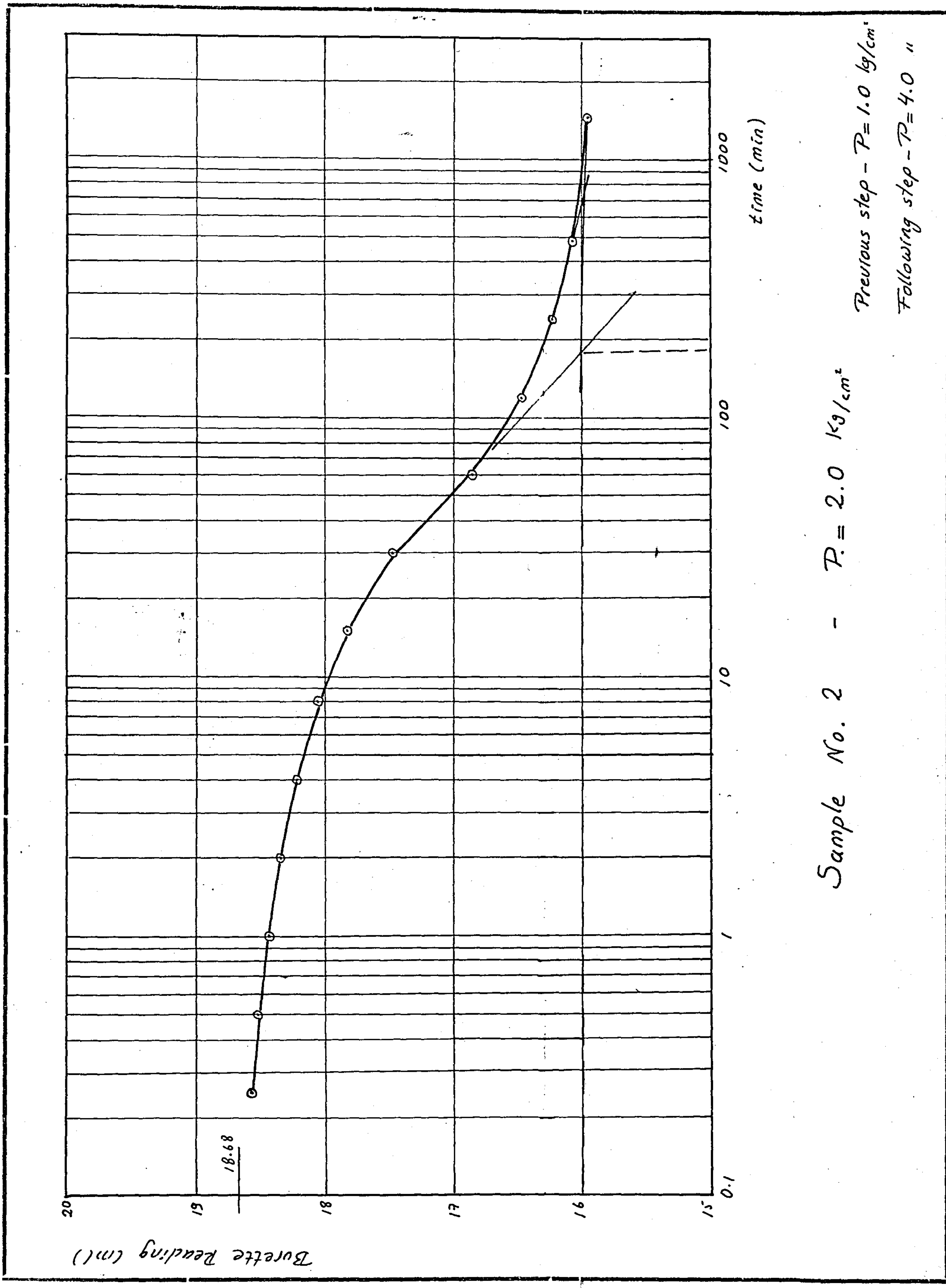
Previous step - P = 3.78 Kg/cm²
Following step - P = 8.5 "

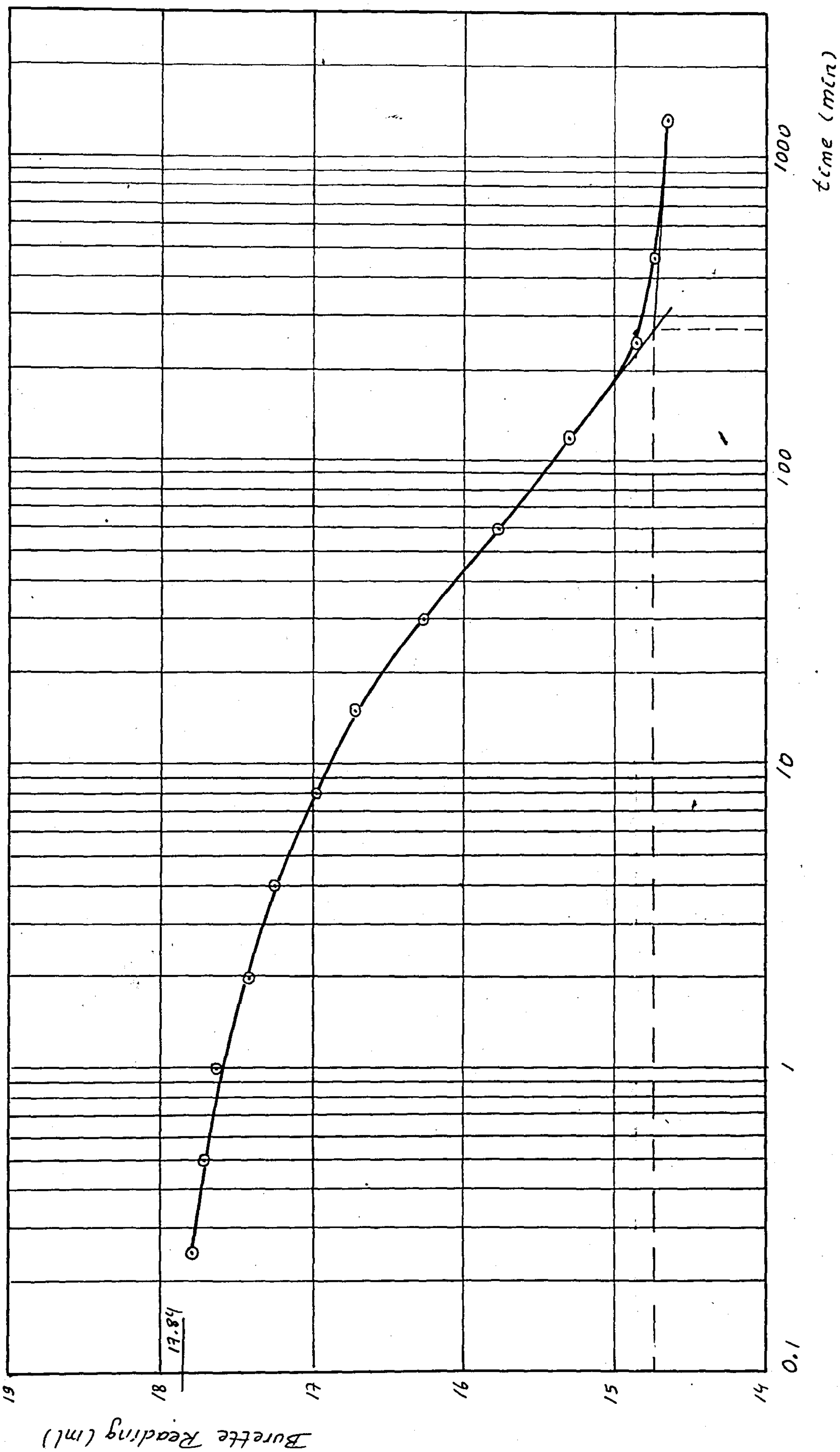


time (min)
1000
100
10
1
0.1
15
14
13
14.76
Burette Reading (ml)
Sample No. 1 - P= 8.5 Kg/cm²
Previous step - P= 5.67 kg/cm²


time (min)
1000
100
10
1
0.1
17
16.95
16
15
Burette Reading (ml)
Sample No. 2 - P= 0.5 kg/cm²
Previous step - P=0
Following step - P= 1.0 kg/cm²

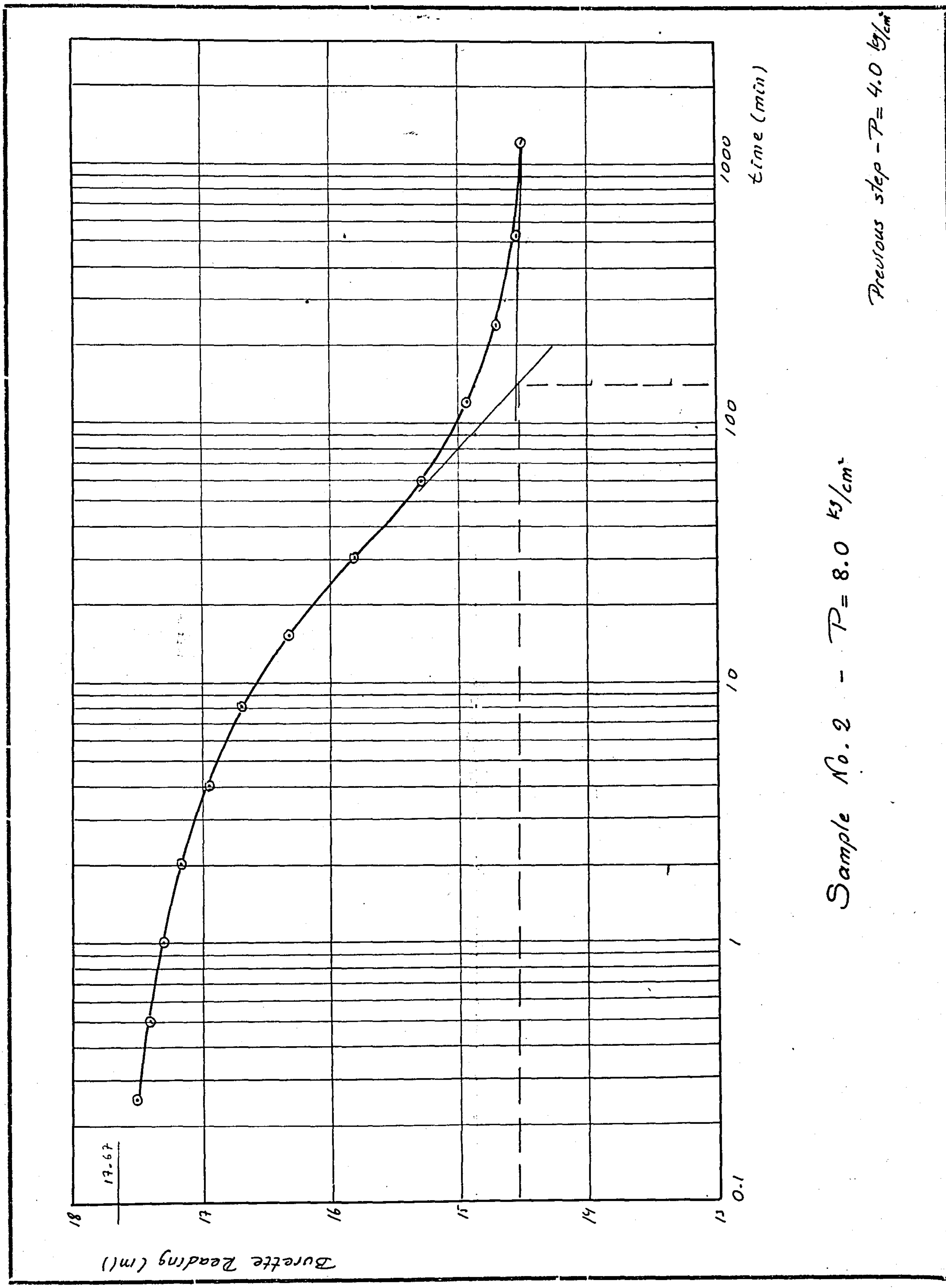

time (min)
1000
100
10
1
0.1
15
16
17
17.19
Burette Reading (ml)
Sample No. 2 - P = 1.0 Kg/cm²
Previous step - P = 0.5 Kg/cm²
Following step - P = 2.0 "


Sample No. 2 - P = 2.0 Kg/cm²
Previous step - P = 1.0 kg/cm²
Following step - P = 4.0 "
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
20
19
18
17
16
15
18.68

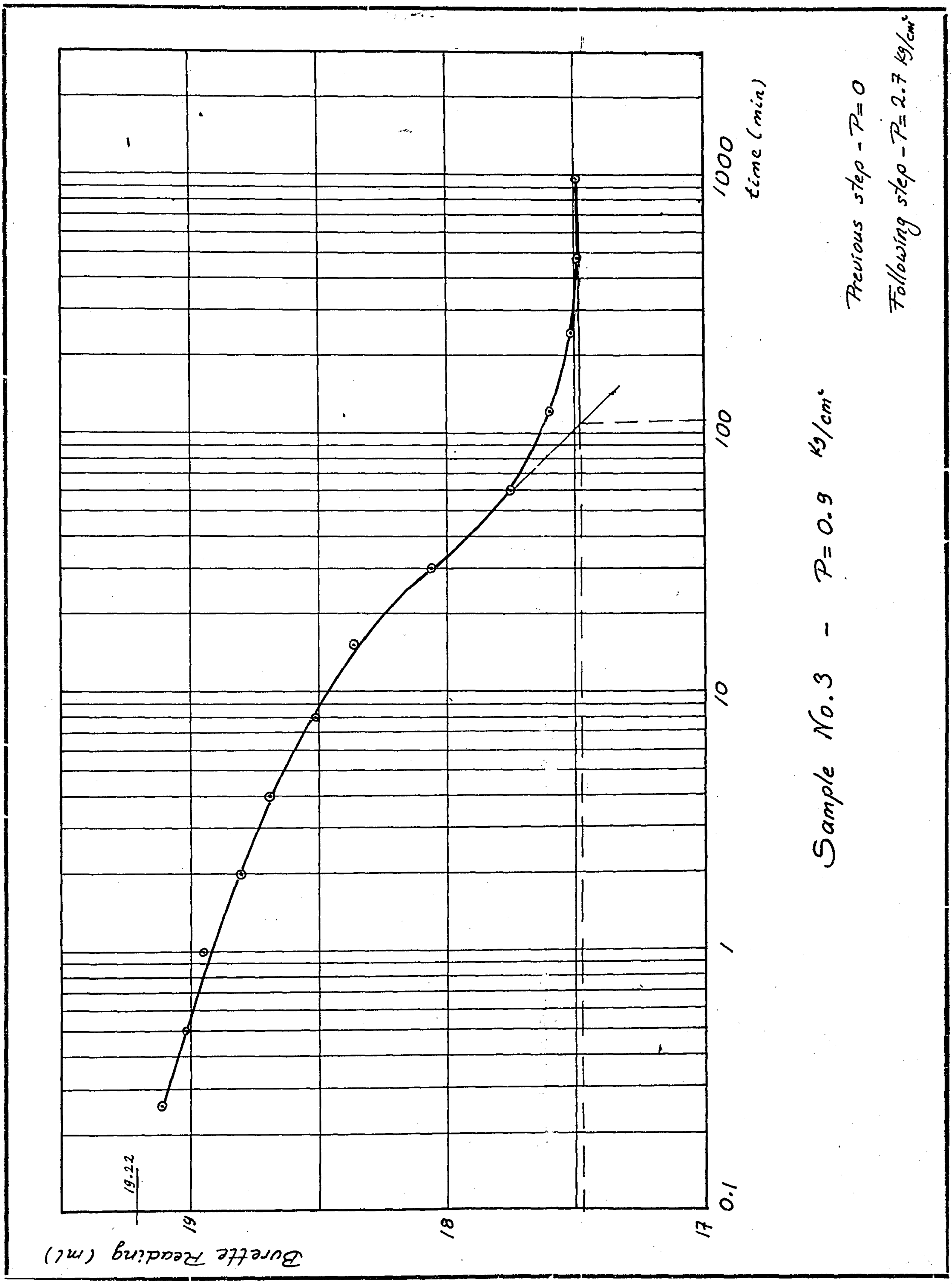


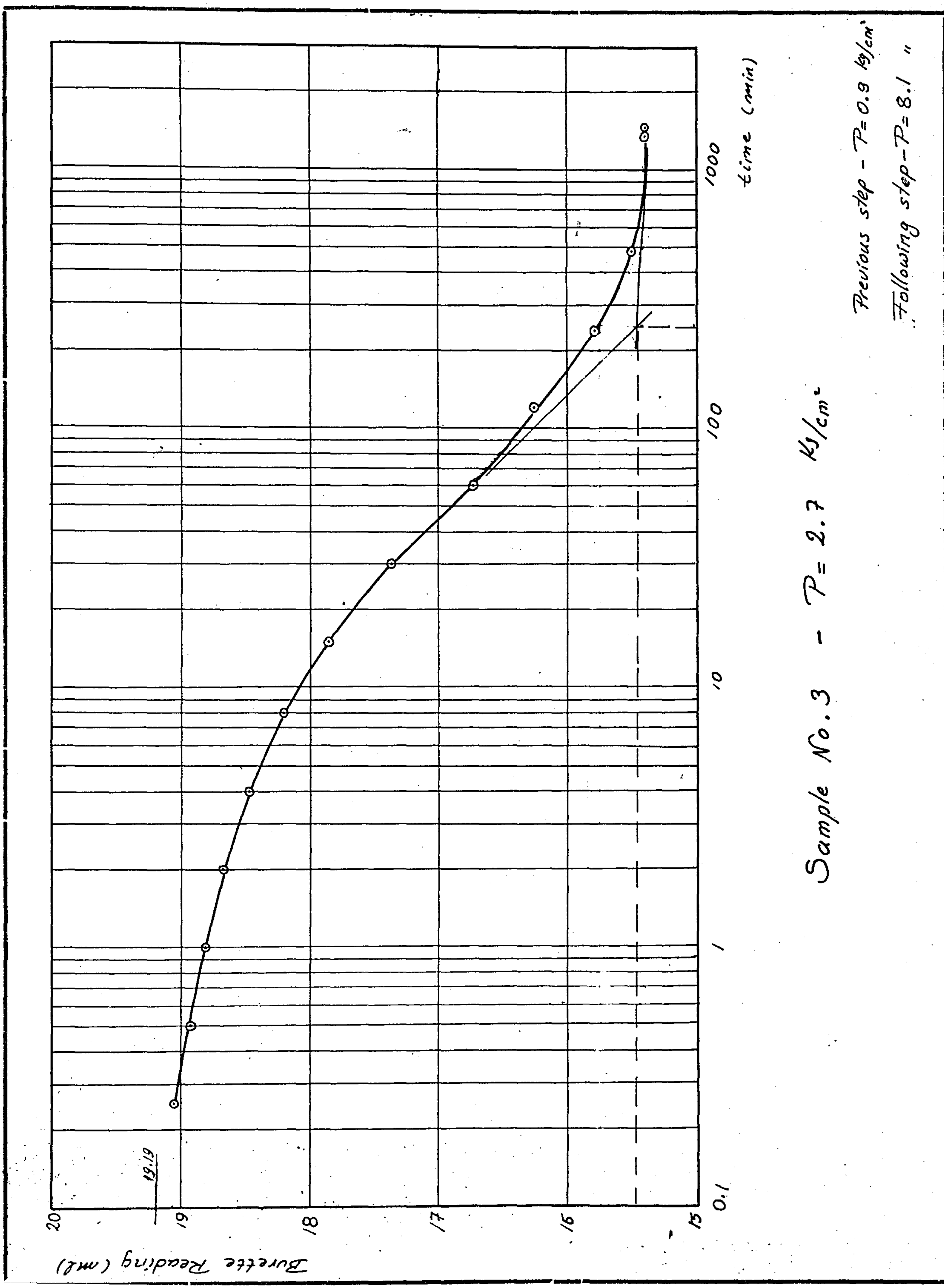
Sample No. 2 - P = 4.0 Kg/cm²

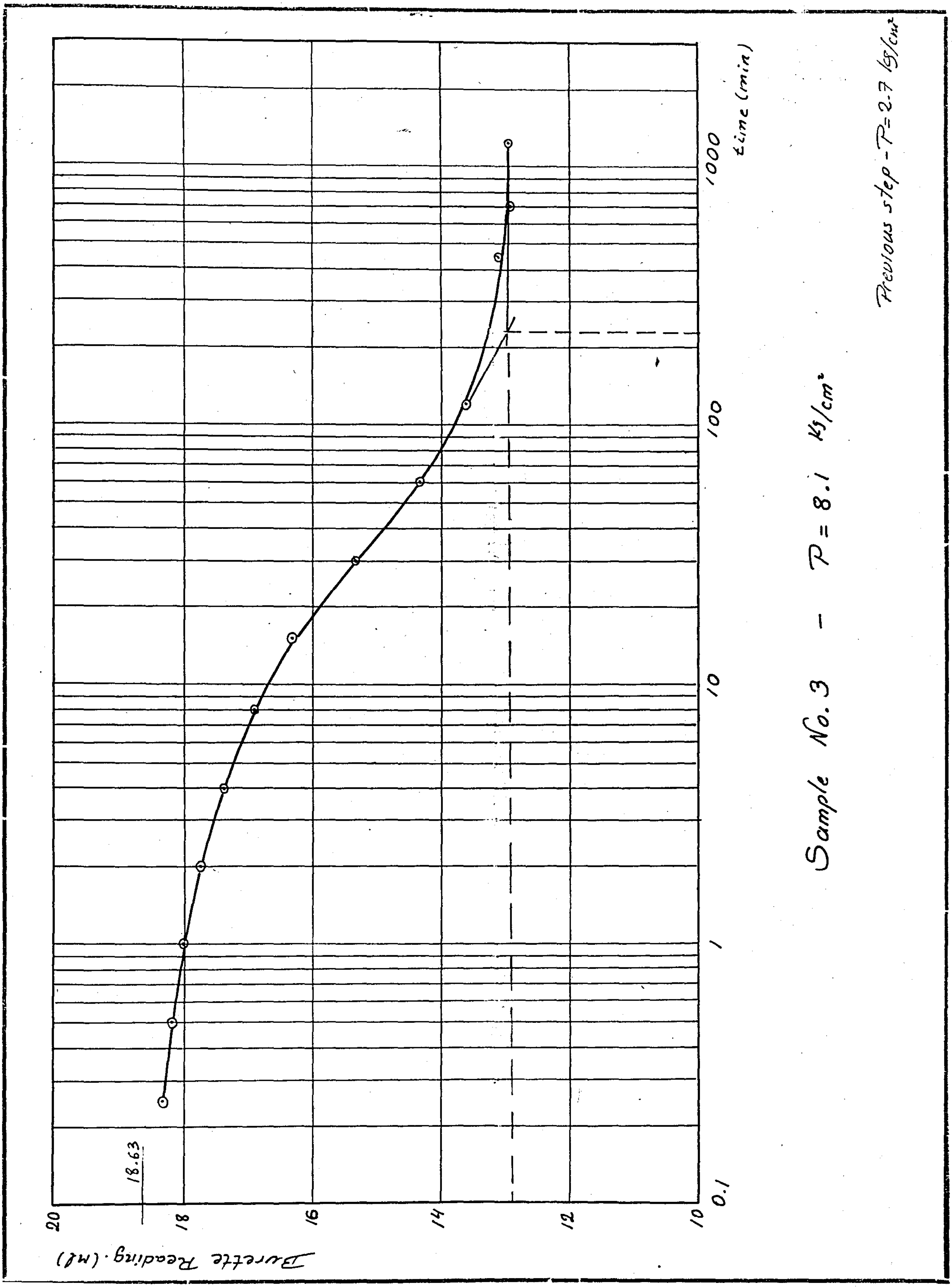
Previous step - P = 2.0 kg/cm²
Following step - P = 8.0 "

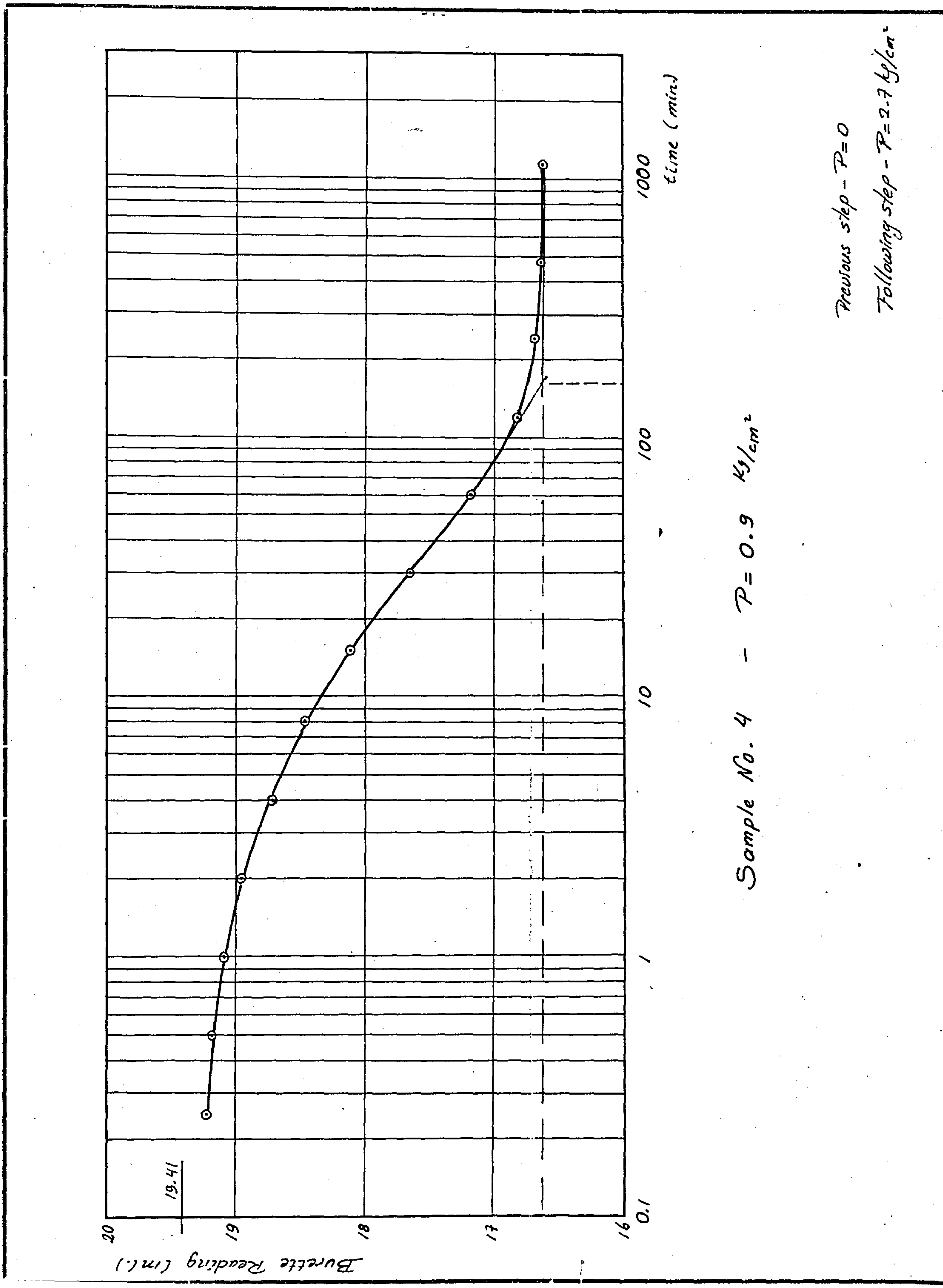


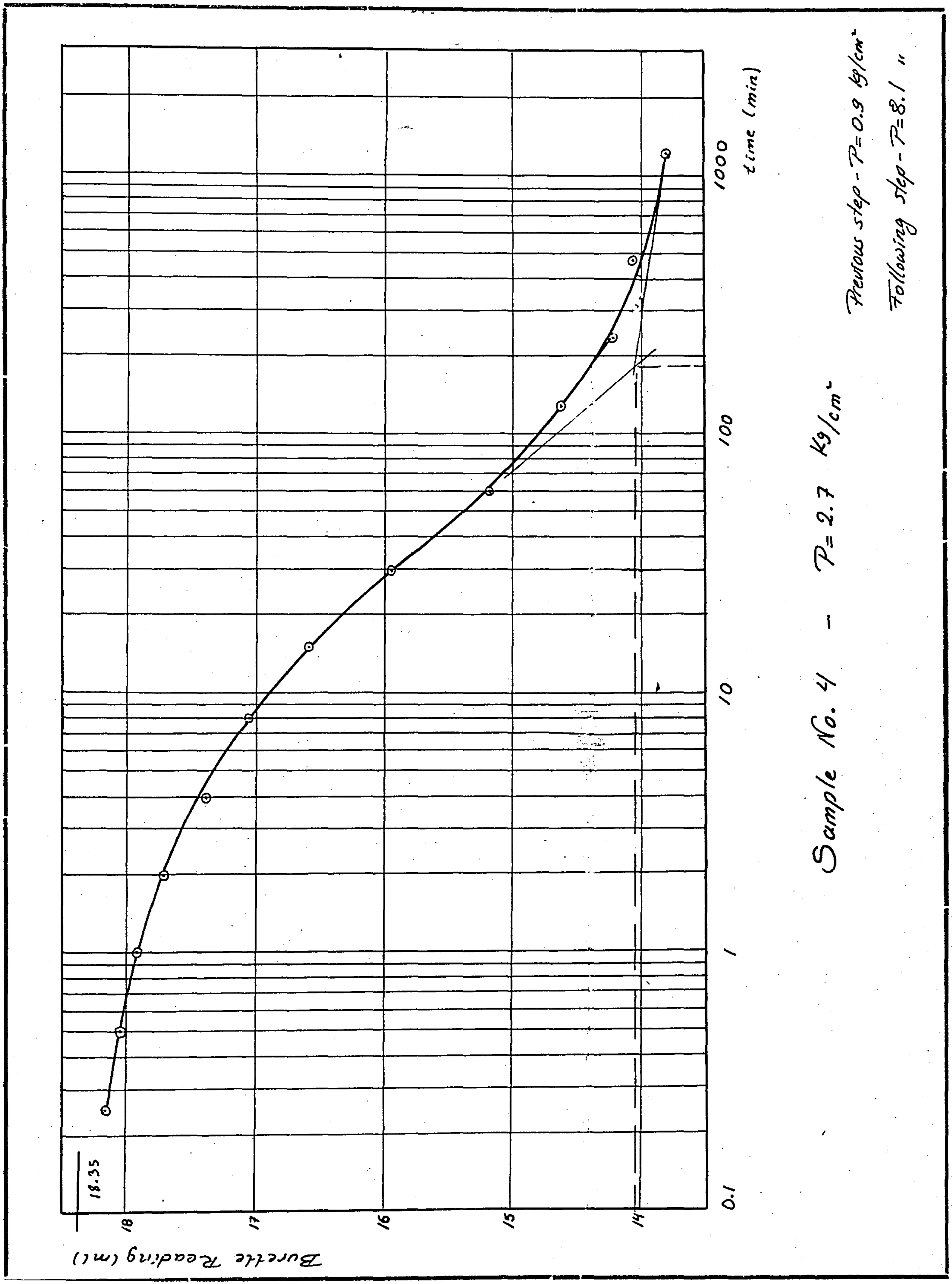
Previous step - P= 4.0 kg/cm²
time (min)
1000
100
10
1
0.1
Sample No. 2 - P= 8.0 kg/cm²
17.67
18
17
16
15
14
13
Burette Reading (ml)

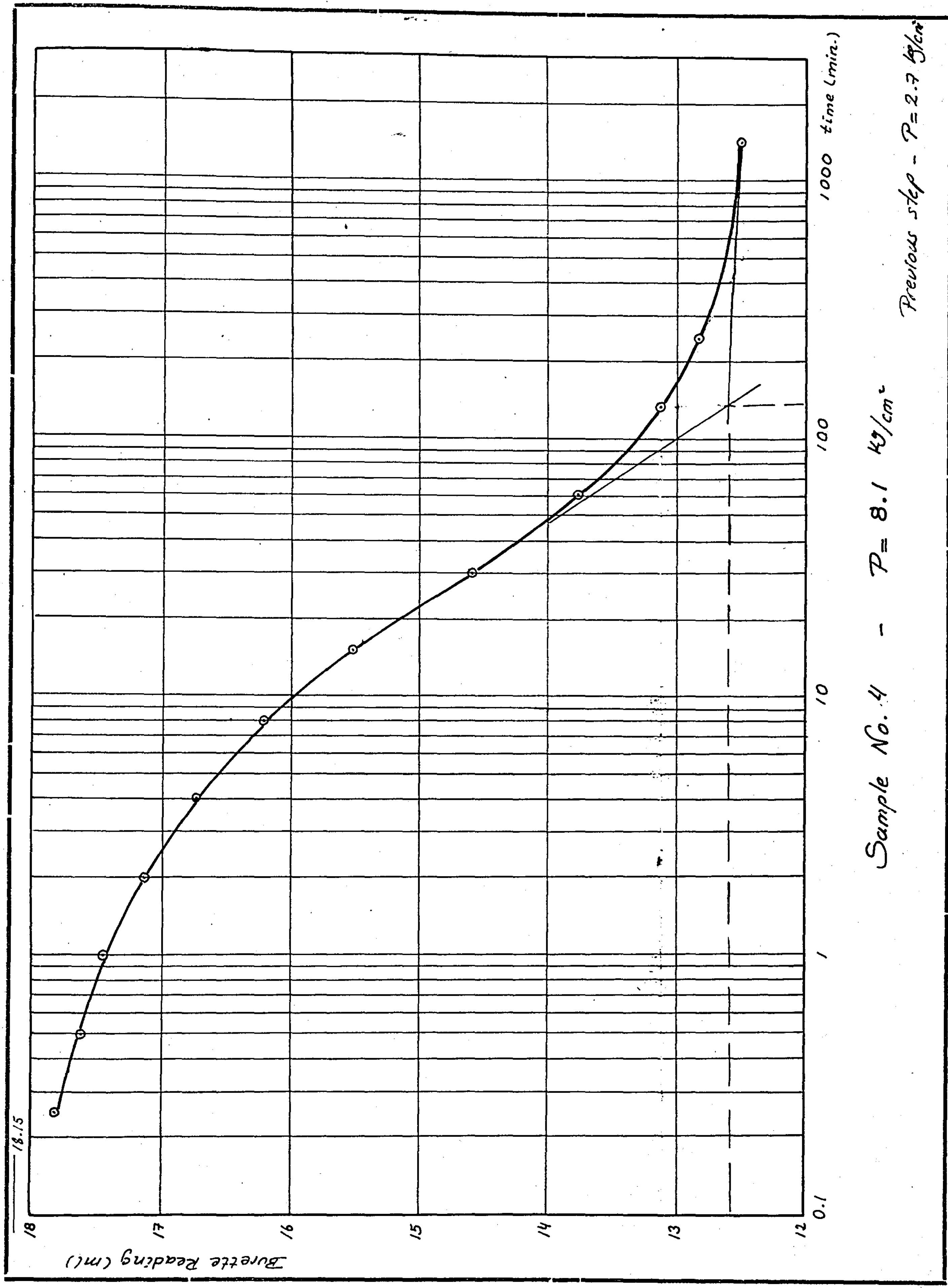

Sample No.3 - P = 0.9 kg/cm²
Previous step - P = 0
Following step - P = 2.7 kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17
18
19
19.22


time (min)
0.1
1
10
100
1000
20
19
18
17
16
15
19.19
Burette Reading (ml)
Sample No. 3 - P = 2.7 Kg/cm²
Previous step - P = 0.9 kg/cm²
Following step - P = 8.1 "

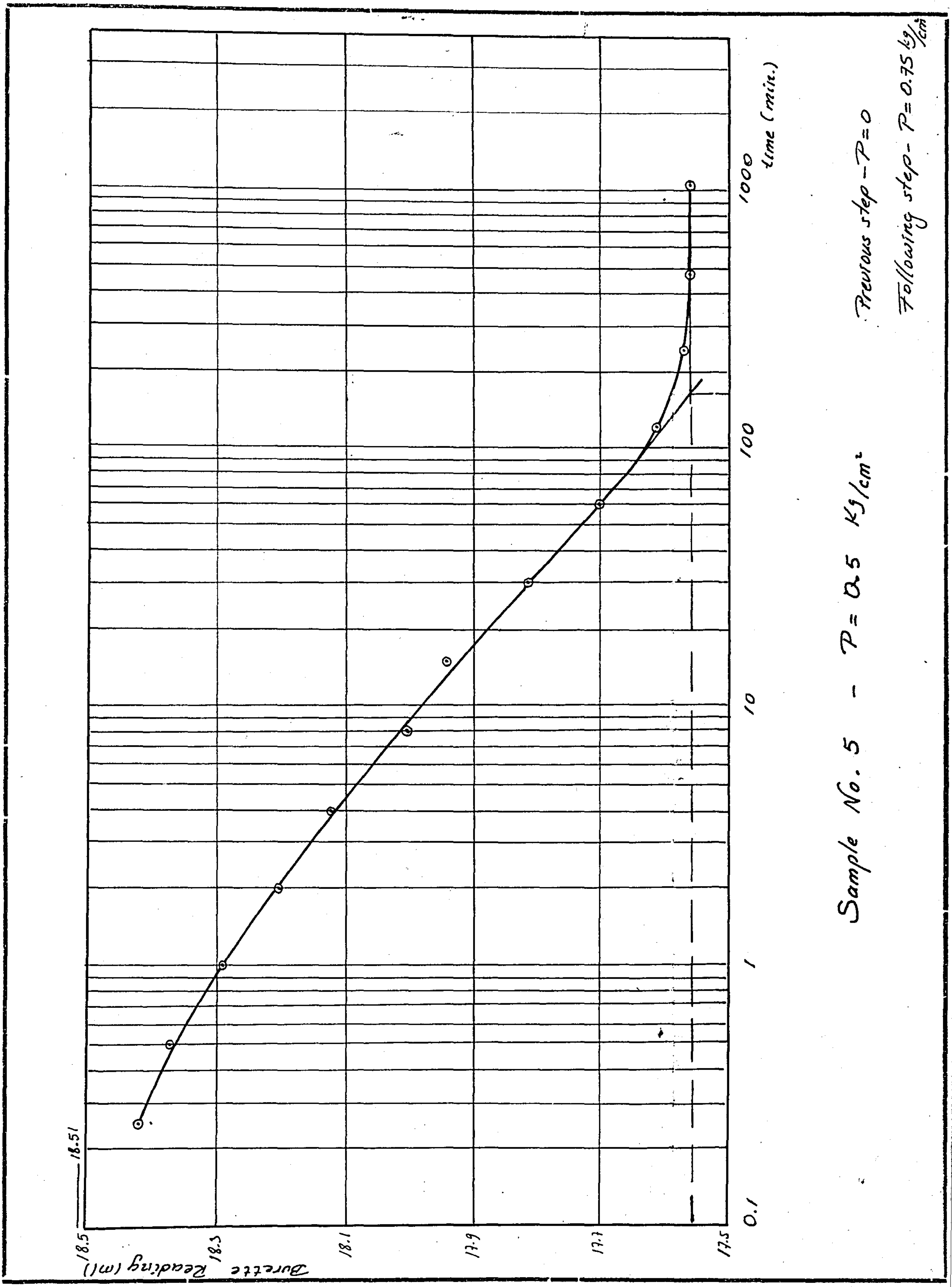

time (min)
Previous step - P = 2.7 kg/cm²
Sample No. 3 - P = 8.1 kg/cm²
Burette Reading (ml)
18.63
0.1
1
10
100
1000
20
18
16
14
12
10

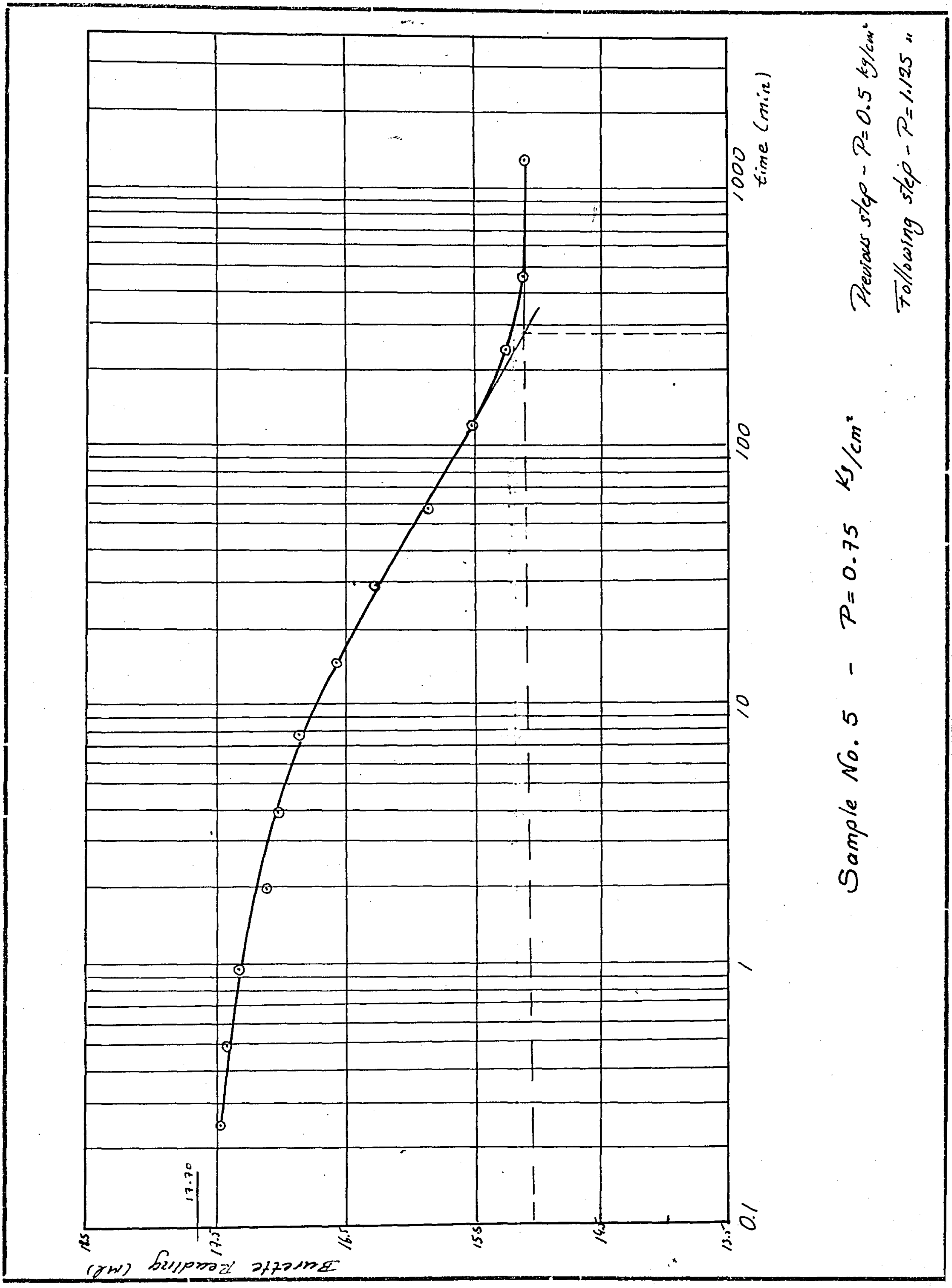

Sample No. 4 - P = 0.9 Kg/cm²
Previous step - P = 0
Following step - P = 2.7 kg/cm²
time (min.)
0.1
1
10
100
1000
Burette Reading (ml.)
20
19
18
17
16
19.41

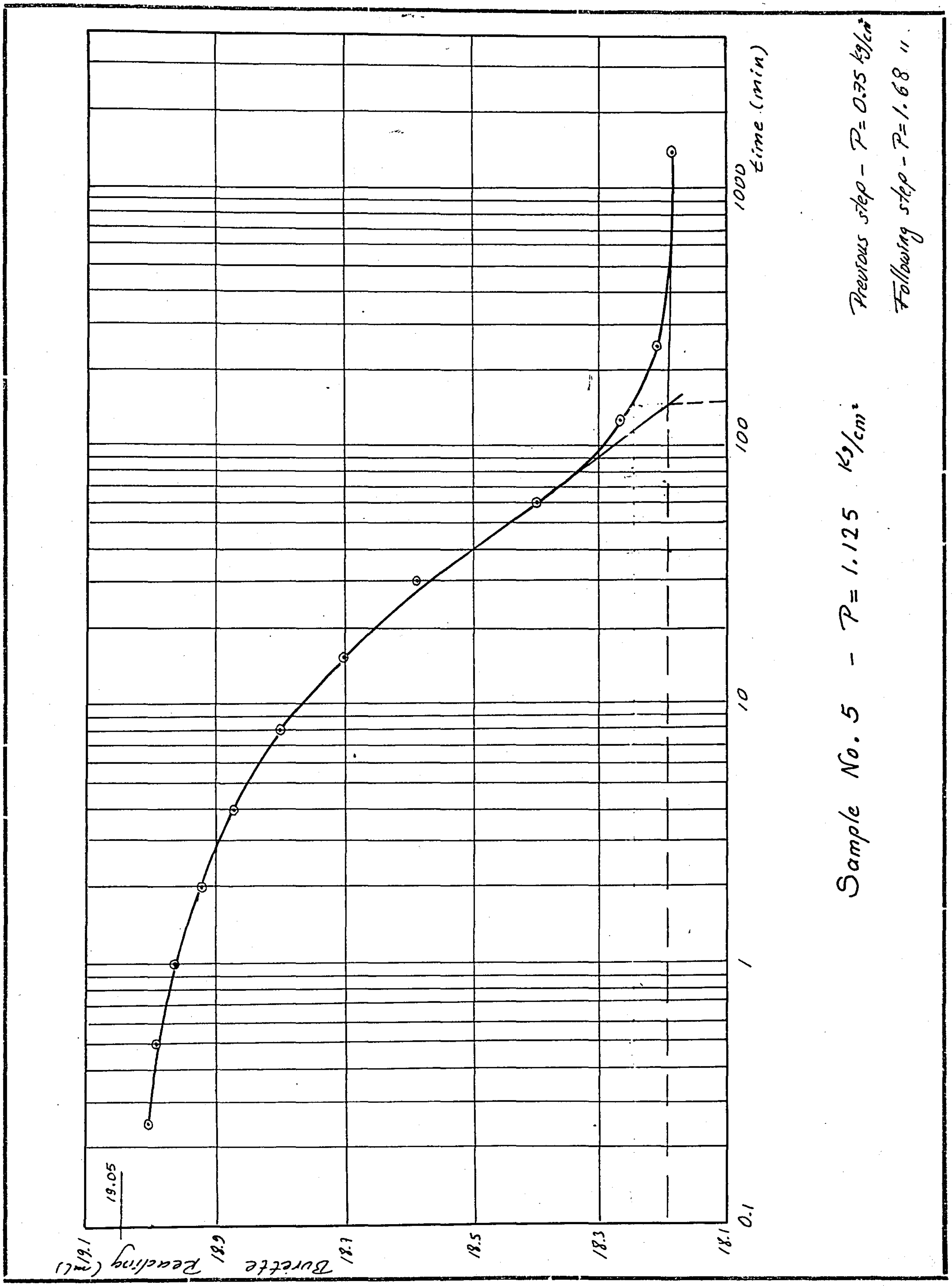

time (min)
1000
100
10
1
0.1
Burette Reading (ml)
18.35
18
17
16
15
14
Sample No. 4 - P= 2.7 Kg/cm²
Previous step - P=0.9 Kg/cm²
Following step - P=8.1 "

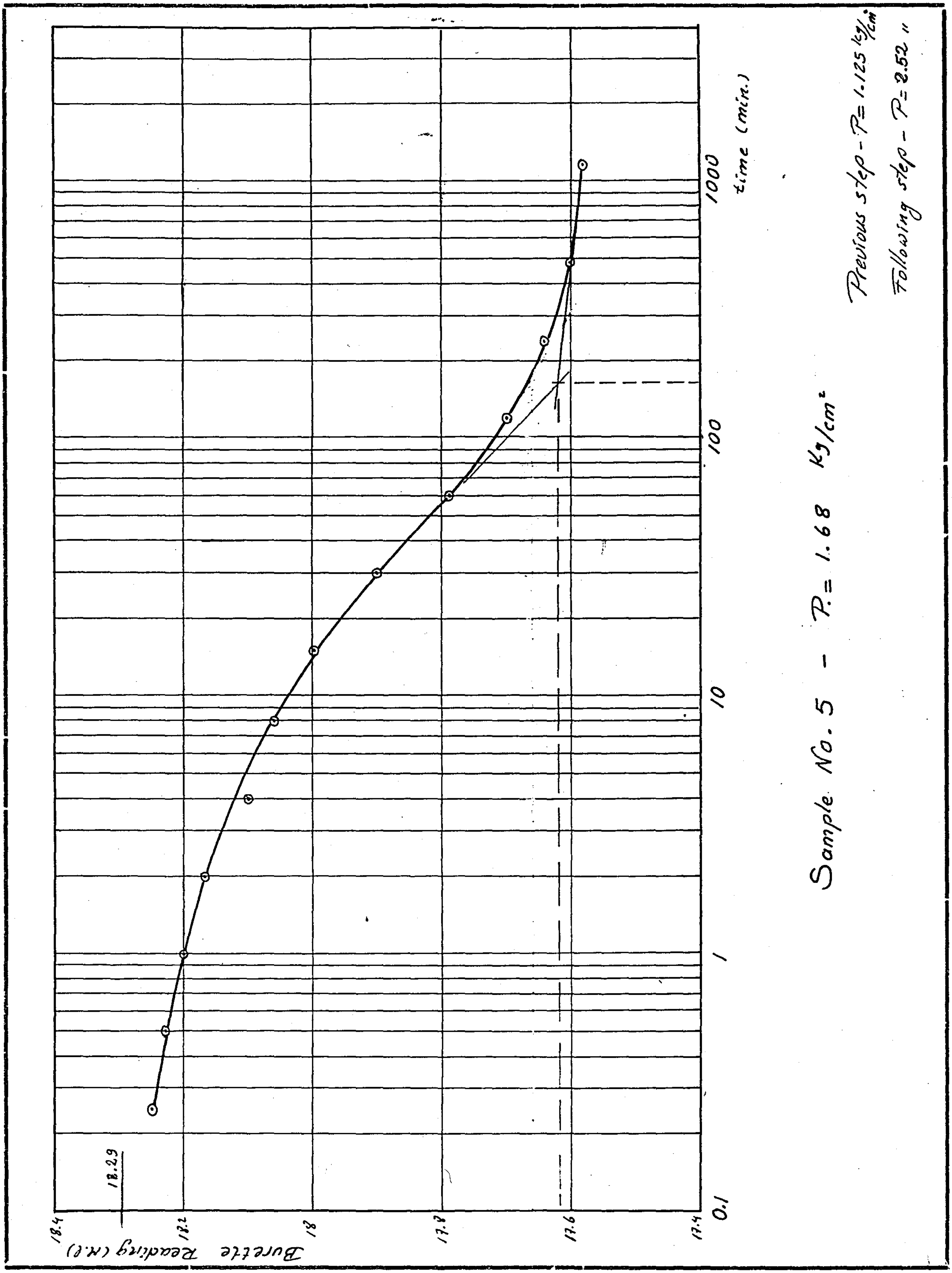


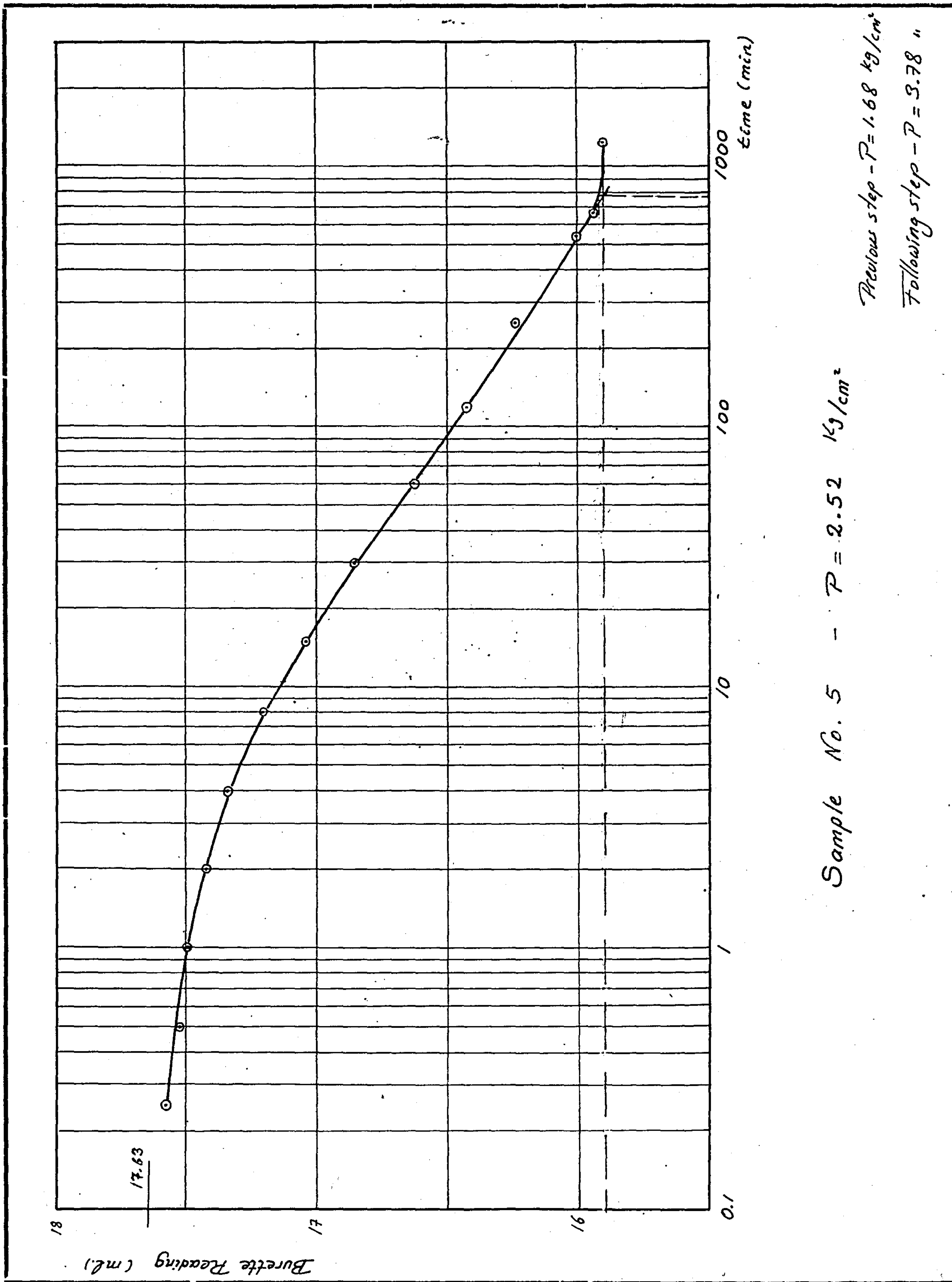
time (min.)
1000
100
10
1
0.1
18
17
16
15
14
13
12
18.15
Burette Reading (ml)
Sample No. 4 - P = 8.1 kg/cm²
Previous step - P = 2.7 kg/cm²

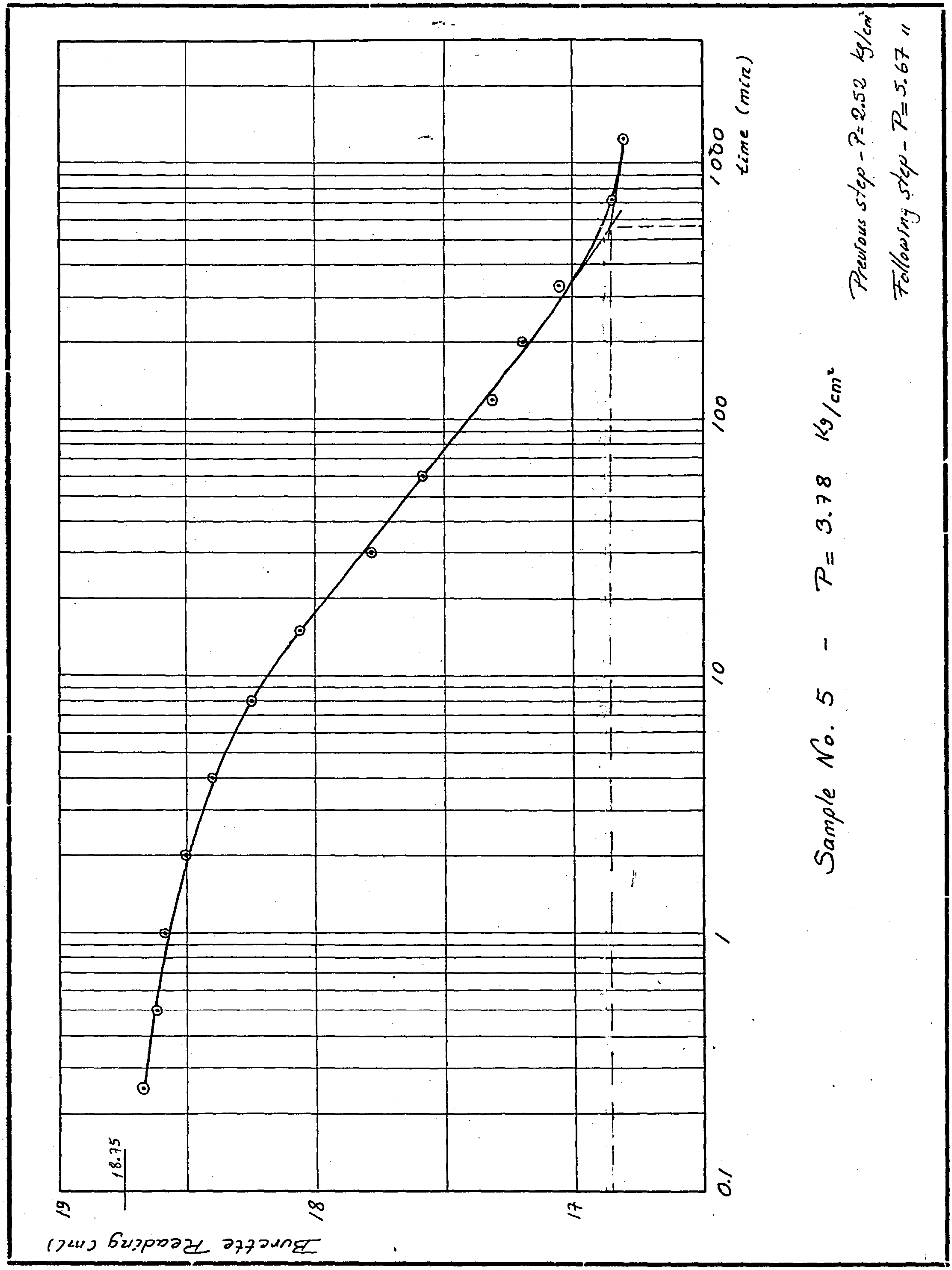

Sample No. 5 - P = 0.5 Kg/cm²
Previous step - P = 0
Following step - P = 0.75 kg/cm²
time (min.)
0.1
1
10
100
1000
Burette Reading (ml)
18.5
18.3
18.1
17.9
17.7
17.5
18.51

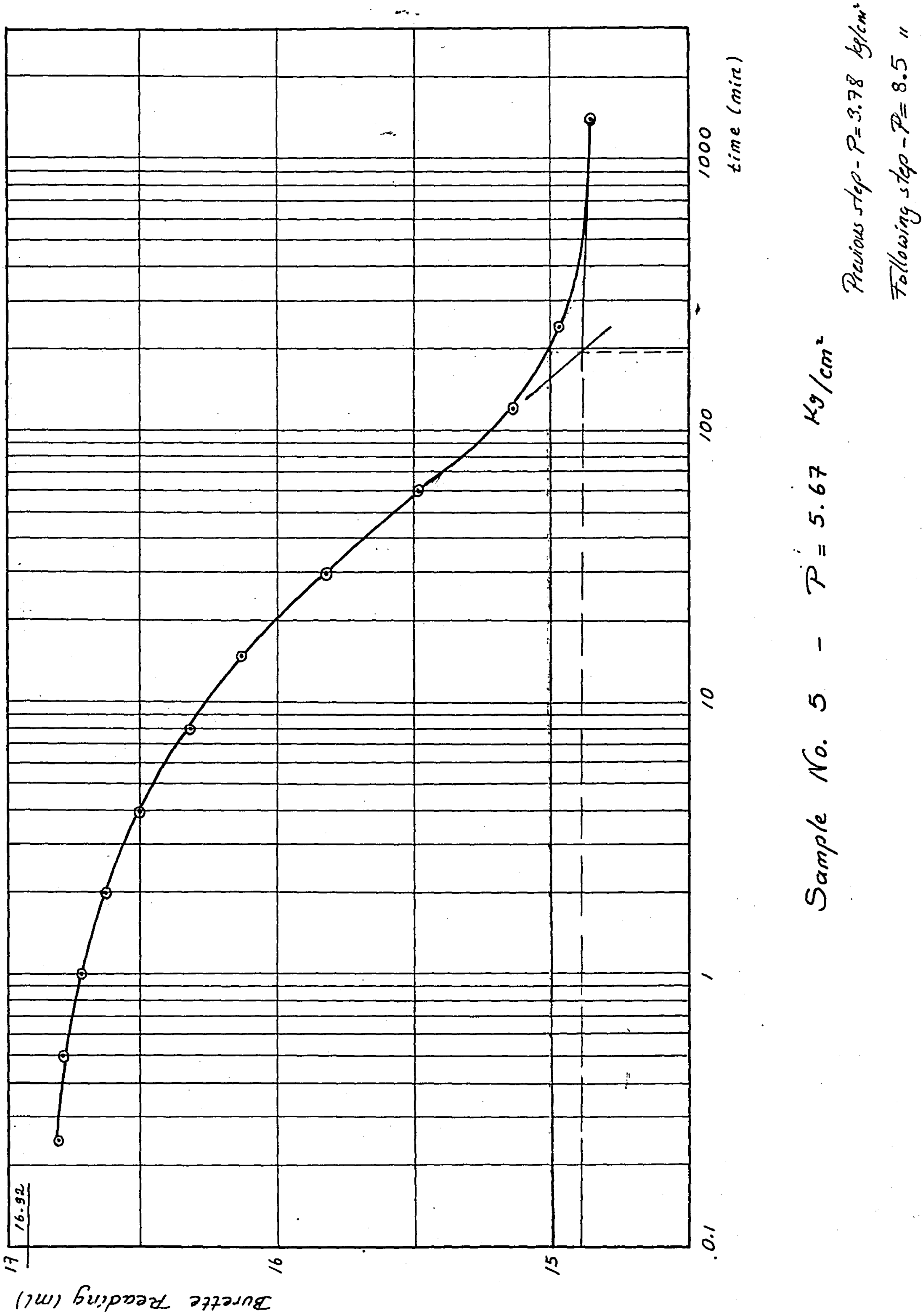

Previous step - P=0.5 kg/cm²
Following step - P=1.125 "
Sample No. 5 - P=0.75 Kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17.70
18.5
17.5
16.5
15.5
14.5
13.5

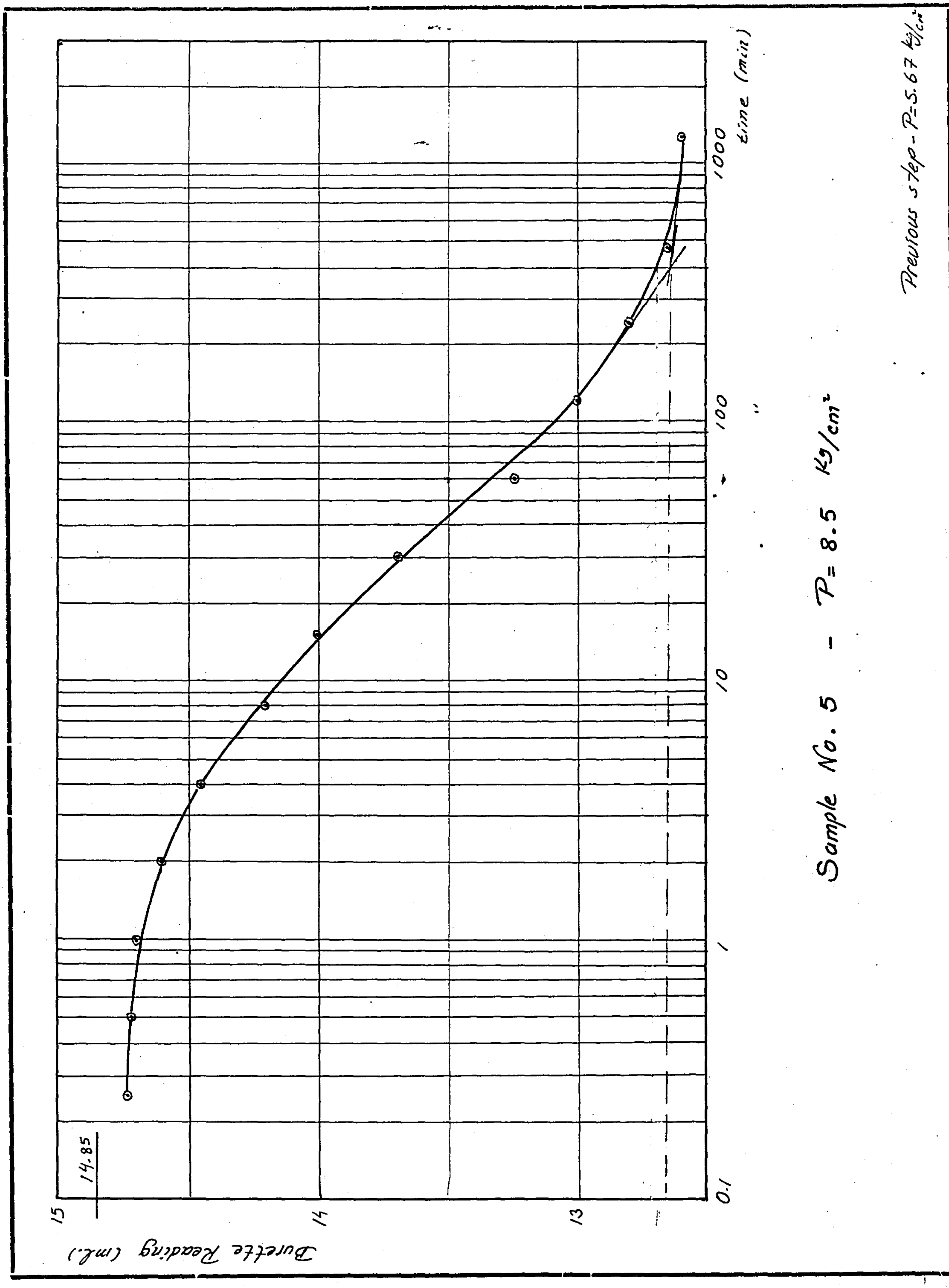

time (min)
0.1
1
10
100
1000
Burette Reading (ml)
19.1
19.05
18.9
18.7
18.5
18.3
18.1
Sample No. 5 - P = 1.125 kg/cm²
Previous step - P= 0.75 kg/cm²
Following step - P= 1.68 "

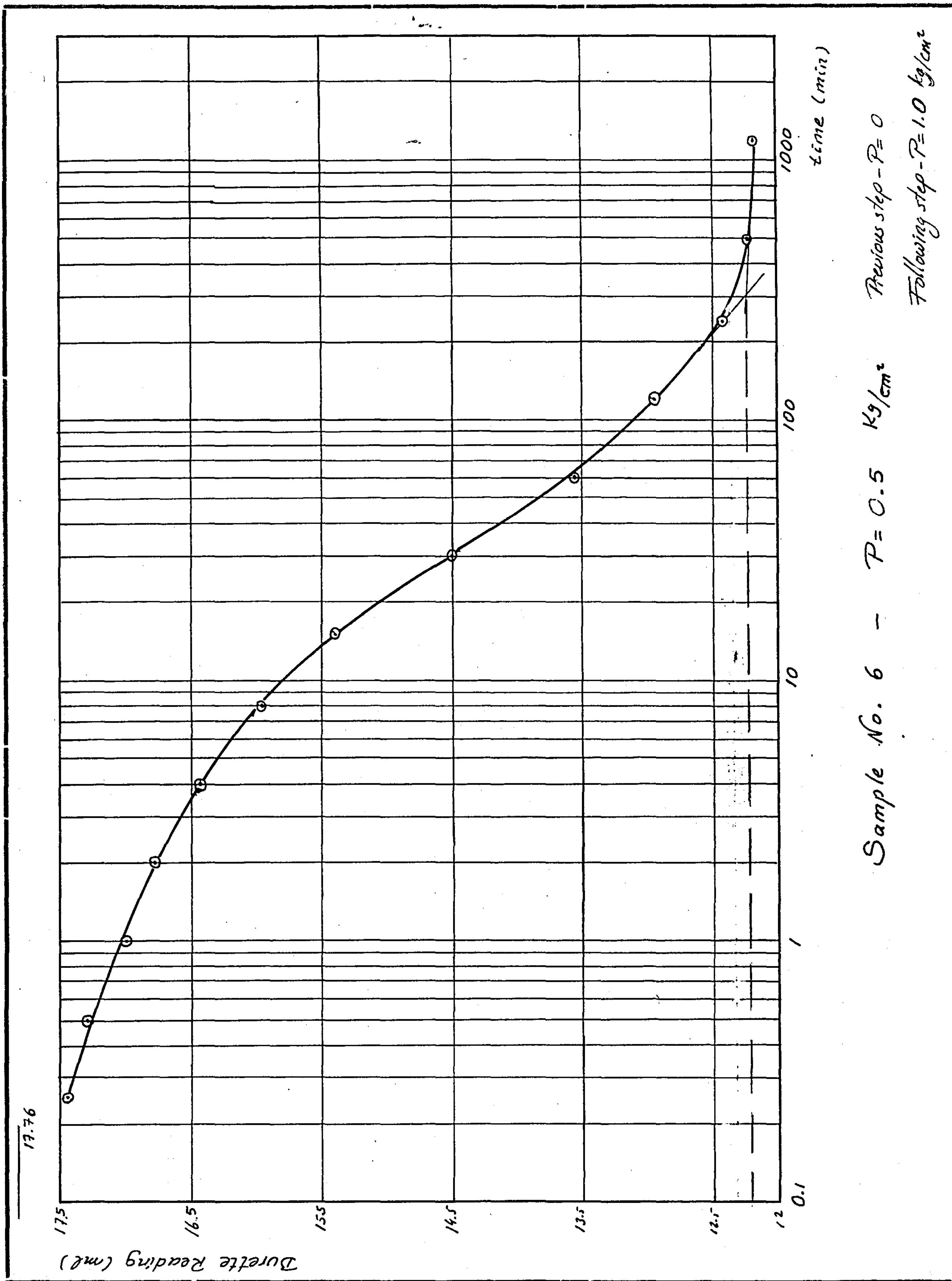

Previous step - P= 1.125 kg/cm²
Following step - P= 2.52 "
Sample No. 5 - P.= 1.68 Kg/cm²
time (min.)
1000
100
10
1
0.1
Burette Reading (M.L)
18.4
18.29
18.2
18
17.8
17.6
17.4

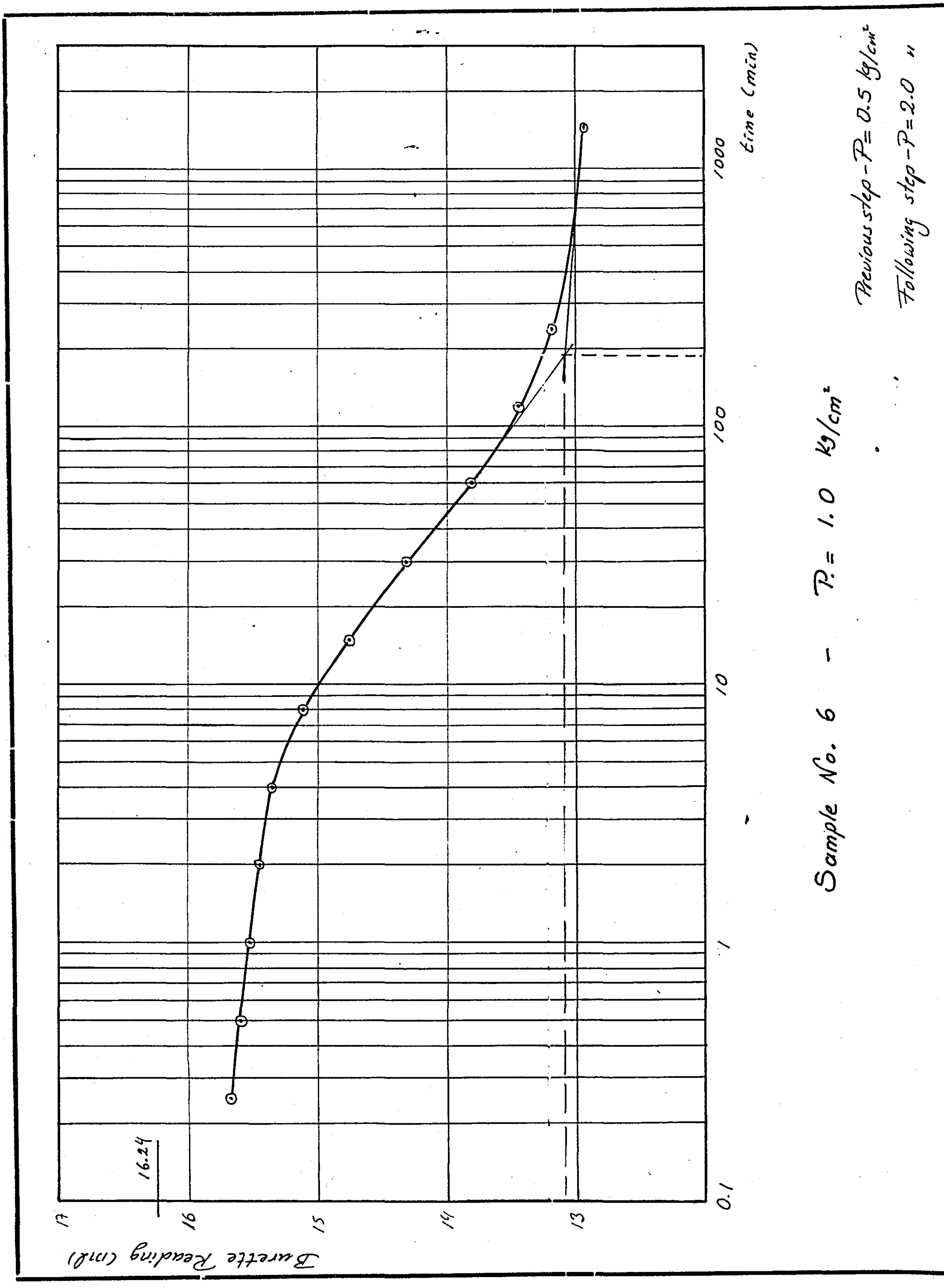

time (min)
1000
100
10
1
0.1
18
17
16
17.63
Burette Reading (ml.)
Sample No. 5 - P = 2.52 Kg/cm²
Previous step - P = 1.68 kg/cm²
Following step - P = 3.78 "

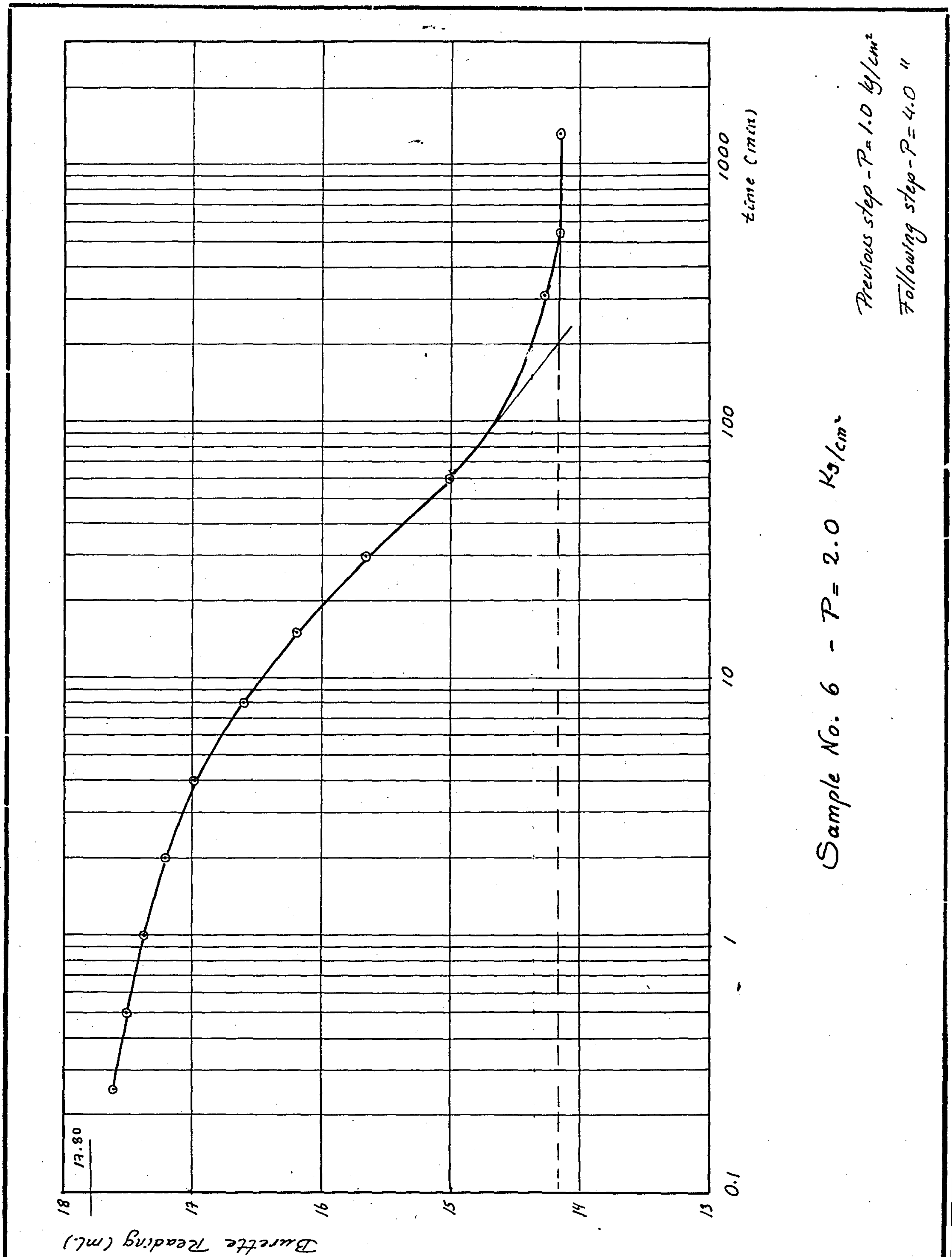

Sample No. 5 - P= 3.78 kg/cm²
Previous step - P= 2.52 kg/cm²
Following step - P= 5.67 "
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
19
18.75
18
17

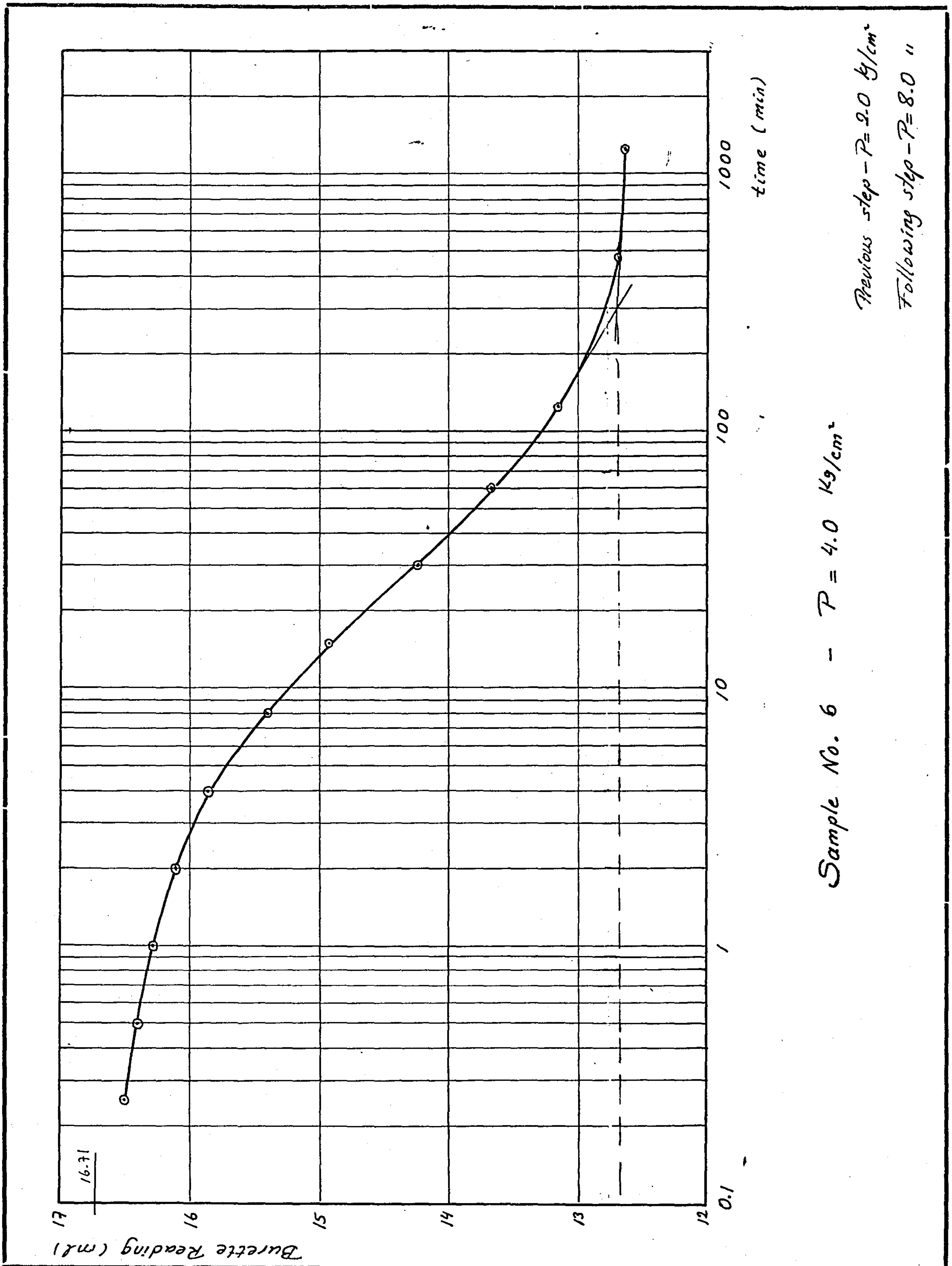

Sample No. 5 - P = 5.67 Kg/cm²
Previous step - P=3.78 kg/cm²
Following step - P= 8.5 "
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17
16
15
16.92

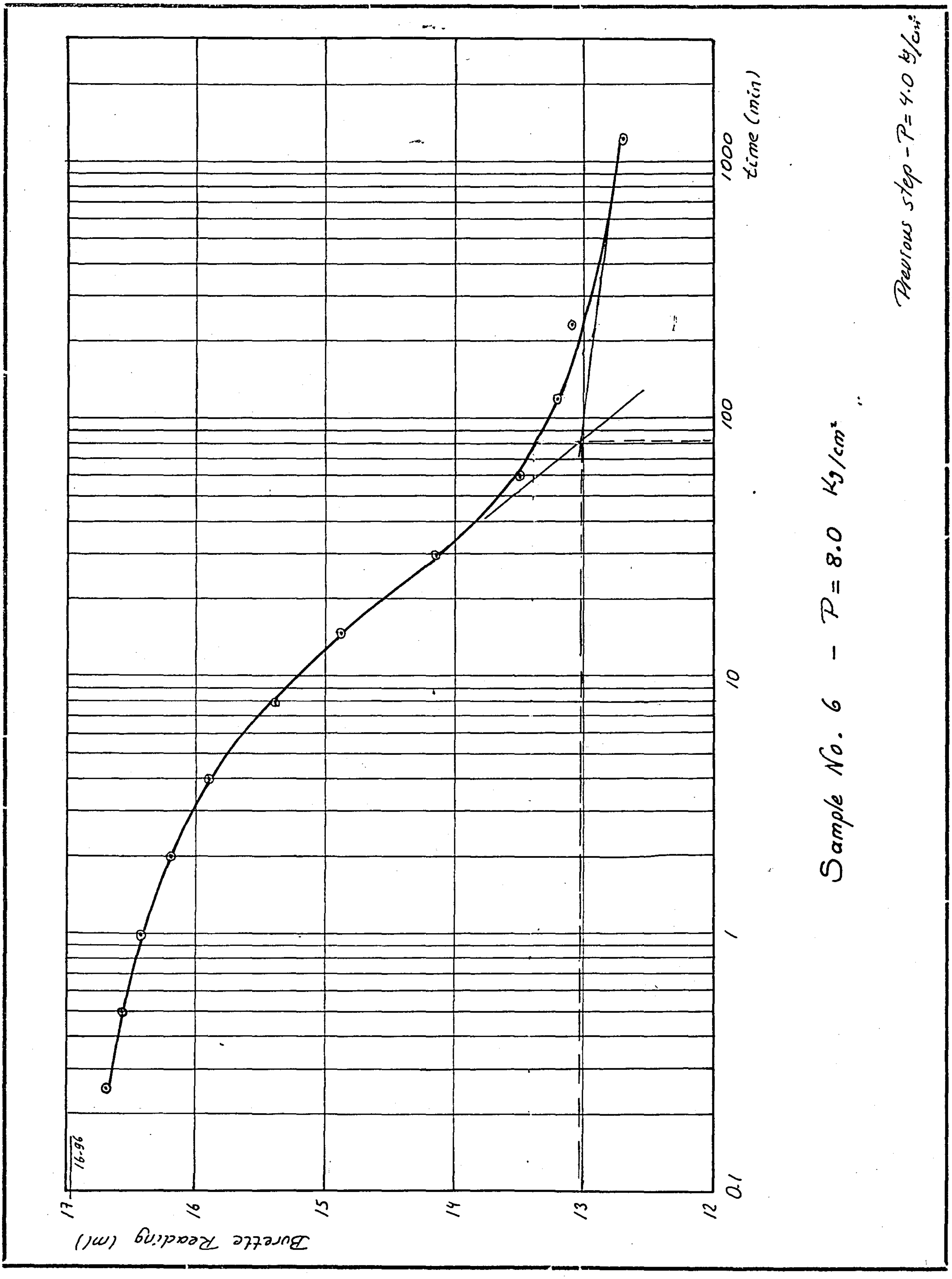

Previous step - P=5.67 Kg/cm²
Sample No. 5 - P = 8.5 Kg/cm²
time (min)
1000
100
10
1
0.1
15
14
13
14.85
Burette Reading (ml.)

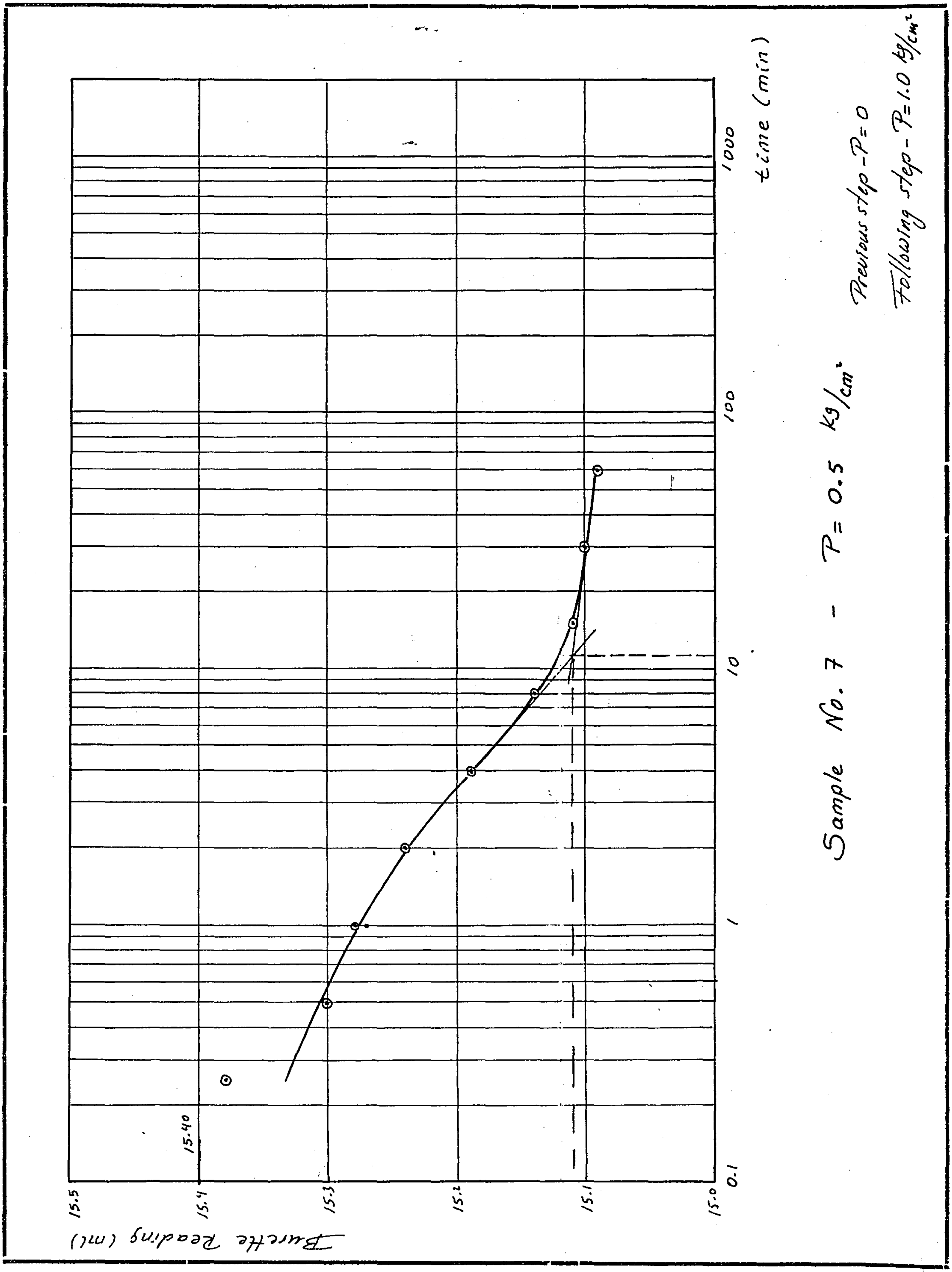

Sample No. 6 - P= 0.5 Kg/cm²
Previous step - P= 0
Following step - P=1.0 kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17.5
16.5
15.5
14.5
13.5
12.5
12
17.76

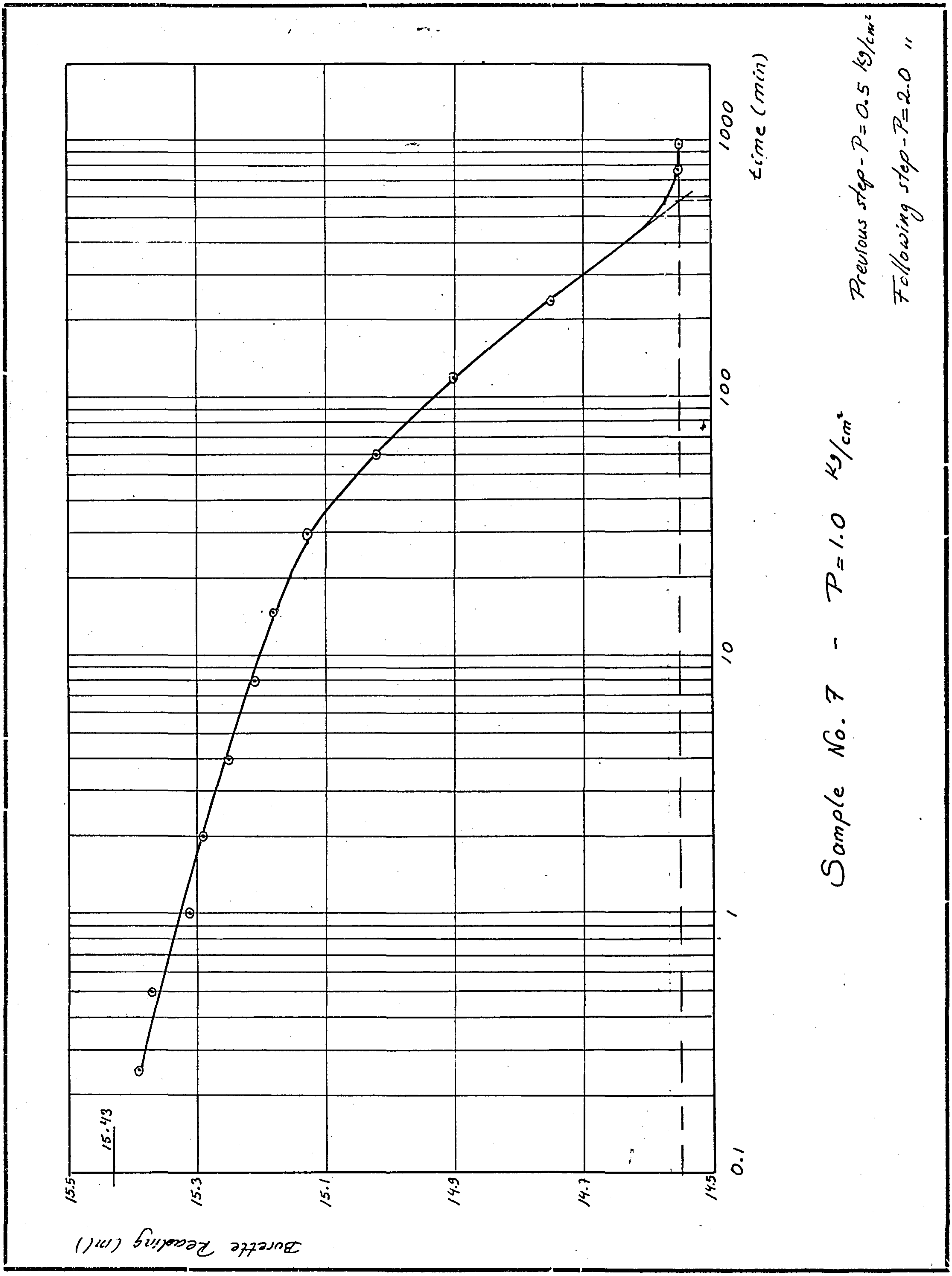

Sample No. 6 - P = 1.0 kg/cm²
Previous step - P = 0.5 kg/cm²
Following step - P = 2.0 "
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17
16
15
14
13
16.24


Previous step - P = 1.0 Kg/cm²
Following step - P = 4.0 "
Sample No. 6 - P = 2.0 Kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml.)
18
17
16
15
14
13
17.80

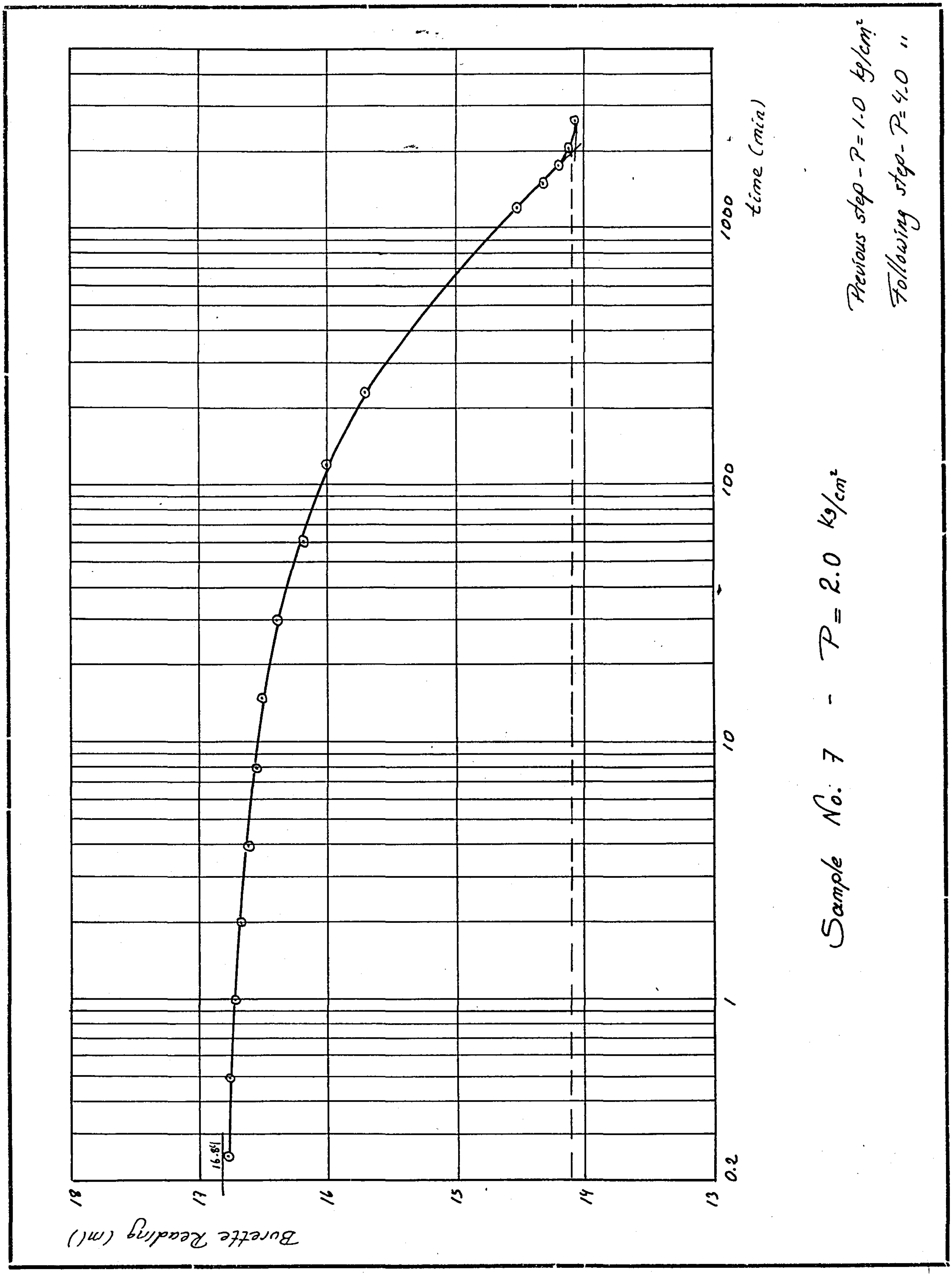

Previous step - P = 2.0 Kg/cm²
Following step - P = 8.0 "
time (min)
1000
100
10
1
0.1
Sample No. 6 - P = 4.0 Kg/cm²
Burette Reading (ml)
17
16
15
14
13
12
16.71

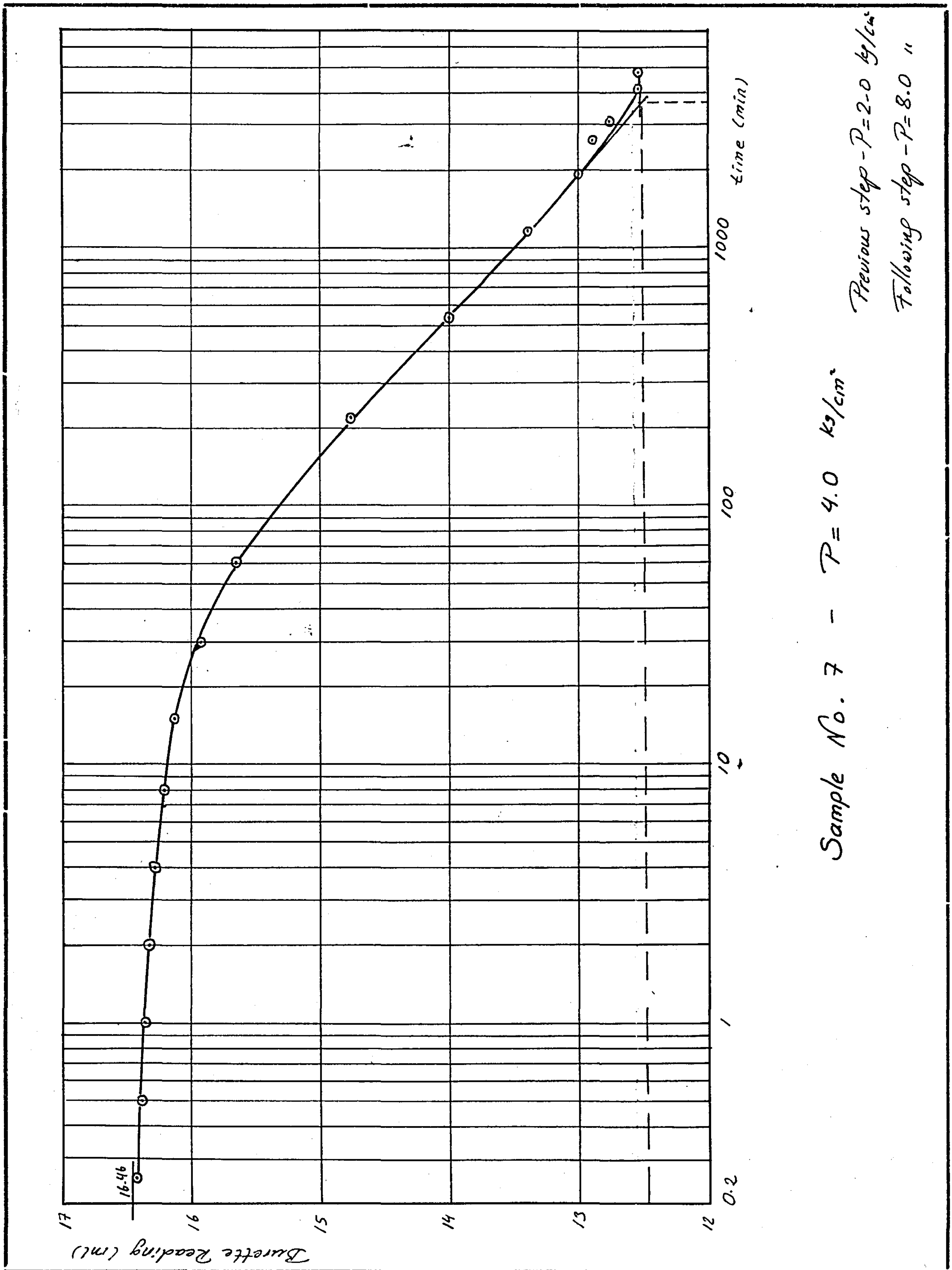

Previous step - P = 4.0 Kg/cm²
Sample No. 6 - P = 8.0 Kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
17
16
15
14
13
12
16.96

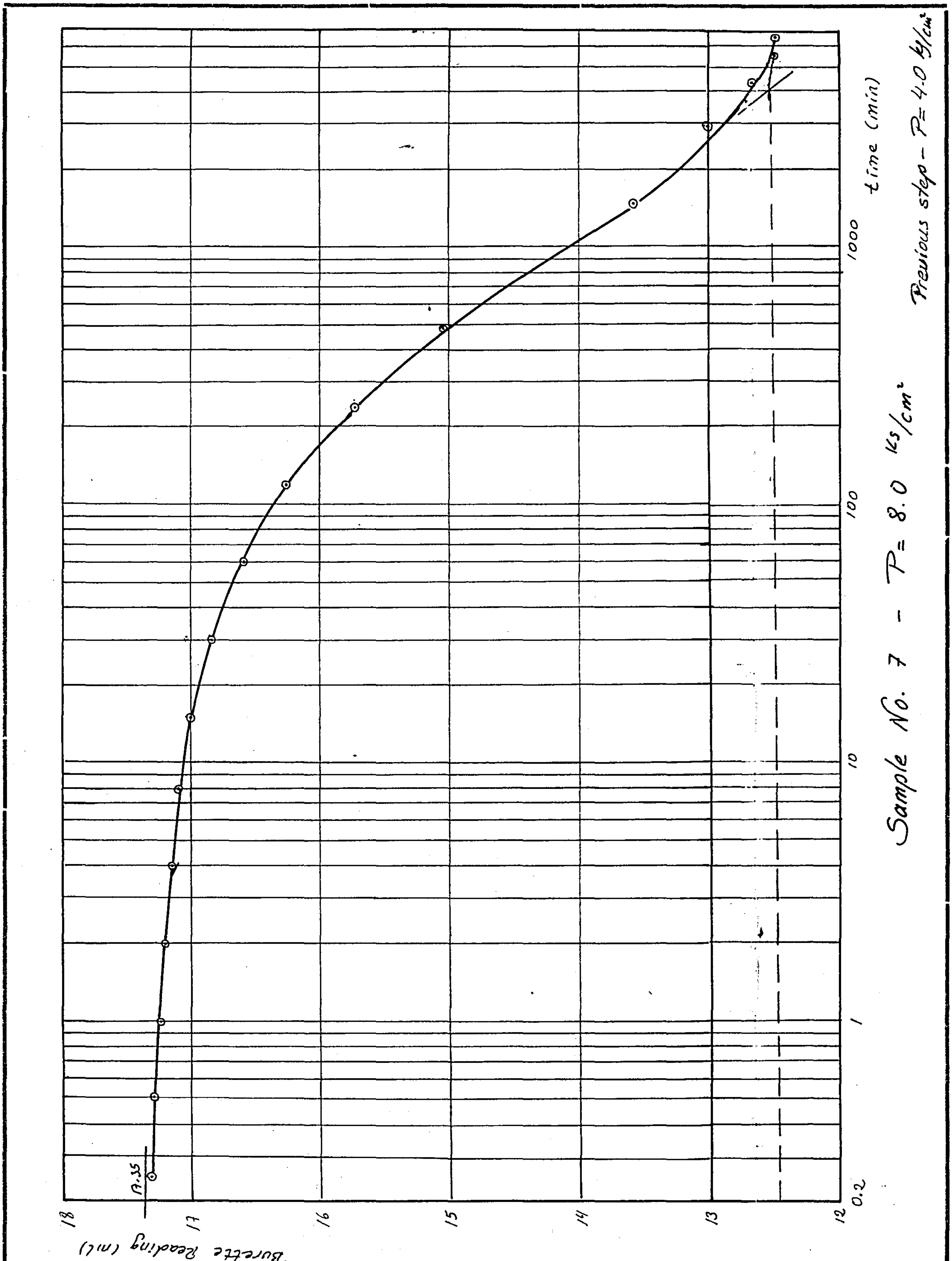

time (min)
0.1
1
10
100
1000
15.5
15.4
15.3
15.2
15.1
15.0
15.40
Burette Reading (ml)
Sample No. 7 - P = 0.5 Kg/cm²
Previous step - P = 0
Following step - P = 1.0 Kg/cm²

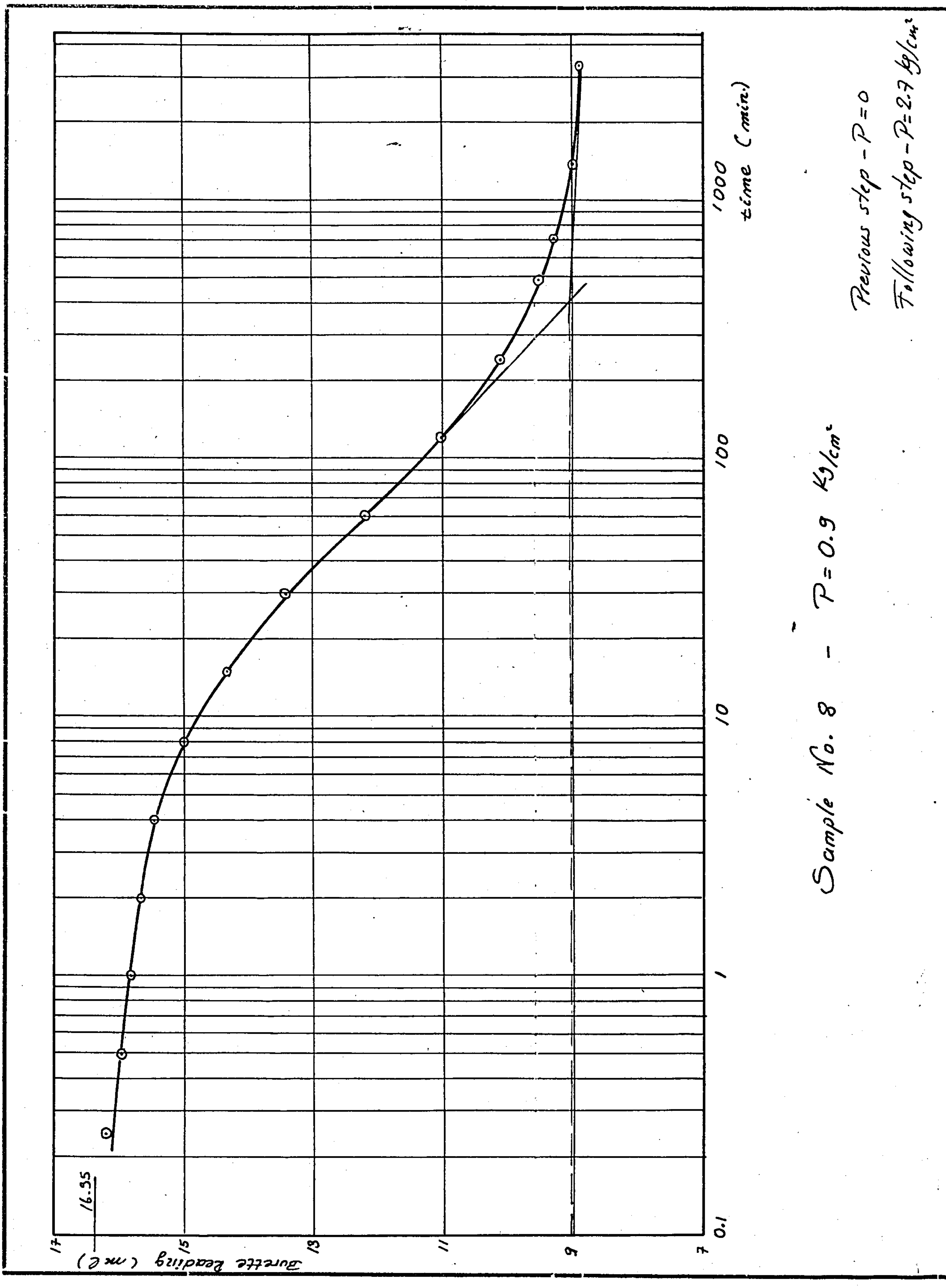


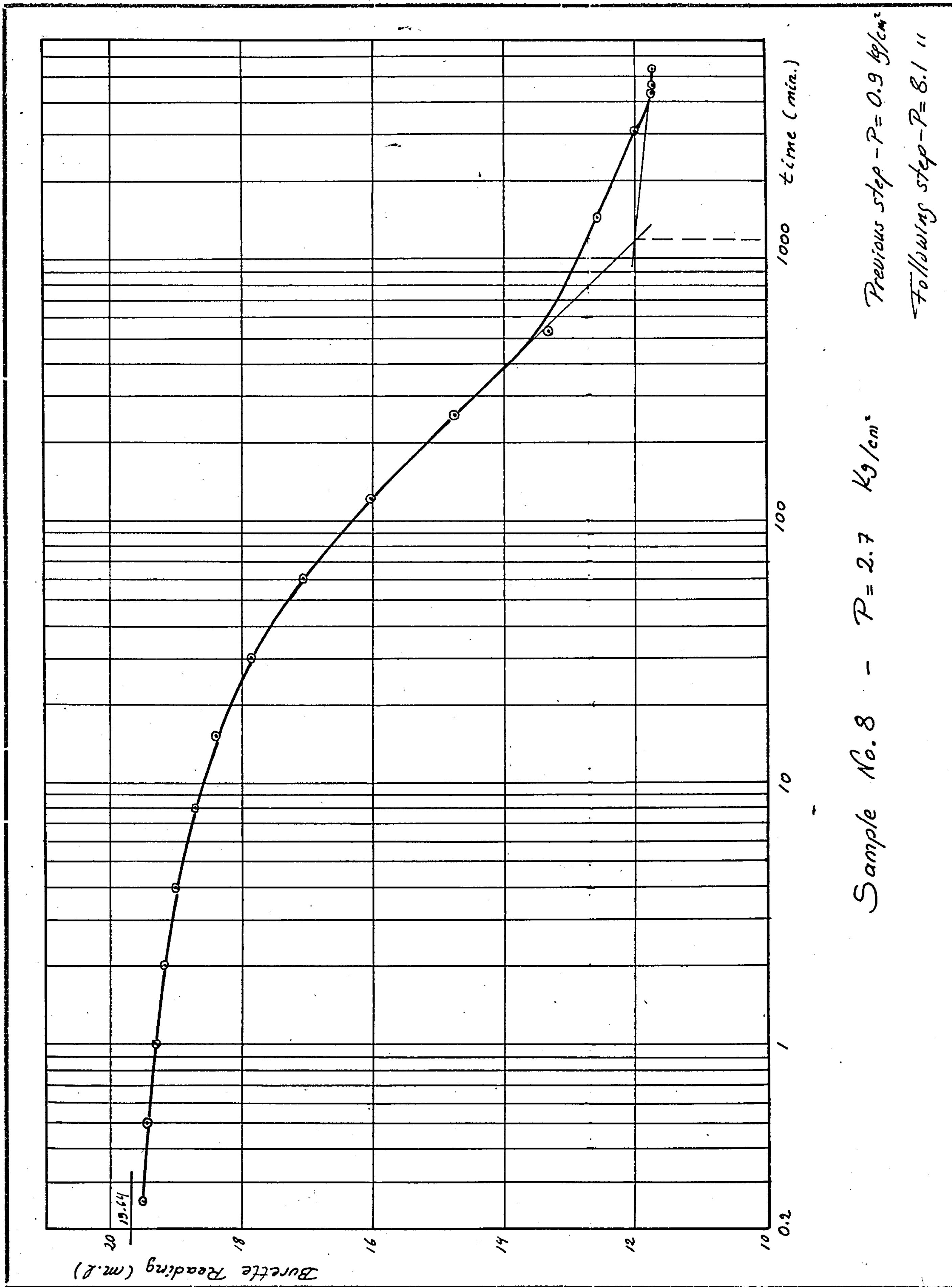
time (min)
1000
100
10
1
0.1
15.5
15.3
15.1
14.9
14.7
14.5
15.43
Burette Reading (ml)
Sample No. 7 - P=1.0 kg/cm²
Previous step - P=0.5 kg/cm²
Following step - P=2.0 "

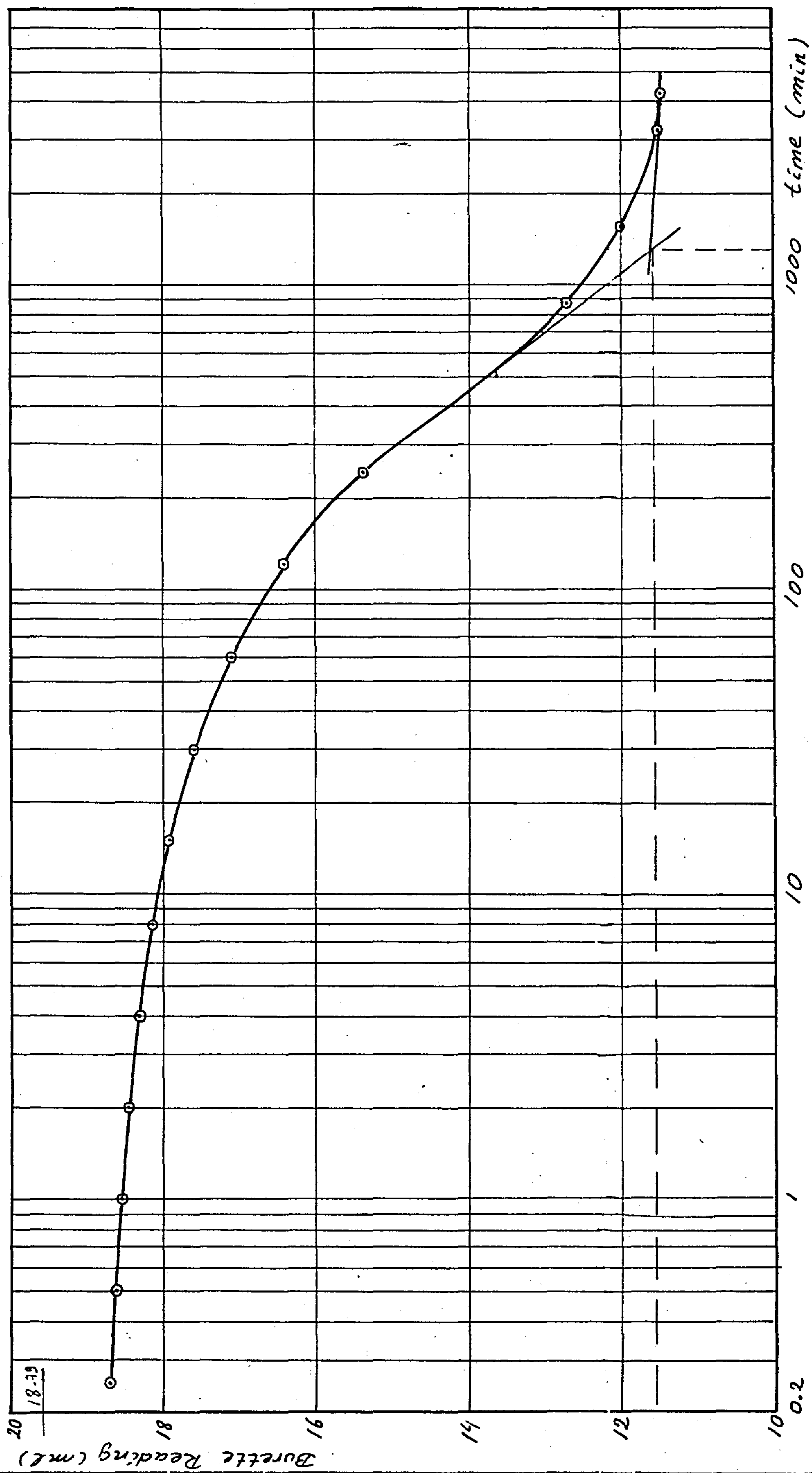

Previous step - P = 1.0 kg/cm²
Following step - P = 4.0 ″
Sample No: 7 - P = 2.0 kg/cm²
time (min)
0.2
1
10
100
1000
Burette Reading (ml)
18
17
16
15
14
13
16.84


Burette Reading (ml)
17
16
15
14
13
12
16.46
time (min)
0.2
1
10
100
1000
Sample No. 7 - P = 4.0 kg/cm²
Previous step - P=2.0 kg/cm²
Following step - P=8.0 "


Sample No. 7 - P = 8.0 Ks/cm²
Previous step - P = 4.0 Kg/cm²
time (min)
0.2
1
10
100
1000
Burette Reading (ml)
18
17
16
15
14
13
12
17.35

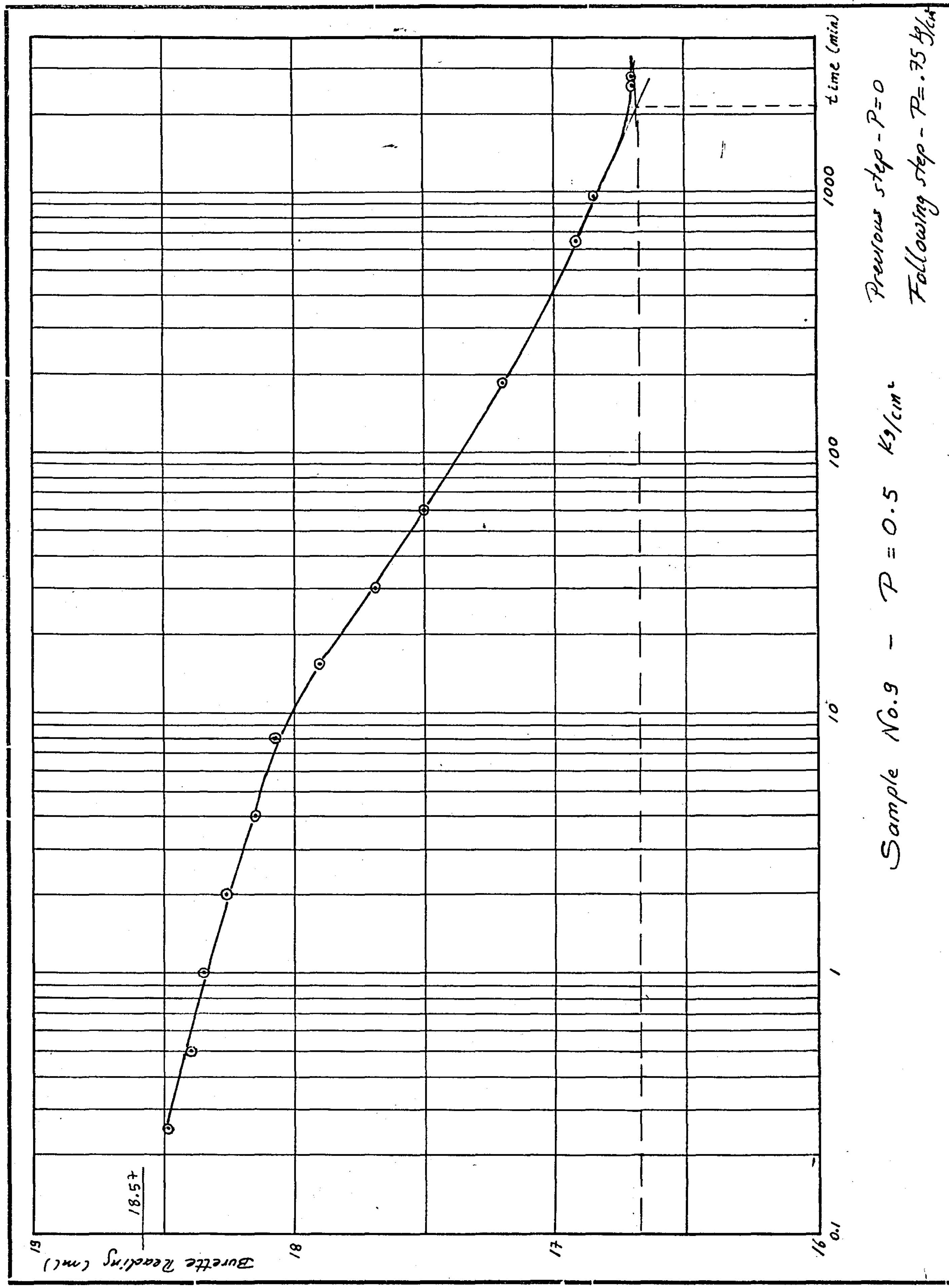

Sample No. 8 - P = 0.9 Kg/cm²
Previous step - P = 0
Following step - P = 2.7 Kg/cm²
time (min.)
0.1
1
10
100
1000
Burette Reading (ml)
17
15
13
11
9
7
16.55

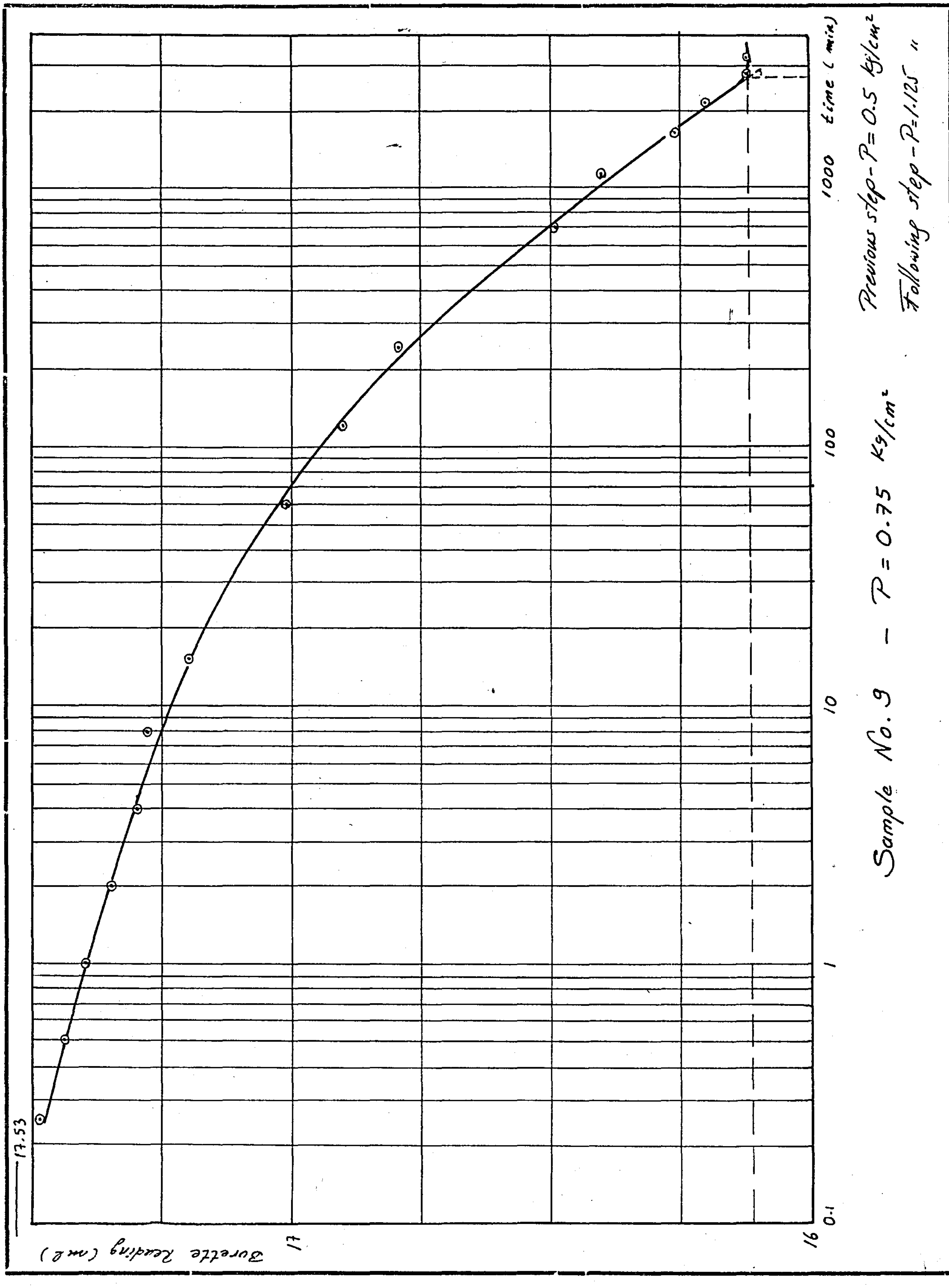

Previous step - P = 0.9 kg/cm²
Following step - P = 8.1 "
time (min.)
1000
100
10
1
0.2
Sample No. 8 - P = 2.7 Kg/cm²
20
18
16
14
12
10
19.64
Burette Reading (m.l)

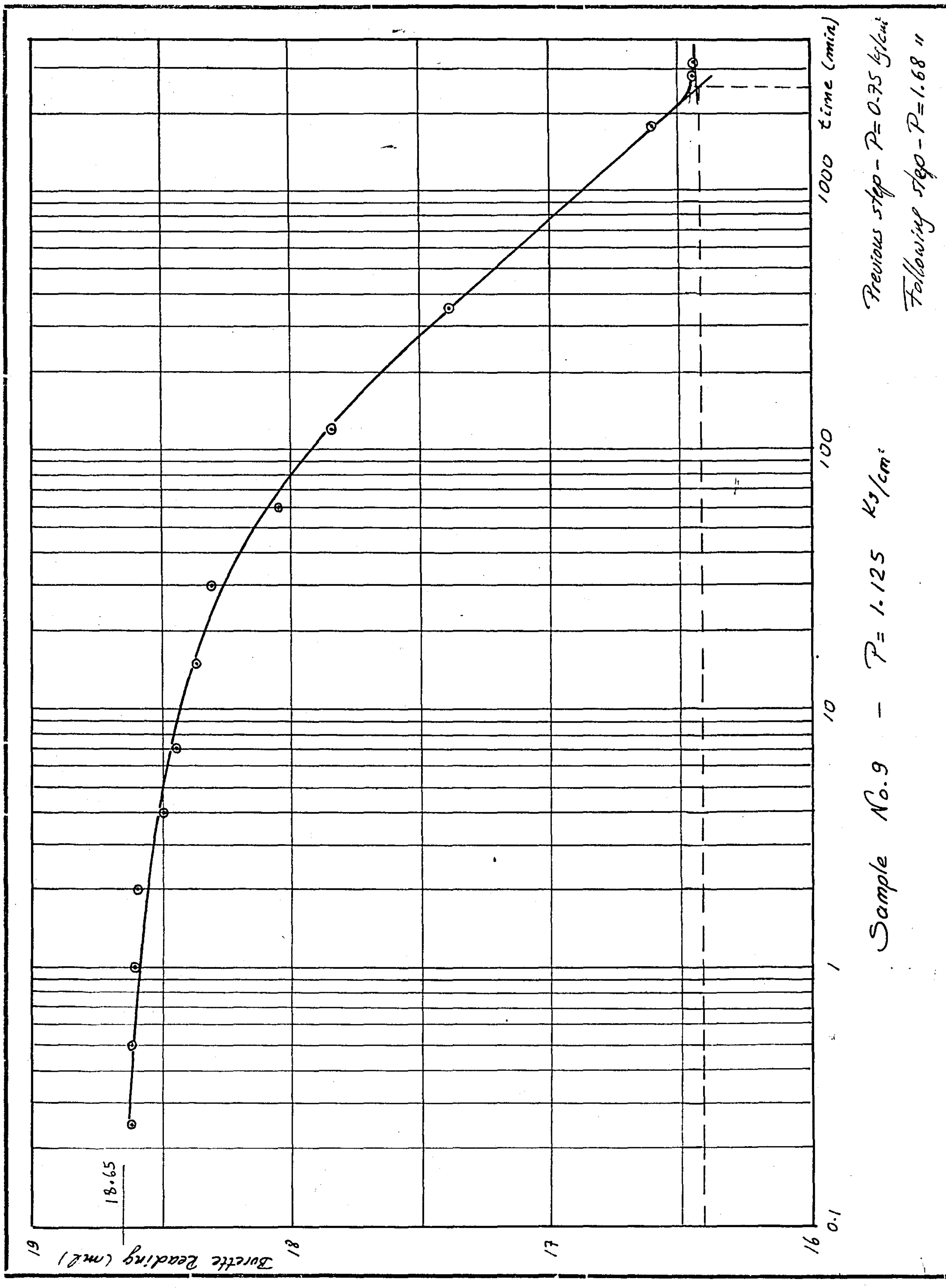


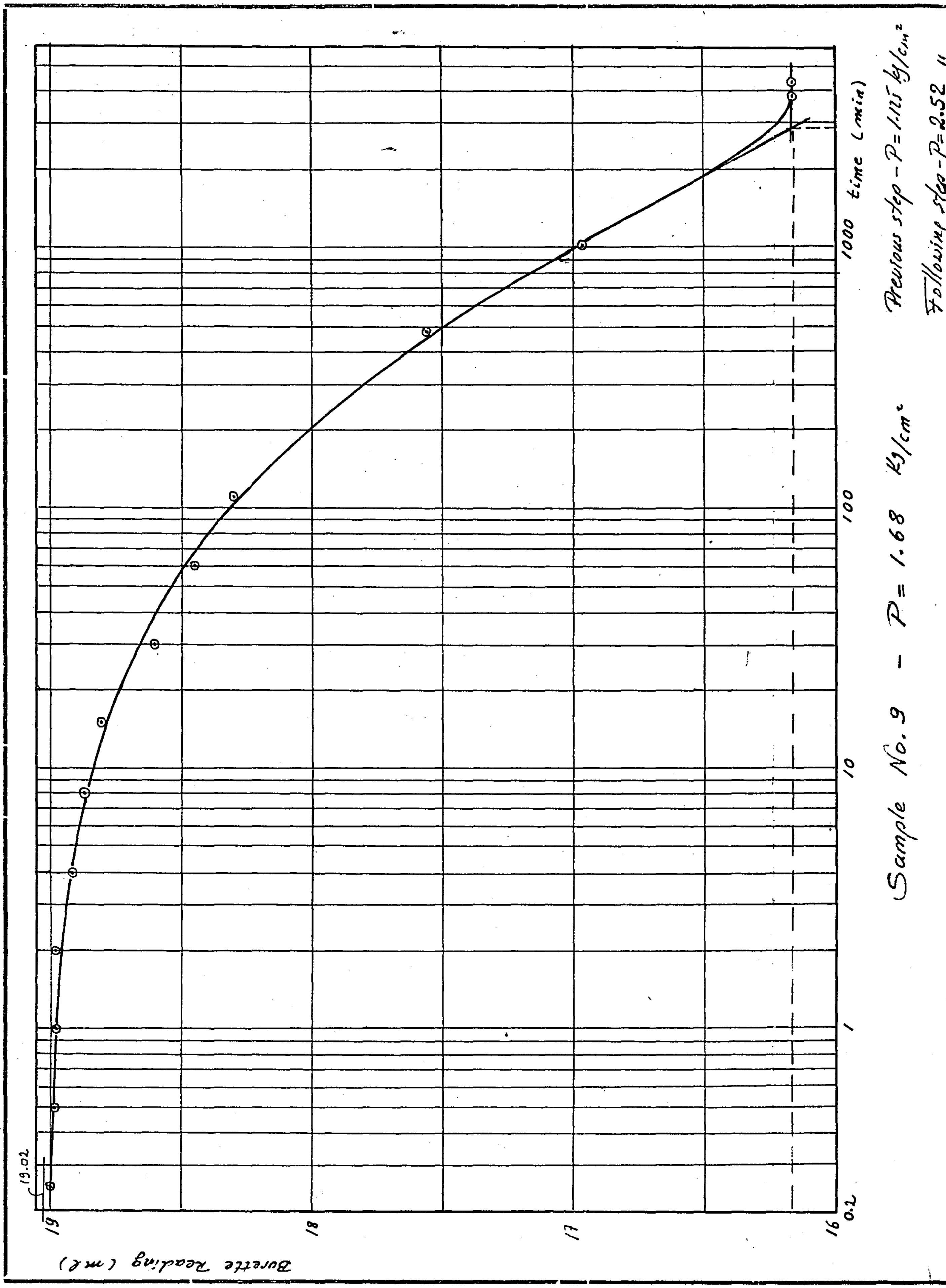
Sample No. 8 - P=8.1 Kg/cm²

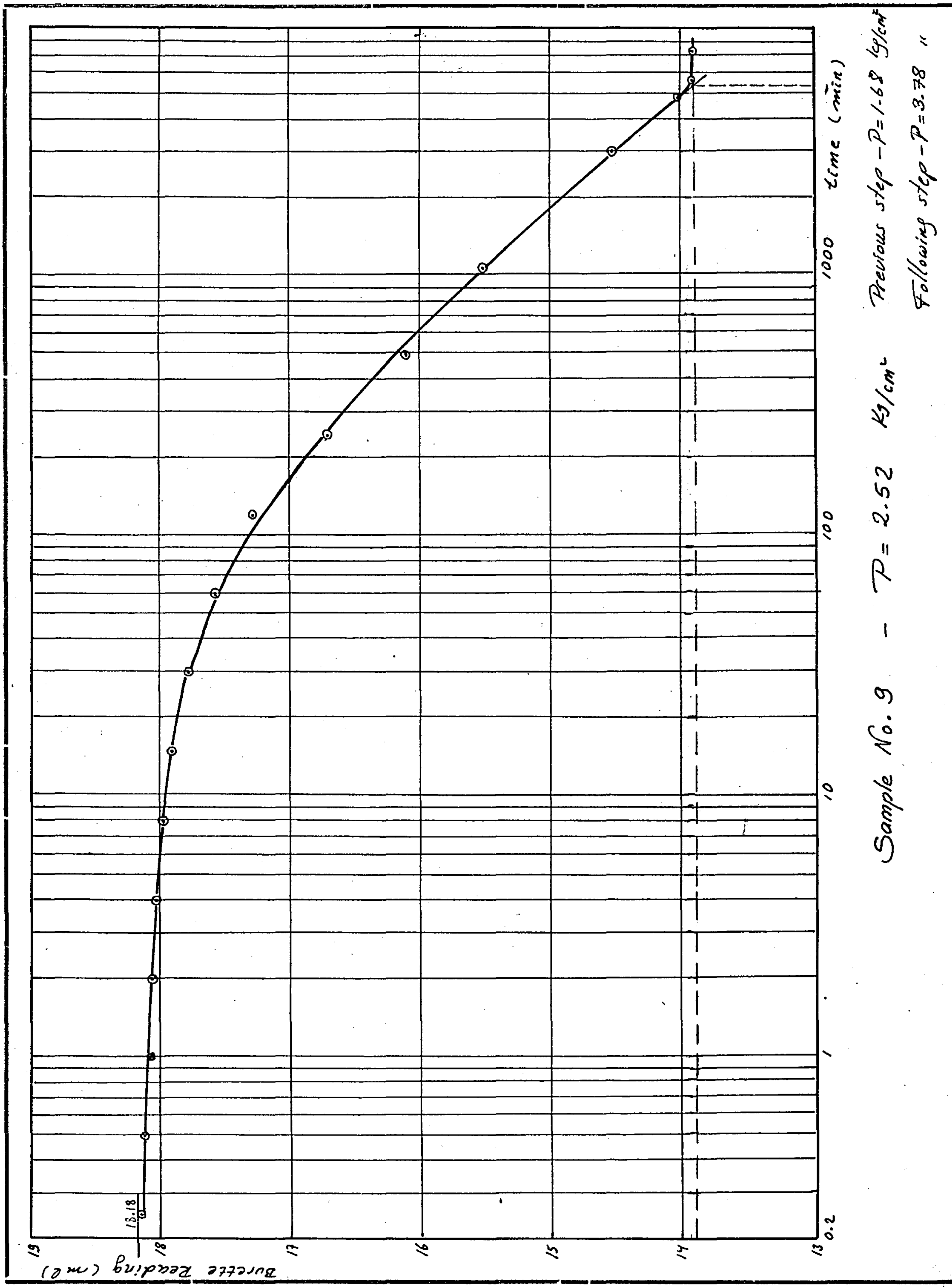
Previous step - P=2.7 Kg/cm²

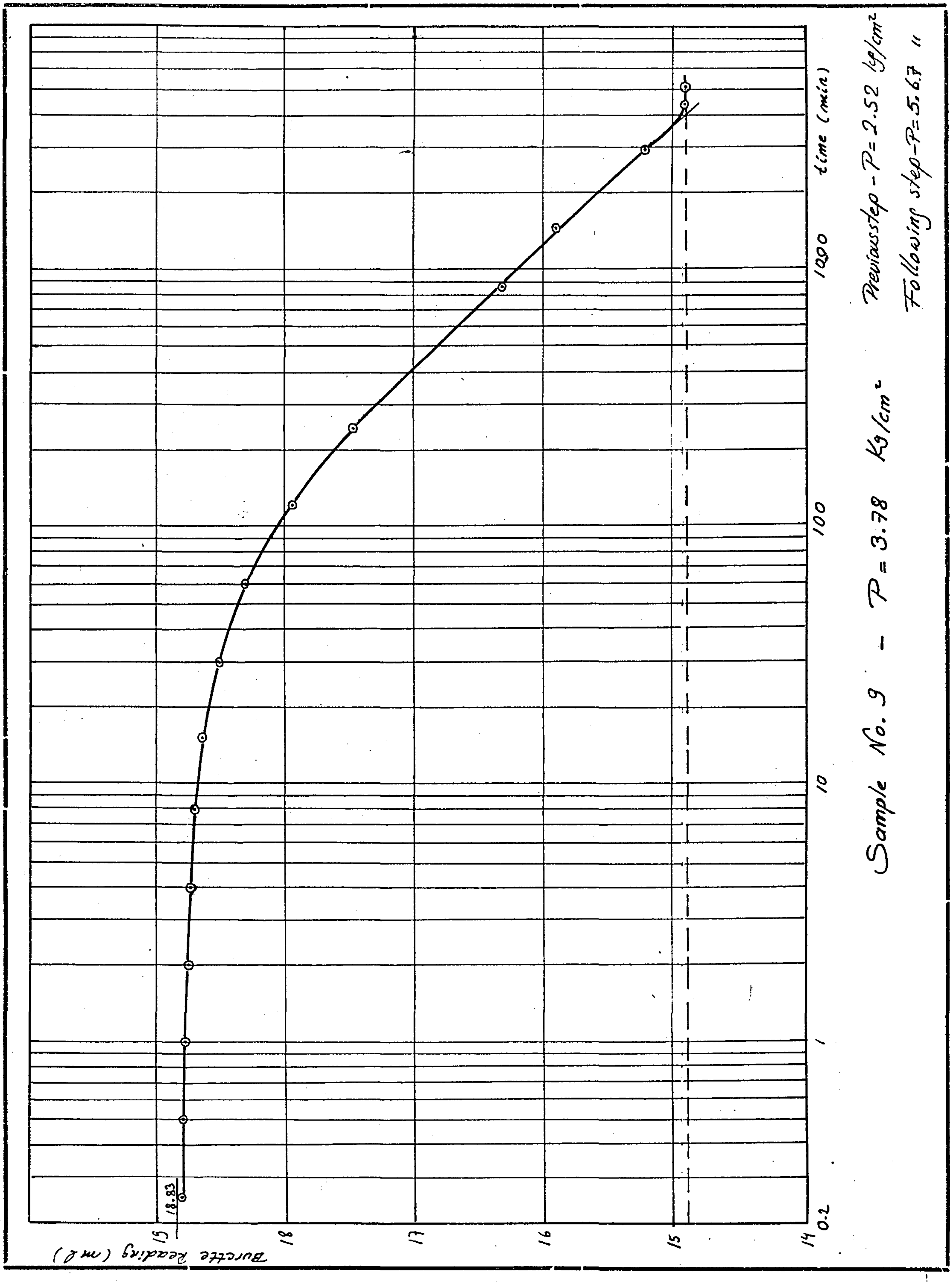

Sample No.9 - P = 0.5 Kg/cm²
Previous step - P=0
Following step - P=.75 Kg/cm²
time (min)
0.1
1
10
100
1000
Burette Reading (ml)
19
18
17
16
18.57

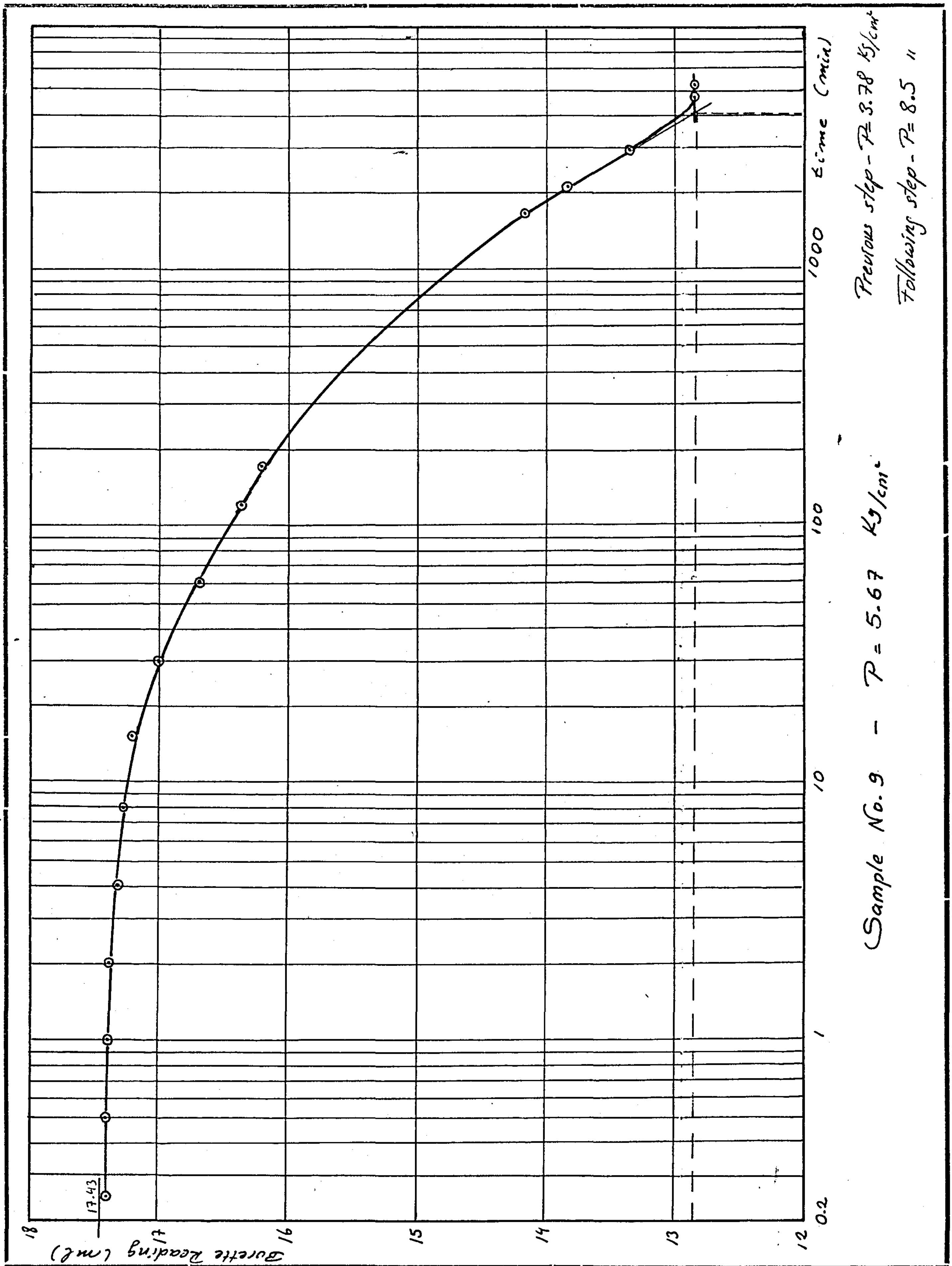

time (min)
1000
100
10
1
0.1
17.53
17
16
Burette Reading (ml)
Sample No. 9 - P = 0.75 Kg/cm²
Previous step - P = 0.5 Kg/cm²
Following step - P = 1.125 "

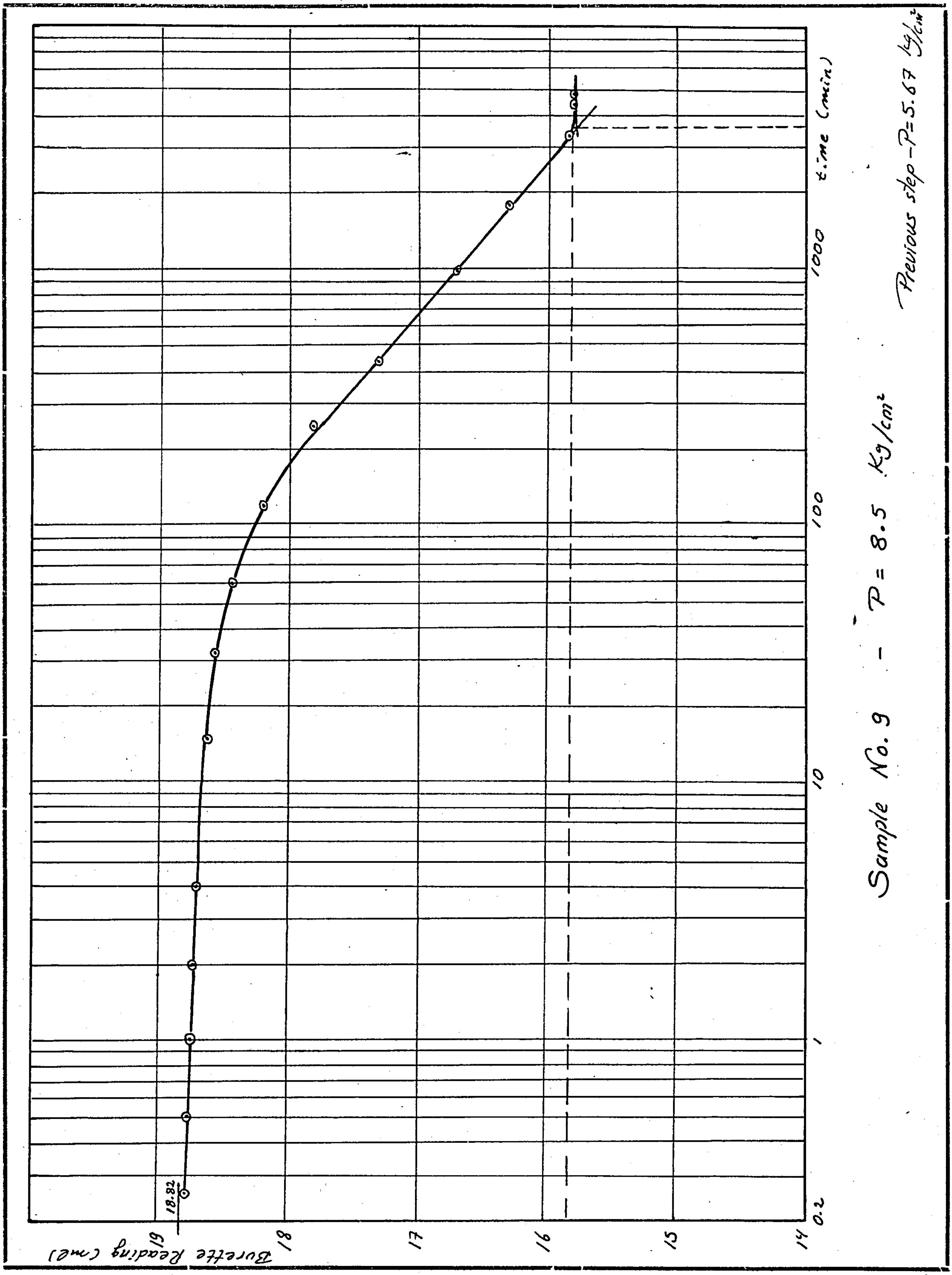

time (min)
1000
100
10
1
0.1
Burette Reading (ml)
19
18
17
16
18.65
Sample No.9 - P= 1.125 Kg/cm²
Previous step - P= 0.75 kg/cm²
Following step - P=1.68 "


Sample No. 9 - P = 1.68 kg/cm²
Previous step - P = 1.125 kg/cm²
Following step - P = 2.52 "
time (min)
1000
100
10
1
0.2
19.02
19
18
17
16
Burette Reading (ml)


Sample No. 9 - P = 2.52 Kg/cm²
Previous step - P=1.68 kg/cm²
Following step - P=3.78 "
time (min)
0.2
1
10
100
1000
Burette Reading (ml)
19
18
17
16
15
14
13
13.18


Previous step - P=2.52 kg/cm²
Following step-P=5.67 "
Sample No. 9 - P = 3.78 Kg/cm²
time (min)
0.2
1
10
100
1000
Burette Reading (ml)
14
15
16
17
18
19
18.83


time (min)
0.2
1
10
100
1000
Burette Reading (ml)
18
17
16
15
14
13
12
17.43
Sample No. 9 - P = 5.67 Kg/cm²
Previous step - P = 3.78 Kg/cm²
Following step - P = 8.5 "


Previous step – P=5.67 kg/cm²
Sample No. 9 – P = 8.5 Kg/cm²
time (min)
0.2
1
10
100
1000
Burette Reading (ml)
19
18
17
16
15
14
18.82

C. Calculations

CROSS-SECTIONAL AREAS :

In order to find the final cross-sectional area of a sample, its final volume is divided by its final height at the end of each consolidation step.

The symbols used in the following calculations are :

H_f = Final height of the sample at the end of the step.

V_i =Volume of the sample at the beginning of the step.

ΔV = Change in the sample volume.

V_f = Volume of the sample at the end of the step.

A_f = Cross-sectional area of the sample at the end of the step.

SAMPLE NO. 1

$P = 0.5\ Kg/cm^2$

$$H_f = 4.79\ cm. \quad , H_i = 4.82\ cm.$$

$$V_i = (20.65)(4.82) = 99.53\ cm^3$$

$$\Delta V = 16.70 - 12.78 = 3.92\ cm^3$$

$$V_f = 99.53 - 3.92 = 95.61\ cm^3$$

$$A_f = \frac{95.61}{4.79} = 19.96\ cm^2.$$

$P = 0.75 \ kg/cm^2$

$H_f = 4.76 \ cm.$

$V_i = 95.61 \ cm^3$

$\Delta V = 16.69 - 15.50 = 1.19 \ cm^3$

$V_f = 95.61 - 1.19 = 94.42 \ cm^3$

$A_f = \frac{94.42}{4.76} = 19.81 \ cm^2$

$P = 1.125 \ kg/cm^2$

$H_f = 4.74 \ cm$

$V_i = 94.42 \ cm^3$

$\Delta V = 18.68 - 16.90 = 1.78 \ cm^3$

$V_f = 94.42 - 1.78 = 92.64 \ cm^3$

$A_f = \frac{92.64}{4.74} = 19.54 \ cm^2$

$P = 1.68 \ kg/cm^2$

$H_f = 4.72 \ cm.$

$V_i = 92.64 \ cm^3$

$\Delta V = 16.60 - 14.72 = 1.88 \ cm^3$

$V_f = 92.64 - 1.88 = 90.76 \ cm^3$

$A_f = \frac{90.76}{4.72} = 19.22 \ cm^2$

$P = 2.52 \ kg/cm^2$

$H_f = 4.67 \ cm$

$V_i = 90.76 \ cm^3$

$\Delta V = 16.29 - 14.50 = 1.79 \ cm^3$

$V_f = 90.76 - 1.79 = 88.97 \ cm^3$

$A_f = \frac{88.97}{4.67} = 19.06 \ cm^2$

$P = 3.78\ Kg/cm^2$

$H_f = 4.65\ cm$

$V_i = 88.97\ cm^3$

$\Delta V = 15.49 - 13.25 = 2.24\ cm^3$

$V_f = 88.97 - 2.24 = 86.73\ cm^3$

$A_f = \frac{86.73}{4.65} = 18.66\ cm^2$

$P = 5.67\ Kg/cm^2$

$H_f = 4.62\ cm$

$V_i = 86.73\ cm^3$

$\Delta V = 14.42 - 12.55 = 1.87\ cm^3$

$V_f = 86.73 - 1.87 = 84.86\ cm^3$

$A_f = \frac{84.86}{4.62} = 18.37\ cm^2$

$P = 8.5\ Kg/cm^2$

$H_f = 4.57\ cm$

$V_i = 84.86\ cm^3$

$\Delta V = 14.70 - 13.02 = 1.68\ cm^3$

$V_f = 84.86 - 1.68 = 83.18\ cm^3$

$A_f = \frac{83.18}{4.57} = 18.20\ cm^2$

SAMPLE NO. 2

$P = 0.5\ Kg/cm^2$

$H_f = 4.80\ cm\ ,\ H_i = 4.82\ cm$

$V_i = (20.65)(4.82) = 99.53\ cm^3$

$\Delta V = 16.89 - 14.59 = 2.30\ cm^3$

$V_f = 99.53 - 2.30 = 97.23\ cm^3$

$A_f = \frac{97.23}{4.80} = 20.17\ cm^2$.

$P = 1.0 \ Kg/cm^2$

$H_f = 4.80 \ cm$

$V_i = 97.23 \ cm^3$

$\Delta V = 17.19 - 15.79 = 1.40 \ cm^3$

$V_f = 97.23 - 1.40 = 95.83 \ cm^3$

$A_f = \frac{95.83}{4.80} = 19.96$

$P = 2.0 \ Kg/cm^2$

$H_f = 4.79 \ cm$

$V_i = 95.83 \ cm^3$

$\Delta V = 18.70 - 15.97 = 2.73 \ cm^3$

$V_f = 95.83 - 2.73 = 93.10 \ cm^3$

$A_f = \frac{93.10}{4.79} = 19.45 \ cm^2$

$P = 4.0 \ Kg/cm^2$

$H_f = 4.72 \ cm$

$V_i = 93.10 \ cm^3$

$\Delta V = 17.88 - 14.65 = 3.23 \ cm^3$

$V_f = 93.10 - 3.23 = 89.87 \ cm^3$

$A_f = \frac{89.87}{4.72} = 19.04 \ cm^2$

$P = 8.0 \ Kg/cm^2$

$H_f = 4.63 \ cm$

$V_i = 89.87 \ cm^3$

$\Delta V = 17.67 - 14.52 = 3.15 \ cm^3$

$V_f = 89.87 - 3.15 = 86.72 \ cm^3$

$A_f = \frac{86.72}{4.63} = 18.72 \ cm^2$

SAMPLE NO. 3

$P = 0.9\ Kg/cm^2$

$H_f = 4.85\ cm,\ H_i = 4.90\ cm$

$V_i = (20.65)(4.90) = 101.19\ cm^3$

$\Delta V = 19.30 - 17.49 = 1.81\ cm^3$

$V_f = 101.19 - 1.81 = 99.38\ cm^3$

$A_f = \frac{99.38}{4.85} = 20.48\ cm^2$

$P = 2.7\ Kg/cm^2$

$H_f = 4.78\ cm$

$V_i = 99.38\ cm^3$

$\Delta V = 19.28 - 15.40 = 3.88\ cm^3$

$V_f = 99.38 - 3.88 = 95.50\ cm^3$

$A_f = \frac{95.50}{4.78} = 19.98\ cm^2$

$P = 8.1\ Kg/cm^2$

$H_f = 4.70\ cm$

$V_i = 95.50\ cm^3$

$\Delta V = 18.60 - 12.92 = 5.68\ cm^3$

$V_f = 95.50 - 5.68 = 89.82\ cm^3$

$A_f = \frac{89.82}{4.70} = 19.13\ cm^2$

SAMPLE NO. 4

$P = 0.9\ Kg/cm^2$

$H_f = 4.80\ cm,\ H_i = 4.83\ cm$

$V_i = (20.65)(4.83) = 99.74\ cm^3$

$\Delta V = 19.30 - 16.63 = 2.67\ cm^3$

$V_f = 99.74 - 2.67 = 97.07 \ cm^3$

$A_f = \frac{97.07}{4.80} = 20.22 \ cm^2$

$P = 2.7 \ Kg/cm^2$

$H_f = 4.76 \ cm$

$V_i = 97.07 \ cm^3$

$\Delta V = 18.39 - 13.80 = 4.59 \ cm^3$

$V_f = 97.07 - 4.59 = 92.48 \ cm^3$

$A_f = \frac{92.48}{4.76} = 19.40 \ cm^2$

$P = 8.1 \ Kg/cm^2$

$H_f = 4.69 \ cm$

$V_i = 92.48 \ cm^3$

$\Delta V = 18.11 - 12.49 = 5.62 \ cm^3$

$V_f = 92.48 - 5.62 = 86.86 \ cm^3$

$A_f = \frac{86.86}{4.69} = 18.51 \ cm^2$

SAMPLE NO. 5

$P = 0.5 \ Kg/cm^2$

$H_f = 4.99 \ cm, \ H_i = 5.00 \ cm$

$V_i = (20.65)(5.00) = 103.25 \ cm^3$

$\Delta V = 18.60 - 17.56 = 1.04 \ cm^3$

$V_f = 103.25 - 1.04 = 102.21 \ cm^3$

$A_f = \frac{102.21}{4.99} = 20.49 \ cm^2$

$P = 0.75 \ Kg/cm^2$

$H_f = 4.99 \ cm$

$V_i = 102.21 \ cm^3$

$\Delta V = 18.90 - 18.42 = .48 \ cm^3$

$V_f = 102.21 - .48 = 101.73 \ cm^3$

$A_f = \frac{101.73}{4.99} = 20.36 \ cm^2$

$P = 1.125 \ Kg/cm^2$

$H_f = 4.98 \ cm$

$V_i = 101.73 \ cm^3$

$\Delta V = 19.08 - 18.19 = .89 \ cm^3$

$V_f = 101.73 - .89 = 100.84 \ cm^3$

$A_f = \frac{100.84}{4.98} = 20.21 \ cm^2$

$P = 1.68 \ Kg/cm^2$

$H_f = 4.97 \ cm$

$V_i = 100.84 \ cm^3$

$\Delta V = 18.30 - 17.58 = .72 \ cm^3$

$V_f = 100.84 - .72 = 100.12 \ cm^3$

$A_f = \frac{100.12}{4.97} = 20.15 \ cm^2$

$P = 2.52 \ Kg/cm^2$

$H_f = 4.96 \ cm$

$V_i = 100.12 \ cm^3$

$\Delta V = 17.59 - 15.90 = 1.69 \ cm^3$

$V_f = 100.12 - 1.69 = 99.43 \ cm^3$

$A_f = \frac{99.43}{4.96} = 20.05 \ cm^2$

$P = 3.78 \ Kg/cm^2$

$H_f = 4.95 \ cm$

$V_i = 99.43 \ cm^3$

$\Delta V = 18.69 - 16.80 = 1.89 \ cm^3$

$V_f = 99.43 - 1.89 = 97.54 \ cm^3$

$A_f = \frac{97.54}{4.95} = 19.71 \ cm^2$

$P = 5.67 \ Kg/cm^2$

$H_f = 4.94 \ cm$

$V_i = 97.54 \ cm^3$

$\Delta V = 16.80 - 14.85 = 1.95 \ cm^3$

$V_f = 97.54 - 1.95 = 95.59 \ cm^3$

$A_f = \frac{95.59}{4.94} = 19.46 \ cm^2$

$P = 8.5 \ Kg/cm^2$

$H_f = 4.93 \ cm$

$V_i = 95.59 \ cm^3$

$\Delta V = 14.78 - 12.62 = 2.16 \ cm^3$

$V_f = 95.59 - 2.16 = 93.43 \ cm^3$

$A_f = \frac{93.43}{4.93} = 18.94 \ cm^2$

SAMPLE NO. 6

$P = 0.5 \ Kg/cm^2$

$H_f = 4.79 \ cm$, $H_i = 4.86 \ cm$

$V_i = (20.65)(4.86) = 99.90 \ cm^3$

$\Delta V = 17.60 - 12.20 = 5.40 \ cm^3$

$V_f = 99.90 - 5.40 = 94.50 \ cm^3$

$A_f = \frac{94.50}{4.79} = 19.72 \ cm^2$

$P = 1.0 \ Kg/cm^2$

$H_f = 4.78 \ cm$

$V_i = 94.50 \ cm^3$

$\Delta V = 16.20 - 13.45 = 2.75 \ cm^3$

$V_f = 94.50 - 2.75 = 91.75 \ cm^3$

$A_f = \frac{91.75}{4.78} = 19.20 \ cm^2$

$P = 2.0 \ Kg/cm^2$

$H_f = 4.72 \ cm$

$V_i = 91.75 \ cm^3$

$\Delta V = 17.79 - 14.15 = 3.64 \ cm^3$

$V_f = 91.75 - 3.64 = 88.11 \ cm^3$

$A_f = \frac{88.11}{4.72} = 18.66 \ cm^2$

$P = 4.0 \ Kg/cm^2$

$H_f = 4.66 \ cm$

$V_i = 88.11 \ cm^3$

$\Delta V = 16.95 - 12.65 = 4.30 \ cm^3$

$V_f = 88.11 - 4.30 = 83.81 \ cm^3$

$A_f = \frac{83.81}{4.66} = 17.99 \ cm^2$

$P = 8.0 \ Kg/cm^2$

$H_f = 4.49 \ cm$

$V_i = 83.81 \ cm^3$

$\Delta V = 16.90 - 12.70 = 4.20 \ cm^3$

$V_f = 83.81 - 4.20 = 79.61 \ cm^3$

$A_f = \frac{79.61}{4.49} = 17.74 \ cm^2$

SAMPLE NO. 7

$P = 0.5 \ Kg/cm^2$

$H_f = 4.82 \ cm, \ H_i = 4.82 \ cm.$

$V_i = (20.65)(4.82) = 99.53 \ cm^3$

$\Delta V = 16.04 - 15.09 = .95 \ cm^3$

$V_f = 99.53 - .95 = 98.58 \ cm^3$

$A_f = \frac{98.58}{4.82} = 20.46 \ cm^2$

$P = 1.0$ Kg/cm^2

$H_f = 4.81$ cm

$V_c = 98.58$ cm^3

$\Delta V = 15.40 - 14.55 = .85$ cm^3

$V_f = 98.58 - .85 = 97.73$ cm^3

$A_f = \frac{97.73}{4.81} = 20.31$ cm^2

$P = 2.0$ Kg/cm^2

$H_f = 4.78$ cm

$V_c = 97.73$ cm^3

$\Delta V = 16.86 - 14.08 = 2.78$ cm^3

$V_f = 97.73 - 2.78 = 94.95$ cm^3

$A_f = \frac{94.95}{4.78} = 19.86$ cm^2

$P = 4.0$ Kg/cm^2

$H_f = 4.72$ cm

$V_c = 94.95$ cm^3

$\Delta V = 16.51 - 12.55 = 3.96$ cm^3

$V_f = 94.95 - 3.96 = 90.99$ cm^3

$A_f = \frac{90.99}{4.72} = 19.27$ cm^2

$P = 8.0$ Kg/cm^2

$H_f = 4.67$ cm

$V_c = 90.99$ cm^3

$\Delta V = 17.40 - 12.50 = 4.90$ cm^3

$V_f = 90.99 - 4.90 = 86.09$ cm^3

$A_f = \frac{86.09}{4.76} = 18.44$ cm^2

SAMPLE NO. 8

$P = 0.9$ Kg/cm²

$H_f = 4.71$ cm , $H_i = 4.82$ cm

$V_i = (20.65)(4.82) = 99.53$ cm³

$\Delta V = 16.35 - 8.89 = 7.46$ cm³

$V_f = 99.53 - 7.46 = 92.07$ cm³

$A_f = \frac{92.07}{4.71} = 19.55$ cm²

$P = 2.7$ Kg/cm²

$H_f = 4.51$ cm

$V_i = 92.07$ cm³

$\Delta V = 19.70 - 11.71 = 7.99$ cm³

$V_f = 92.07 - 7.99 = 84.08$ cm³

$A_f = \frac{84.08}{4.51} = 18.64$ cm²

$P = 8.1$ Kg/cm²

$H_f = 4.37$ cm

$V_i = 84.08$ cm³

$\Delta V = 18.85 - 11.43 = 7.42$ cm³

$V_f = 84.08 - 7.42 = 76.66$ cm³

$A_f = \frac{76.66}{4.37} = 17.54$ cm²

SAMPLE NO. 9

$P = 0.5$ Kg/cm²

$H_f = 4.80$ cm , $H_i = 4.82$ cm

$V_i = (20.65)(4.82) = 99.53$ cm³

$\Delta V = 18.80 - 16.70 = 2.10$ cm³

$V_f = 99.53 - 2.10 = 94.43$

$A_f = \frac{94.43}{4.80} = 20.28$ cm²

$P = 0.75$ Kg/cm²

$H_f = 4.76$ cm

$V_i = 97.43$ cm³

$\Delta V = 17.50 - 16.12 = 1.38$ cm³

$V_f = 97.43 - 1.38 = 96.05$ cm³

$A_f = \frac{96.05}{4.76} = 20.19$ cm²

$P = 1.125$ Kg/cm²

$H_f = 4.70$ cm

$V_i = 96.05$ cm³

$\Delta V = 18.62 - 16.35 = 2.27$ cm³

$V_f = 96.05 - 2.27 = 93.78$ cm³

$A_f = \frac{93.78}{4.70} = 19.95$ cm²

$P = 1.68$ Kg/cm²

$H_f = 4.68$ cm

$V_i = 93.78$ cm³

$\Delta V = 19.00 - 16.16 = 2.89$ cm³

$V_f = 93.78 - 2.89 = 90.89$ cm³

$A_f = \frac{90.89}{4.68} = 19.41$ cm²

$P = 2.52$ Kg/cm

$H_f = 4.63$ cm

$V_i = 90.89$ cm³

$\Delta V = 18.20 - 13.90 = 4.30$ cm³

$V_f = 90.89 - 4.30 = 86.59$ cm³

$A_f = \frac{86.59}{4.63} = 18.70$ cm²

$P = 3.78\ Kg/cm^2$

$H_f = 4.58\ cm$

$V_i = 86.59\ cm^3$

$\Delta V = 18.80 - 14.90 = 3.90\ cm^3$

$V_f = 86.59 - 3.90 = 82.69\ cm^3$

$A_f = \frac{82.69}{4.58} = 18.06\ cm^2$

$P = 5.67\ Kg/cm^2$

$H_f = 4.53\ cm$

$V_i = 82.69\ cm^3$

$\Delta V = 17.41 - 12.85 = 4.56\ cm^3$

$V_f = 82.69 - 4.56 = 78.13\ cm^3$

$A_f = \frac{78.13}{4.53} = 17.25\ cm^2$

$P = 8.5\ Kg/cm^2$

$H_f = 4.47\ cm$

$V_i = 78.13\ cm^3$

$\Delta V = 18.80 - 15.80 = 3.00\ cm^3$

$V_f = 78.13 - 3.00 = 75.13\ cm^3$

$A_f = \frac{75.13}{4.47} = 16.81\ cm^2$

PERMEABILITY CALCULATIONS :

$$k = \frac{\gamma_\omega}{\gamma_{Hg} - \gamma_\omega} \cdot \frac{a \cdot h \cdot L}{H \cdot t \cdot A}$$

SAMPLE NO. 1

$P = 0.5$ Kg/cm²

$$k = \frac{(.034)(2.18)(4.79)}{(12.55)(64.19)(60)(10)(19.96)} = 37.41 \times 10^{-9} \text{ cm/sec}$$

$P = 0.75$ Kg/cm²

$$k = \frac{(.034)(1.82)(4.76)}{(12.55)(64.19)(60)(10)(19.81)} = 31.23 \times 10^{-9} \text{ cm/sec}$$

$P = 1.125$ Kg/cm²

$$k = \frac{(.034)(1.50)(4.74)}{(12.55)(64.19)(60)(10)(19.54)} = 25.98 \times 10^{-9} \text{ cm/sec}$$

$P = 1.68$ Kg/cm²

$$k = \frac{(.034)(1.14)(4.72)}{(12.55)(64.19)(60)(10)(19.22)} = 20.00 \times 10^{-9} \text{ cm/sec}$$

$P = 2.52$ Kg/cm²

$$k = \frac{(.034)(0.89)(4.67)}{(12.55)(64.19)(10)(19.06)(60)} = 15.59 \times 10^{-9} \text{ cm/sec}$$

$P = 3.78$ Kg/cm²

$$k = \frac{(.034)(1.04)(4.65)}{(12.55)(64.19)(60)(15)(18.66)} = 12.35 \times 10^{-9} \text{ cm/sec}$$

$P = 5.67\ kg/cm^2$

$$k = \frac{(.034)(.85)(4.62)}{(64.19)(12.55)(60)(15)(18.37)} = 10.19 \times 10^{-9}\ cm/sec$$

$P = 8.5\ kg/cm^2$

$$k = \frac{(.034)(.84)(4.57)}{(12.55)(64.19)(60)(20)(18.20)} = 7.54 \times 10^{-9}\ cm/sec.$$

SAMPLE NO. 2

$P = 0.5\ kg/cm^2$

$$k = \frac{(.034)(2.01)(4.80)}{(12.55)(64.41)(60)(10)(20.17)} = 33.55 \times 10^{-9}\ cm/sec$$

$P = 1.0\ kg/cm^2$

$$k = \frac{(.034)(1.70)(4.80)}{(12.55)(64.41)(60)(10)(19.96)} = 28.67 \times 10^{-9}\ cm/sec$$

$P = 2.0\ kg/cm^2$

$$k = \frac{(.034)(1.18)(4.79)}{(12.55)(64.41)(60)(10)(19.45)} = 20.38 \times 10^{-9}\ cm/sec$$

$P = 4.0\ kg/cm^2$

$$k = \frac{(.034)(1.15)(4.72)}{(12.55)(64.41)(60)(15)(19.04)} = 13.32 \times 10^{-9}\ cm/sec.$$

$P = 8.0\ kg/cm^2$

$$k = \frac{(.034)(.95)(4.63)}{(12.55)(64.41)(60)(20)(18.72)} = 8.25 \times 10^{-9}\ cm/sec.$$

SAMPLE NO. 4

$P = 0.9\ kg/cm^2$

$$k = \frac{(.034)(2.52)(4.80)}{(12.55)(64.23)(60)(20)(20.48)} = 27.1 \times 10^{-9}\ cm/sec$$

$P = 2.7$ kg/cm²

$$k = \frac{(.034)(1.53)(4.76)}{(12.55)(64.23)(10)(60)(20.22)} = 42.04 \times 10^{-9} \text{ cm/sec}$$

$P = 8.1$ kg/cm²

$$k = \frac{(.034)(4.69)(1.47)}{(12.55)(64.23)(60)(20)(18.51)} = 12.90 \times 10^{-9} \text{ cm/sec}$$

SAMPLE NO. 3

$P = 0.9$ kg/cm²

$$k = \frac{(.034)(4.85)(3.26)}{(12.55)(64.23)(60)(20)(20.48)} = 27.10 \times 10^{-9} \text{ cm/sec}$$

$P = 2.7$ kg/cm²

$$k = \frac{(.034)(4.78)(2.20)}{(12.55)(64.23)(60)(20)(19.48)} = 18.52 \times 10^{-9} \text{ cm/sec}$$

$P = 8.1$ kg/cm²

$$k = \frac{(.034)(4.70)(.61)}{(12.55)(64.23)(60)(20)(19.13)} = 5.27 \times 10^{-9} \text{ cm/sec.}$$

SAMPLE NO. 5

$P = 0.5$ kg/cm²

$$k = \frac{(.034)(1.90)(4.99)}{(12.55)(64.19)(60)(10)(20.49)} = 32.45 \times 10^{-9} \text{ cm/sec}$$

$P = 0.75$ kg/cm²

$$k = \frac{(.034)(1.81)(4.99)}{(12.55)(64.19)(60)(10)(20.36)} = 31.10 \times 10^{-9} \text{ cm/sec}$$

$P = 1.125 \ kg/cm^2$

$$k = \frac{(.034)(1.59)(4.88)}{(12.55)(64.19)(60)(10)(20.21)} = 27.46 \times 10^{-9} \ cm/sec$$

$P = 1.68 \ kg/cm^2$

$$k = \frac{(.034)(1.51)(4.97)}{(12.55)(64.19)(60)(10)(20.15)} = 26.12 \times 10^{-9} \ cm/sec$$

$P = 2.52 \ kg/cm^2$

$$k = \frac{(.034)(1.30)(4.96)}{(12.55)(64.19)(60)(10)(20.05)} = 22.54 \times 10^{-9} \ cm/sec$$

$P = 3.78 \ kg/cm^2$

$$k = \frac{(.034)(1.08)(4.95)}{(12.55)(64.19)(60)(10)(19.71)} = 19.06 \times 10^{-9} \ cm/sec$$

$P = 5.67 \ kg/cm^2$

$$k = \frac{(.034)(1.27)(4.94)}{(12.55)(64.19)(60)(15)(19.46)} = 14.86 \times 10^{-9} \ cm/sec$$

$P = 8.5 \ kg/cm^2$

$$k = \frac{(.034)(1.33)(4.93)}{(12.55)(64.19)(60)(20)(18.94)} = 12.15 \times 10^{-9} \ cm/sec$$

SAMPLE NO. 6

$P = 0.5 \ kg/cm^2$

$$k = \frac{(.034)(2.65)(4.79)}{(12.55)(64.28)(60)(5)(19.72)} = 90.5 \times 10^{-9} \ cm/sec$$

$P = 1.0 \ kg/cm^2$

$$k = \frac{(.034)(1.98)(4.79)}{(12.55)(64.28)(60)(5)(19.20)} = 69.4 \times 10^{-9} \ cm/sec$$

$P = 2.0 \ kg/cm^2$

$$k = \frac{(.034)(2.60)(4.72)}{(12.55)(64.28)(60)(10)(18.66)} = 46.24 \times 10^{-9} \ cm/sec$$

$P = 4.0 \ kg/cm^2$

$$k = \frac{(.034)(2.32)(4.66)}{(12.55)(64.28)(60)(15)(17.99)} = 28.13 \times 10^{-9} \ cm/sec$$

$P = 8.0 \ kg/cm^2$

$$k = \frac{(.034)(1.39)(4.49)}{(12.55)(64.28)(60)(15)(17.74)} = 16.5 \times 10^{-9} \ cm/sec$$

SAMPLE NO. 7

$P = 0.5 \ kg/cm^2$

$$k = \frac{(.034)(1.43)(4.82)}{(12.55)(64.40)(60)(20)(20.46)} = 11.79 \times 10^{-9} \ cm/sec$$

$P = 1.0 \ kg/cm^2$

$$k = \frac{(.034)(.89)(4.81)}{(12.55)(64.40)(60)(20)(20.31)} = 7.39 \times 10^{-9} \ cm/sec$$

$P = 2.0 \ kg/cm^2$

$$k = \frac{(.034)(.73)(4.78)}{(12.55)(64.40)(60)(30)(19.86)} = 4.10 \times 10^{-9} \ cm/sec$$

$P = 4.0 \ kg/cm^2$

$$k = \frac{(.034)(.52)(4.72)}{(12.55)(64.28)(60)(60)(19.27)} = 1.49 \times 10^{-9} \ cm/sec$$

$P = 8.0 \ kg/cm^2$

$$k = \frac{(.034)(.22)(4.67)}{(12.55)(64.28)(60)(100)(18.44)} = .39 \times 10^{-9} \ cm/sec$$

SAMPLE NO. 8

$P = 0.9 \ kg/cm^2$

$$k = \frac{(.034)(4.71)(3.0)}{(12.55)(62.15)(60)(19.55)} = 26.27 \times 10^{-9} \ cm/sec$$

$P = 2.7\ kg/cm^2$

$$k = \frac{(.034)(4.51)(1.57)}{(12.55)(62.15)(60)(60)(18.64)} = 4.60 \times 10^{-9}\ cm/sec$$

$P = 8.1\ kg/cm^2$

$$k = \frac{(.034)(4.37)(.41)}{(12.55)(62.15)(60)(60)(17.54)} = 1.24 \times 10^{-9}\ cm/sec$$

SAMPLE NO. 9

$P = 0.5\ kg/cm^2$

$$k = \frac{(.034)(4.80)(2.75)}{(12.55)(62.25)(60)(20)(20.28)} = 23.58 \times 10^{-9}\ cm/sec$$

$P = 0.75\ kg/cm^2$

$$k = \frac{(.034)(4.76)(2.64)}{(12.55)(62.25)(60)(20)(20.19)} = 22.59 \times 10^{-9}\ cm/sec$$

$P = 1.125\ kg/cm^2$

$$k = \frac{(.034)(4.70)(1.66)}{(12.55)(62.25)(60)(20)(19.95)} = 14.16 \times 10^{-9}\ cm/sec$$

$P = 1.68\ kg/cm^2$

$$k = \frac{(.034)(4.68)(1.12)}{(12.55)(62.25)(60)(20)(19.41)} = 9.74 \times 10^{-9}\ cm/sec$$

$P = 2.52\ kg/cm^2$

$$k = \frac{(.034)(4.63)(.56)}{(12.55)(62.25)(20)(60)(18.70)} = 5.03 \times 10^{-9}\ cm/sec$$

$P = 3.78\ kg/cm^2$

$$k = \frac{(.034)(4.58)(.46)}{(12.55)(62.25)(60)(30)(18.06)} = 2.82 \times 10^{-9}\ cm/sec$$

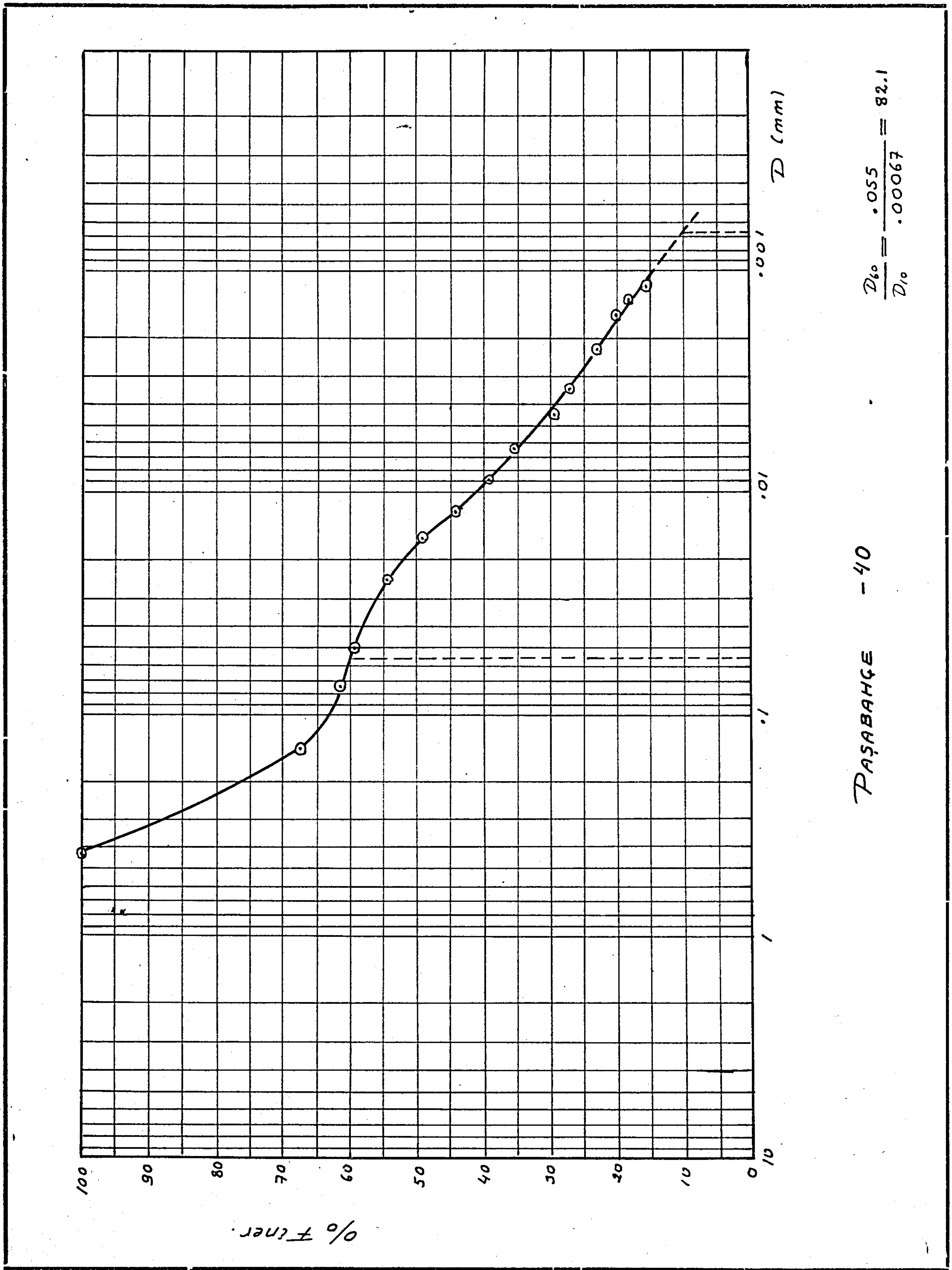
$P = 5.67\ kg/cm^2$

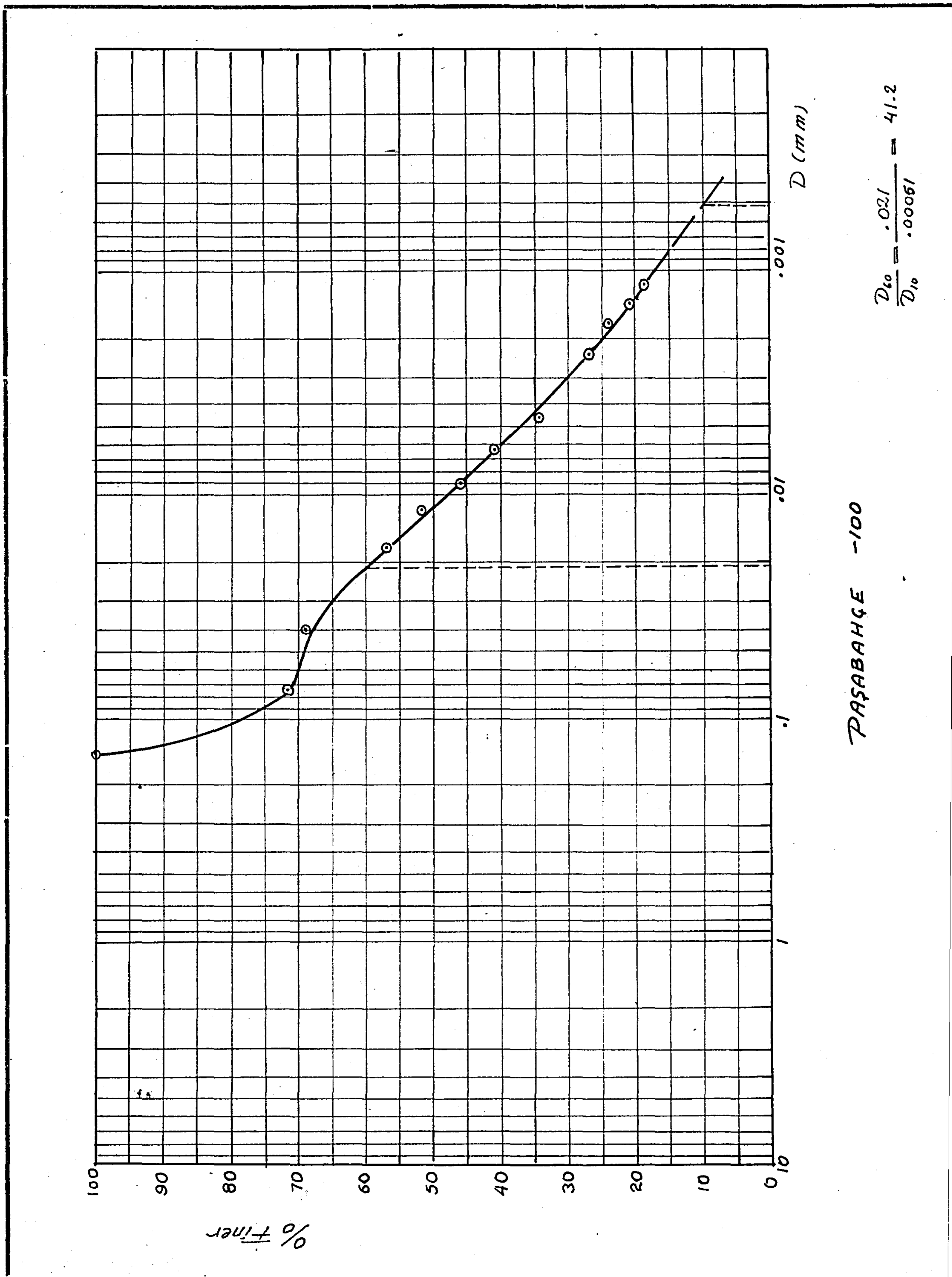
$$k = \frac{(.034)(4.53)(.42)}{(12.55)(62.25)(60)(60)(17.25)} = 1.33 \times 10^{-9}\ cm/sec$$

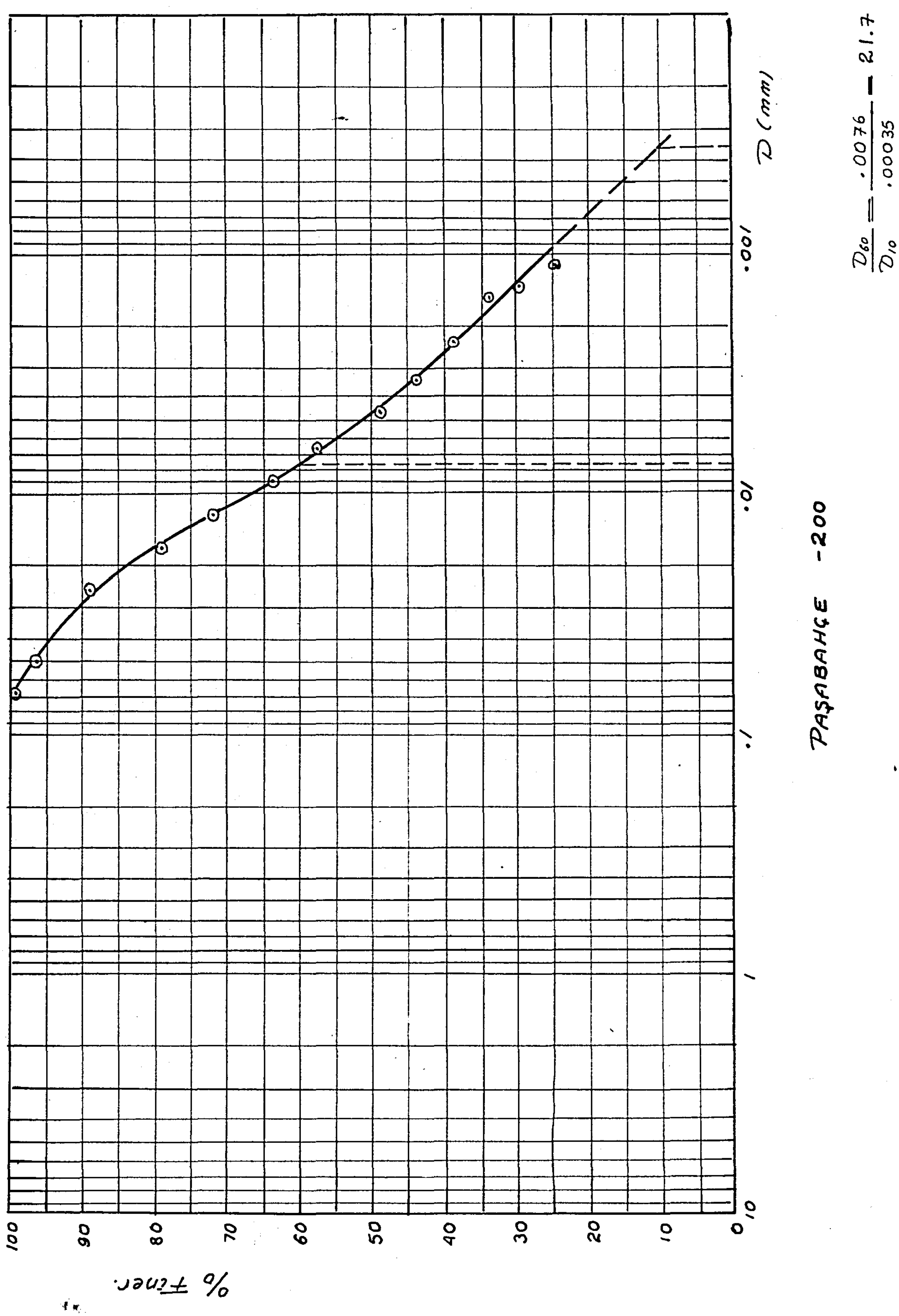
$P = 8.1 \ kg/cm^2$

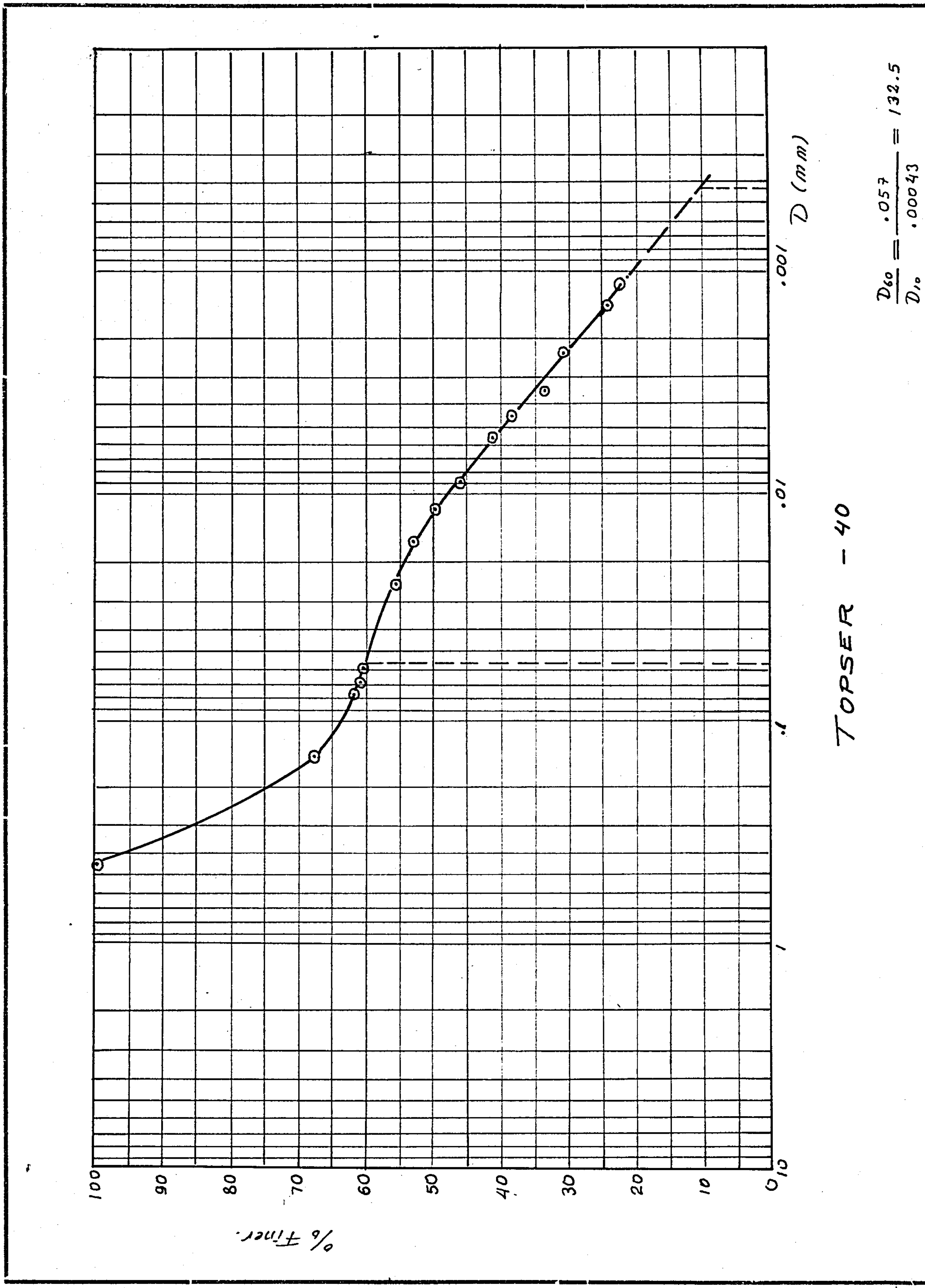
$$k = \frac{(.034)(4.47)(46)}{(12.55)(62.25)(60)(120)(16.81)} = .87 \times 10^{-9} \ cm/sec.$$

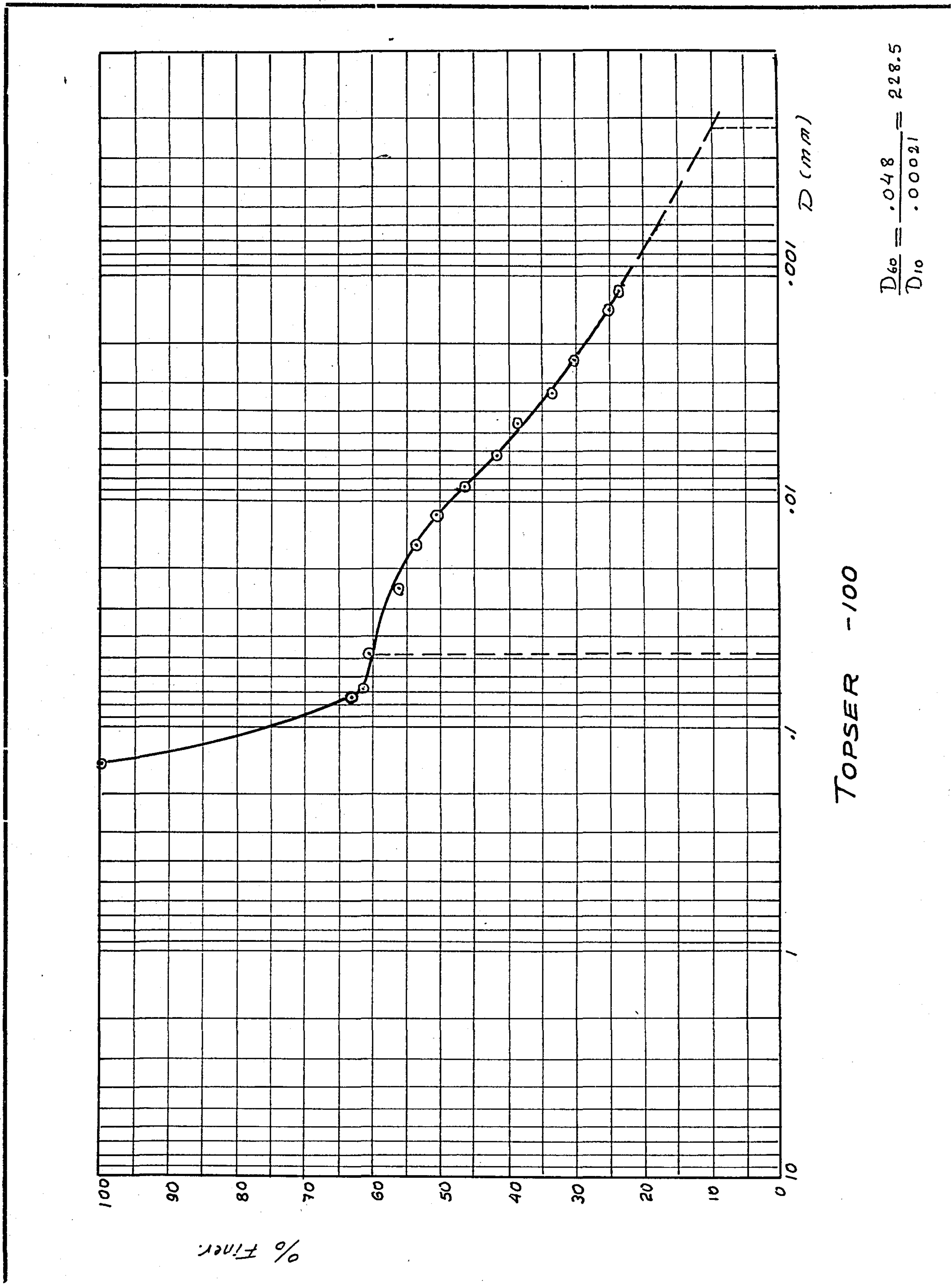
D. Gradation Curves

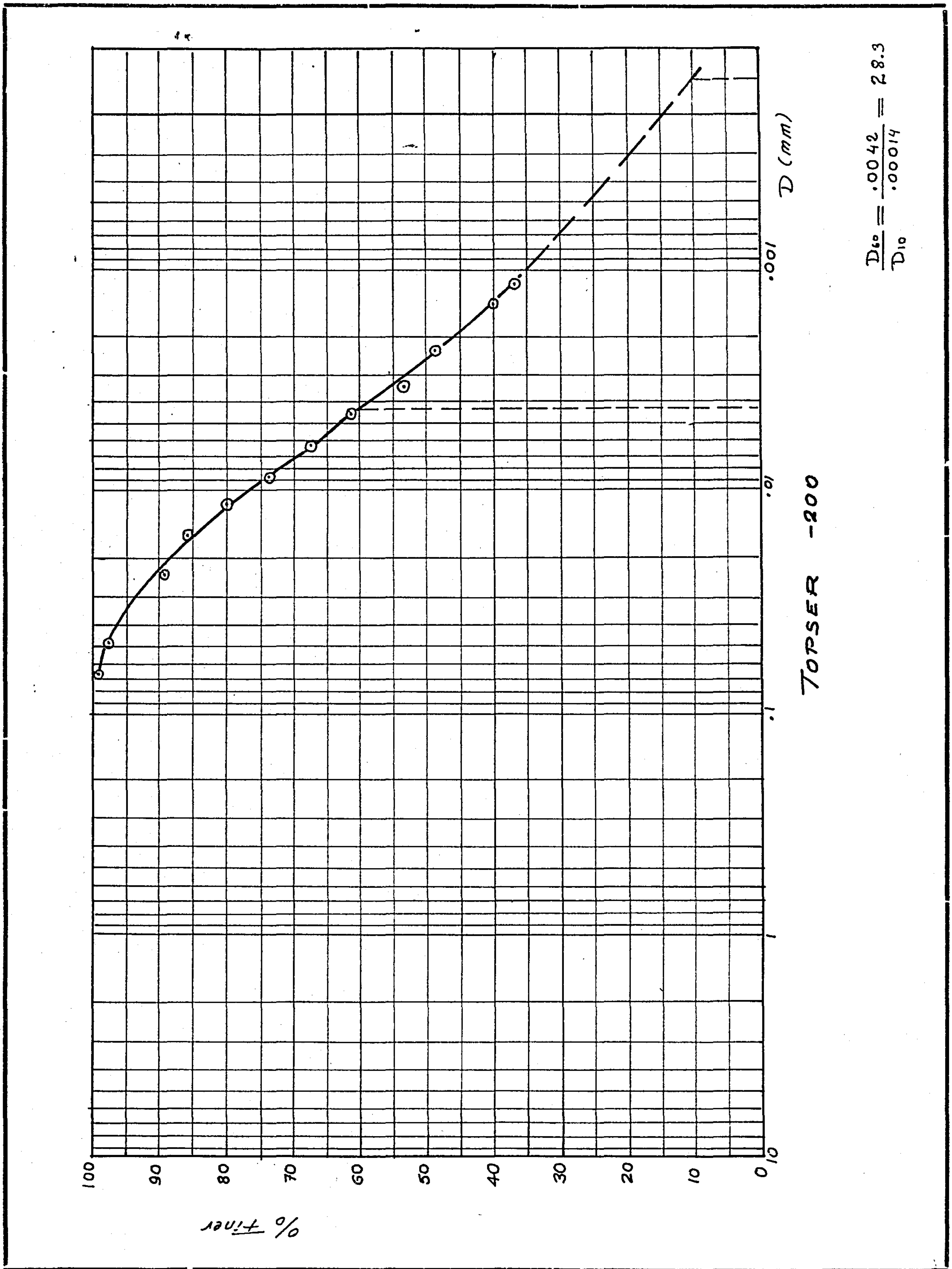

D (mm)
.001
.01
.1
1
10
100 90 80 70 60 50 40 30 20 10 0
% Finer.
PAŞABAHÇE -40
D60/D10 = .055/.00067 = 82.1

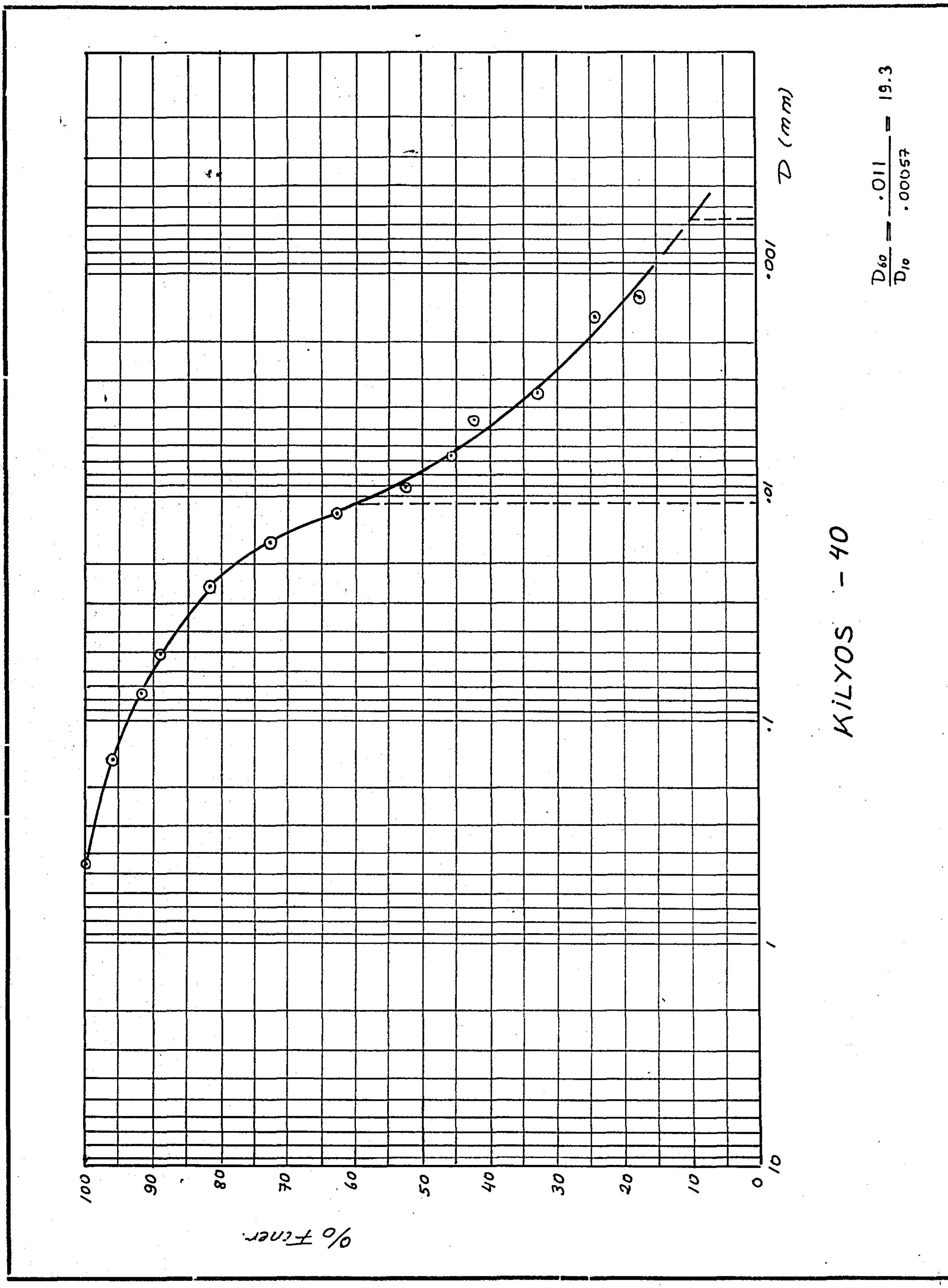

D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer
PAŞABAHÇE -100
$\frac{D_{60}}{D_{10}} = \frac{.021}{.00061} = 41.2$

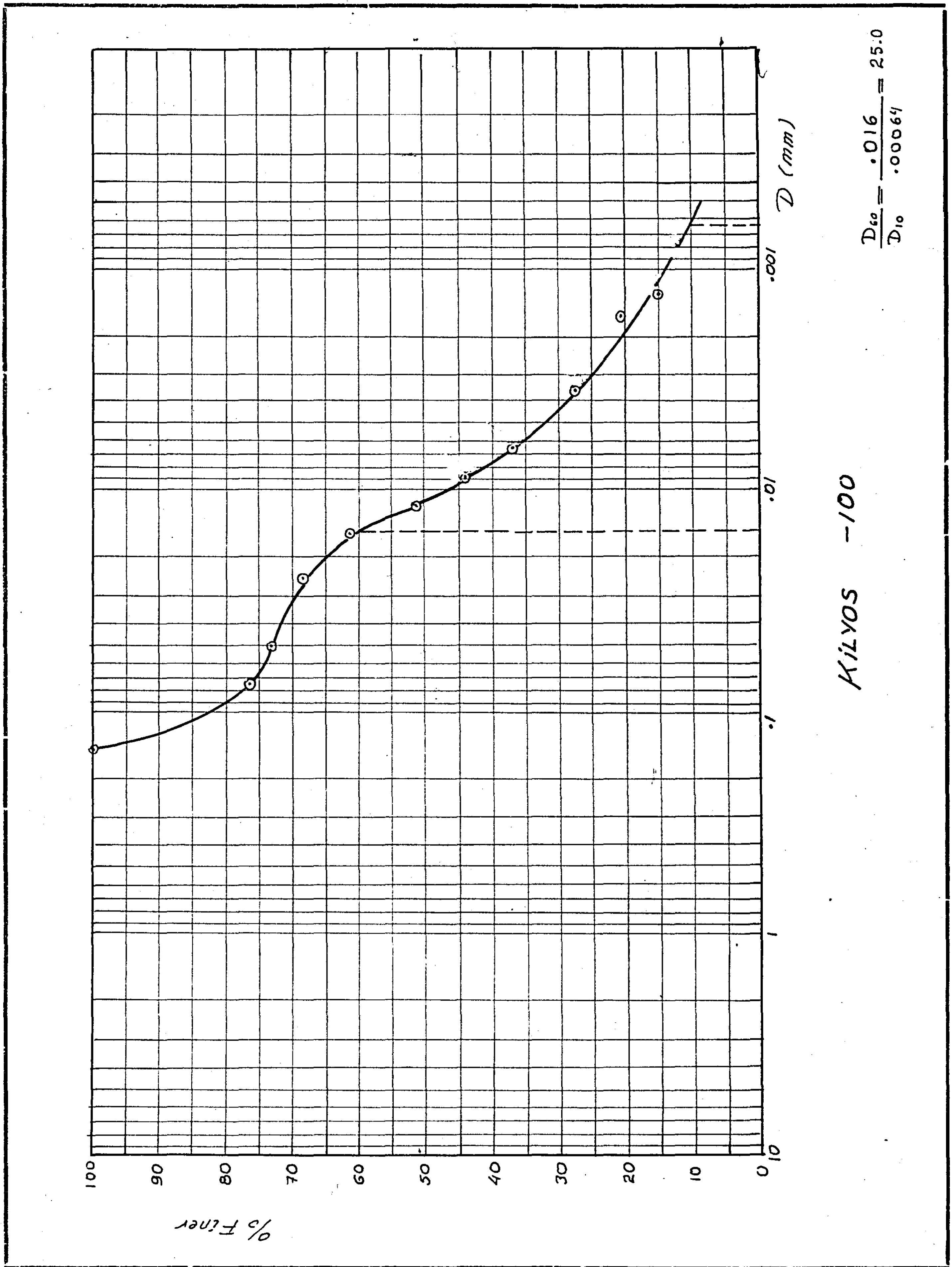

D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer.
$\frac{D_{60}}{D_{10}} = \frac{.0076}{.00035} = 21.7$
PAŞABAHÇE -200

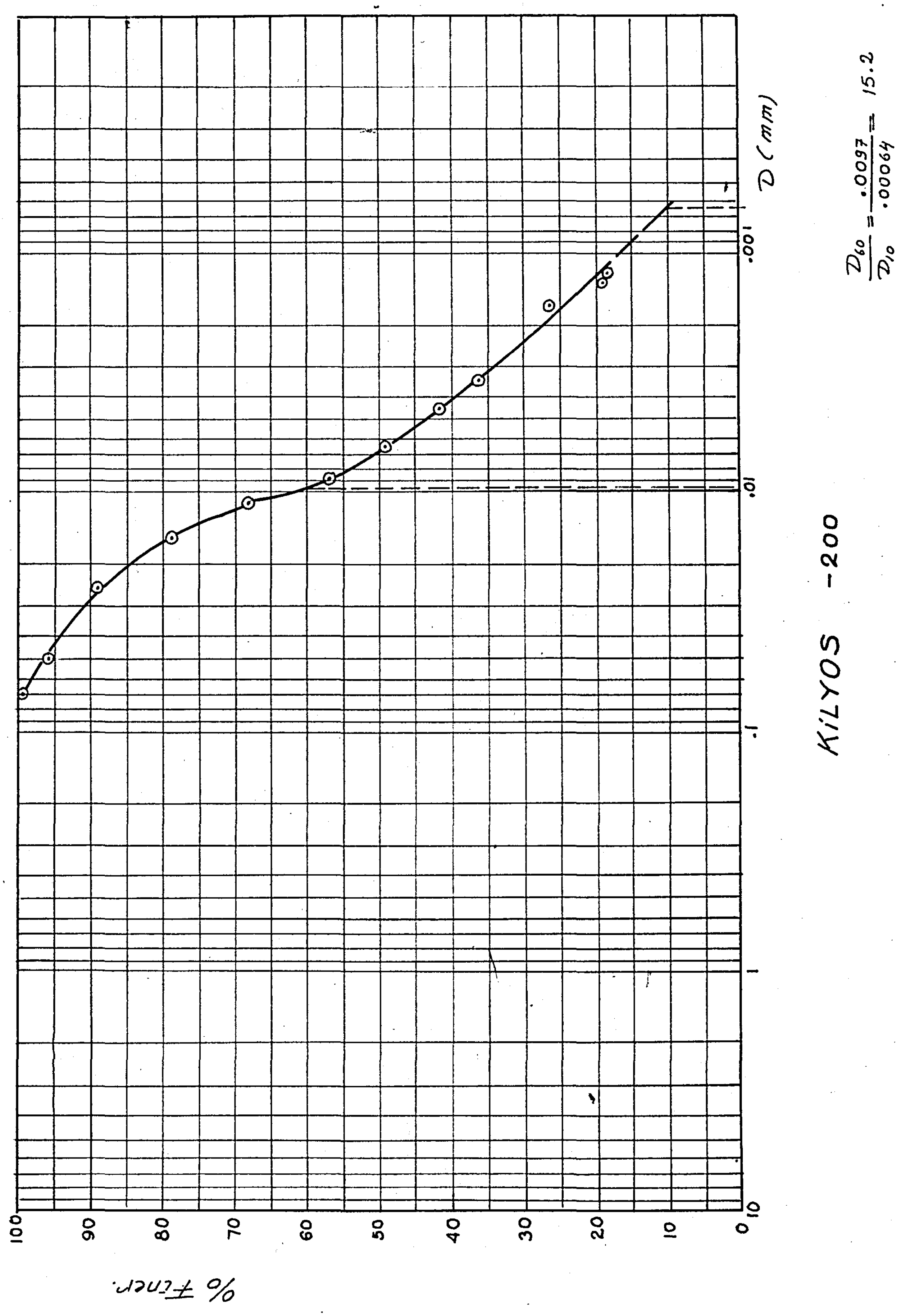

D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer.
TOPSER - 40
$\frac{D_{60}}{D_{10}} = \frac{.057}{.00043} = 132.5$


D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer
TOPSER -100
$\frac{D_{60}}{D_{10}} = \frac{.048}{.00021} = 228.5$


$\frac{D_{60}}{D_{10}} = \frac{.0042}{.00014} = 28.3$
D (mm)
.001
.01
.1
1
10
TOPSER -200
100
90
80
70
60
50
40
30
20
10
0
% finer


D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer.
KiLYOS - 40
D60/D10 = .011/.00057 = 19.3


$\frac{D_{60}}{D_{10}} = \frac{.016}{.00064} = 25.0$
D (mm)
.001
.01
.1
1
10
KiLYOS -100
100
90
80
70
60
50
40
30
20
10
0
% Finer


D (mm)
.001
.01
.1
1
10
100
90
80
70
60
50
40
30
20
10
0
% Finer.
KİLYOS -200
$\frac{D_{60}}{D_{10}} = \frac{.0097}{.00064} = 15.2$

E. Computer Programs and Results

Program One - Greco-Latin variance analysis program.

Sample data. Sample output.

Program Two - Multiple regression analysis program.

Sample data.

Outputs :

A. Problem 10021 - Regression with log k, $e/e_o = 0.70$

B. Problem 10022 - Regression with log k, $e/e_o = 0.80$

C. Problem 10023 - Regression with log k, $e/e_o = 0.90$

D. Problem 10031 - Regression with k, $e/e_o = 0.70$

E. Problem 10032 - Regression with k, $e/e_o = 0.80$

F. Problem 10033 - Regression with k, e/e_o - 0.90.

```
                    ***** PROGRAM ONE *****

C     GRECO-LATIN MATRIX VARIANCE ANALYSIS * OVER OZENC *
      DIMENSION X (10)
      READ 1 , ( X(I) , I=1,9)
    1 FORMAT (9F8.2)
      TOT=0.
      DO 10 I=1,9
   10 TOT=TOT+X(I)**2.
      EX=0.
      DO 2 I=1,9
    2 EX=EX+X(I)
      EX2=EX**2.
      PUNCH 20 , EX
      PUNCH 30 , TOT
   20 FORMAT (13HSUM OF TERMS=,F8.2)
   30 FORMAT (15HSUM OF SQUARES=,F8.2)
      A=EX2/9.
      EST=((X(1)+X(2)+X(3))**2.+(X(4)+X(5)+X(6))**2.+(X(7)+X(8)+X(9))**2
     1.)/3.
      EGT=((X(1)+X(4)+X(7))**2.+(X(2)+X(5)+X(8))**2.+(X(3)+X(6)+X(9))**2
     1.)/3.
      EPT=((X(1)+X(6)+X(8))**2.+(X(2)+X(4)+X(9))**2.+(X(3)+X(5)+X(7))**2
     1.)/3.
      ERT=((X(1)+X(5)+X(9))**2.+(X(2)+X(6)+X(7))**2.+(X(3)+X(4)+X(8))**2
     1.)/3.
      AS=EST-A
      AG=EGT-A
      AP=EPT-A
      AR=ERT-A
      FMS=AS/2.
      FMG=AG/2.
      FMP=AP/2.
      FMR=AR/2.
      PUNCH 12,FMS,FMG,FMP,FMR
   12 FORMAT (13HMEAN SQUARES.,4F1).2)
      IF (FMS-FMP) 101,101,102
  101 C=FMS
      GO TO 201
  102 C=FMP
  201 CONTINUE
      IF (FMR-FMG) 103,103,104
  103 D=FMR
      GO TO 202
  104 D=FMG
  202 CONTINUE
      IF (C-D) 301,301,302
  301 T=C
      GO TO 203
  302 T=D
  203 FS=FMS/T
      FG=FMG/T
      FP=FMP/T
      FR=FMR/T
      PUNCH 5,FS,FG,FP,FR
    5 FORMAT (3HFS=,F7.2,5X,3HFG=,F7.2,5X,3HFP=,F7.2,5X,3HFR=,F7.2)
      END
```

```
                    *** SAMPLE DATA ***

8.4     6.6     2.7     11.3     7.3     20.0     0.09     1.4     1.33


                    *** RESULTS ***
SUM OF TERMS=    59.12
SUM OF SQUARES=  706.12
MEAN SQUARES.    107.69      6.35     32.43     12.41
FS=  16.95     FG=   1.00     FP=   5.10     FR=   1.95
```

```
                 ***** PROGRAM TWO *****
C     BASAMAKLI REGRESYON
C
C     ******************************************************************
C     NOTE
C     DEGISKENLERIN MIKTARI BAGIMSIZ + BAGIMLI DEGISKENLERE ESITTIR.
C     BAGIMLI DEGISKEN EN SON DEGISKENDIR.
C     ******************************************************************
C
      DIMENSION DATA(7,100), VECTOR(11,11), AVE(10), SIGMA(10), COEN(10)
     1 , SIGMCO(10), INDEX(10) , RUN(120)
C
  100 READ 5,TOL, EFIN, EFOUT, NOPROB, INVAR, NODATA,
     1IFWT,IFSTEP,IFRAW,IFAVE,IFRESD,IFCOEN,IFPRED,IFCNST
C
C     ******************************************************************
C     IFWT = 1, BUTUN NISBETLER = 1.0
C     IFSTEP = 1.0, HER BASAMAK YAZILMAYACAK
C     IFRAW =1.0, HAM KARELER TOPLAMI YAZILMAYACAK
C     IFAVE = 1.0, ORTALAMALAR YAZILMAYACAK
C     IFRESD = 1.0, ARTIK KARELER TOPLAMI YAZILMAYACAK
C     IFCOEN = 1.0, KISMI KORELASYON KATSAYILARI YAZILMAYACAK
C     IFPRED = 1.0, HESAPLANMIS TAHMINI DEGERLER YAZILMAYACAK
C     IFCNST = 1.0, DENKLEMDE SABIT BULUNMAYACAK
C
C     BASLANGIC PROSEDURU
C     ******************************************************************
      NOIN = 0
      VAR  = 0
      K    = 0
      FLEVEL = 0
      NOENT = 0
      NOMIN = 0
      NOMAX = 0
      NOVAR = INVAR
      NVP1 = NOVAR + 1
      NIX = 1
    2 IF (INVAR- 10) 110,110,1800
  110 DO 120 I = 1, NVP1
  130 DO 120 J = 1, NVP1
  120 VECTOR(I,J) = 0.0
  140 IF(IFWT) 900, 500, 150
  900 TYPE 905
      GO TO 910
C     ******************************************************************
C     ASAGIDAKI DEYIMLER DATAYI CORE HAFIZAYA OKUR
C     ******************************************************************
  150 DO 170 N = 1, NODATA
  160 READ 10 , RUN(N) , (DATA(L,N),  L = 1 , NOVAR )
  180 DO 190 I = 1, NOVAR
  200 VECTOR(I, NOVAR + 1) = VECTOR (I, NOVAR + 1) + DATA(I,N)
  210 DO 220 J = I, NOVAR
  220 VECTOR (I,J) = VECTOR (I,J) + DATA(I,N)*DATA(J,N)
  190 CONTINUE
  170 VECTOR(NVP1, NVP1    )    = VECTOR(NVP1, NVP1)    + 1.0
  230 GO TO 565
```

```
C     ******************************************************************
C     DEGISKENLER NISBETLI OLDUGU VAKIT TOPLAMLARIN HESABI
C     ******************************************************************
  500 DO 510 N = 1, NODATA
  520 READ 10, RUN, (DATA(L,N), L=1,NOVAR), WHT
  530 DO 540 I = 1, NOVAR


  550 VECTOR (I,NOVAR + 1) = VECTOR (I, NOVAR + 1) + DATA (I,N)*WHT
  560 DO 540 J = I , NOVAR
  540 VECTOR (I, J) = VECTOR (I,J) + DATA(I,N)*DATA(J,N)*WHT
  510 VECTOR (NVP1, NVP1)          = VECTOR (NVP1, NVP1)        +WHT
C     ******************************************************************
C     KARELER TOPLAMI HESABI TAMAMLANDI. BU MALUMAT HAFIZADA
C     VECTOR (I,J) LOKASYONUNDA
C     ******************************************************************
  565 NOVMI = NOVAR - 1
  566 NOVPL = NOVAR + 1
  568 PUNCH90, NOPROB,NODATA,NOVAR, EFIN, EFOUT
  570 IF (IFRAW) 900, 580, 650
  580 PUNCH 15
  590 PUNCH 20,(I,VECTOR(I,NOVPL),I=1,NOVMI)
  600 PUNCH 25, VECTOR (NOVAR, NOVPL)
  610 PUNCH 30
  620 PUNCH 35,((I,J,VECTOR(I,J),J=I,NOVMI),I=1,NOVMI)
  630 PUNCH 40,(I,VECTOR(I,NOVAR),I=1,NOVMI)
  640 PUNCH 45, VECTOR(NOVAR,NOVAR)
      GO TO 650
C     ******************************************************************
C     ARTIK KARELER TOPLAMI HESABI
C     ******************************************************************
  650 IF(IFCNST) 900,651,735
  651 IF(VECTOR(NOVPL,NOVPL)) 652,652,655
  652 PUNCH654
      GO TO 910
  655 DO 660 I = 1, NOVAR
  670 DO 660 J = I, NOVAR
  660 VECTOR (I,J) = VECTOR (I,J) - (VECTOR (I,NOVPL) * VECTOR (J,NOVPL)
     1 / VECTOR (NOVPL, NOVPL))
  680 DO 690 I = 1, NOVAR
  690 AVE(I) = VECTOR(I,NOVPL) / VECTOR(NOVPL,NOVPL)
  700 IF (IFAVE) 900, 710, 735
  710 PUNCH 50
  720 PUNCH 20, (I,AVE(I), I=1,NOVMI)
  730 PUNCH 25, AVE(NOVAR)
  735 IF (IFRESD) 900, 740, 780
  740 PUNCH 55
  750 PUNCH 35,((I,J,VECTOR(I,J),J=I,NOVMI),I=1,NOVMI)
  760 PUNCH 40, (I,VECTOR(I,NOVAR),I=1,NOVMI)
  770 PUNCH 45, VECTOR(NOVAR,NOVAR)
  780 NOSTEP = -1
  781 NUMBER = 1
  782 DEFR     = VECTOR(NOVPL,NOVPL) - 1.0
  790 DO 800 I = 1,NOVAR
  791 IF(VECTOR(I,I)) 792,794,810
  792 PUNCH793, I
      GO TO 910
  794 PUNCH 795,I
  796 SIGMA(I) =      1.0
```

```
 797 GO TO 800
 810 SIGMA (I) = SQRTF (VECTOR (I,I))
 800 VECTOR(I,I) = 1.0
 820 DO 830 I = 1,NOVMI
 840 IP1 = I + 1
 841 DO 830 J = IP1, NOVAR
 850 VECTOR(I,J) = VECTOR(I,J) /(SIGMA(I)*SIGMA(J))
 830 VECTOR(J,I) = VECTOR(I,J)
 860 IF (IFCOEN) 900, 870, 1000
 870 PUNCH 60
 874 NOVM2 = NOVMI - 1
 875 DO 885 I = 1, NOVM2


 880 IP1 = I + 1
 885 PUNCH 35,(I,J,VECTOR(I,J),J=IP1,NOVMI )
 890 PUNCH 40, (I,VECTOR(I,NOVAR),I=1,NOVMI)
1000 NOSTEP = NOSTEP + 1
1001 IF (VECTOR( NOVAR,NOVAR)) 1002,1002,1010
1002 NSTPM1 = NOSTEP - 1
     PUNCH 1004, NSTPM1
     GO TO 1381
1010 SIGY = SIGMA(NOVAR) * SQRTF (VECTOR(NOVAR,NOVAR)/ DEFR)
1011 IF(1.0 - VECTOR(NOVAR, NOVAR)) 1013,1013,1012
1012 R = SQRTF(1.0 - VECTOR(NOVAR, NOVAR) )
     GO TO 1015
1013 R = 0.0
1015 DEFR = DEFR-1.
1016 IF (DEFR ) 1017,1017,1020
1017 PUNCH 1019, NOSTEP
     GO TO 1381
1020 VMIN = 0.0
1030 VMAX = 0.0
1035 NOIN = 0
1040 DO 1050 I = 1,NOVMI
1041 IF (VECTOR (I,I)) 1042,1050,1060
1042 PUNCH 1044, I, NOSTEP
1045 GO TO 1381
1060 IF (VECTOR(I,I) - TOL) 1050,1080,1080
1080 VAR = VECTOR(I,NOVAR) * VECTOR(NOVAR,I) / VECTOR(I,I)
1090 IF(VAR)1100,1050,1110
1100 NOIN = NOIN + 1
1120 INDEX(NOIN) = I
1130 COEN(NOIN) = VECTOR(I,NOVAR) * SIGMA(NOVAR) / SIGMA (I)
1140 SIGMCO(NOIN) = (SIGY / SIGMA(I)) * SQRTF(VECTOR(I,I))
1150 IF (VMIN) 1160,1170,904
 904 PUNCH 906
     GO TO 910
1170 VMIN = VAR
1180 NOMIN = I
1190 GO TO 1050
1160 IF(VAR - VMIN)1050,1050,1170
1110 IF (VAR- VMAX)1050,1050,1210
1210 VMAX = VAR
1220 NOMAX = I
1050 CONTINUE
1230 IF (NOIN) 903,1240,1245
```

```
 903 PUNCH 907
     GO TO 910
1240 PUNCH 65, SIGY
1260 GO TO 1350
1245 IF(IFCNST) 900,1250,1246
1246 CNST = 0.0
1247 GO TO 1300
1250 CNST = AVE(NOVAR)
1270 DO 1280 I = 1,NOIN
1290 J = INDEX(I)
1280 CNST = CNST - (COEN(I) * AVE(J))
1300 IF(IFSTEP) 900,1310,1320
1310 IF (NOENT) 1311,1311,1313
1311 PUNCH 91,NOSTEP,K
1312 GO TO 1314
1313 PUNCH 92,NOSTEP,K
1314 PUNCH 70, FLEVEL, SIGY, R, CNST,
    1 (INDEX(J),COEN(J),SIGMCO(J), J = 1, NOIN )
1315  GO TO (1316,1580),NIX
1316 GO TO (1320,1580), NUMBER

1320 FLEVEL = VMIN * DEFR / VECTOR (NOVAR,NOVAR)
1330 IF(EFOUT + FLEVEL) 1350, 1350, 1340
1340 K = NOMIN
1345 NOENT = 0
     GO TO 1391
1350 DENOM = VECTOR(NOVAR,NOVAR) - VMAX
     IF(DENOM) 1351,1351,1352
1351 NIX = 2
     GO TO 1370
1352 FLEVEL = VMAX* DEFR / DENOM
1360 IF (EFIN - FLEVEL) 1370,1361,1380
1361 IF (EFIN) 1380,1380,1370
1370 K = NOMAX
1390 NOENT = K
1391 IF(K) 1392,1392,1400
1392 PUNCH 1395, NOSTEP
1394 GO TO 910
1400 DO 1410   I = 1,NOVAR
1420 IF (I-K) 1430,1410,1430
1430 DO 1440   J = 1, NOVAR
1450 IF (J-K) 1460,1440,1460
1460 VECTOR(I,J) = VECTOR(I,J) - (VECTOR(I,K) * VECTOR (K,J) / VECTOR
    1(K,K))
1440 CONTINUE
1410 CONTINUE
1470 DO 1480  I = 1, NOVAR
1490 IF (I-K) 1500,1480,1500
1500 VECTOR (I,K) = - VECTOR (I,K) / VECTOR (K,K)
1480 CONTINUE
1510 DO 1520 J = 1, NOVAR
1530 IF (J-K) 1540,1520,1540
1540 VECTOR(K,J) =   VECTOR (K,J) / VECTOR (K,K)
1520 CONTINUE
1550 VECTOR(K,K) = 1.0 / VECTOR(K,K)
1560 GO TO (1000,1561),NIX
1561 PUNCH 1004, NOSTEP
```

```
      R = 1.00
      SIGY = 0.0
      IFSTEP = 0
      GO TO 1015
 1380 PUNCH 75, NOSTEP
 1381 IF (IFSTEP) 900, 1580,1570
 1570 NUMBER = 2
 1571 GO TO 1310
 1580 PUNCH 1586,(L,VECTOR(L,L),L=1,NOVMI )
 1581 IF( IFPRED) 900,1582,910
 1582 PUNCH 85
 1590 DO  1660   N = 1, NODATA
 1610 YPRED = CNST
 1620 DO 1630  I = 1,NOIN
 1640 K = INDEX(I)
 1630 YPRED = YPRED + COEN(I)*DATA(K,N)
 1650 DEV = DATA(NOVAR,N) - YPRED
 1660 PUNCH 80, RUN(N) , DATA ( NOVAR , N ) , YPRED , DEV
  910 CONTINUE
      STOP
 1800 PUNCH 93, INVAR
      GO TO 910
C
C     ************************ ******************************************
C     GIRIS/CIKIS DEYIMLERI
C
C     ************************************************,********************


    5 FORMAT (3F10.5,3I5,10I2)
   10 FORMAT (I2,7F10.5)
   15 FORMAT( 21HDEGISKENLERIN TOPLAMI  //  )
   20 FORMAT(12H            X( I2,3H) = F30.4,  /      )
   25 FORMAT(17H                  Y  =F30.4)
   30 FORMAT( // 19HHAM KARELER TOPLAMI  //  )
   35 FORMAT (   7H    X(I2,7H) VS X(I2,3H) = F30.6,      /       )
   40 FORMAT (   7H     X(I2,12H) VS    Y   =   F30.6,  /  )
   45 FORMAT (   21H     Y      VS   Y   =F30.6)
   50 FORMAT( // 32HDEGISKENLERIN ORTALAMA DEGERLERI    //    )
   55 FORMAT(  // 21HARTIK KARELER TOPLAMI    // )
   60 FORMAT( // 28HKISMI KORELASYON KATSAYILARI  //  )
   65 FORMAT (31HY DEGERININ STANDART HATASI  = F20.6 )
   70 FORMAT (//16H   F SEVIYESI = F12.4 /34H   Y DEGERLIIN STANDART HAT
     1 ASI  = F12.4 /36H   COK YONLU KORELASYON KATSAYISI = F12.5 /11H
     2 SABIT = F13.5 /60H                DEGISKEN       KATSAYI   KATSAYI ST
     3NDRT. HATASI //  (16H                  X-I3,F15.5, F15.5 ))
   75 FORMAT (/42HTAMAMLANAN REGRESYON BASAMAKLARI SAYISI = I5 // )
   80 FORMAT (7X  F7.2       ,2H  F12.5,3H   F12.5,2H  F12.5)
   85 FORMAT (// 47HTAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI //55H
     1             OKUMA      HAKIKI         TAHMINI         FARK // )
   90 FORMAT (21H BASAMAKLI REGRESYON //12H PROBLEM NO.I10 //15H DATA SA
     1YISI = I5 //18H DEGISKEN SAYISI = I10 //44H DEGISKENIN REGRESYONA
     2GIRECEGI F SEVIYESI = F10.3 //50H DEGISKENIN REGRESYONDAN CIKARILA
     3CAGI F SEVIYESI = F9.3 ///)
   91 FORMAT (/ 11HBASAMAK NO.I5 /35H   REGRESYONDAN CIKARTILAN DEGISKEN
     1 I8 )
   92 FORMAT ( 11HBASAMAK NO.I5 /28H   REGRESYONA GIREN DEGISKEN I8 )
   93 FORMAT (48HDEGISKEN SAYISININ ONDAN BUYUK OLMAMASI LAZIMDIR )
```

```
  654 FORMAT (15HDATA VERILMEDI )
  793 FORMAT (39HARTIK KARELERDE YANLIS VAR.DEGISKEN NO.I4,30HNEGATIVDIR
     1.PROBLEM DURDURULDU.)
  795 FORMAT (// I5,24HNO.LU DEGISKEN SABITTIR )
  905 FORMAT (28HKONTROL KARTINDA YANLIS VAR.)
  906 FORMAT (21HVMIN POSITIV, YANLIS )
  907 FORMAT (21HNOIN NEGATIV, YANLIS )
 1004 FORMAT (// 26HY KARE NEGATIV.BASAMAK NO.I4,22HDA PROBLEM DURDURULD
     1U )
 1019 FORMAT (/35HSERBESTLIK DERECESI YOK.BASAMAK NO.I4 )
 1044 FORMAT (/ 12HDEGISKEN NO.I4,16H KARESI NEGATIV.20H BASAMAK HESAPLA
     1NDI )
 1395 FORMAT (/ 17HK=0. BASAMAK NO. I4)
 1586 FORMAT (24HDIYAGONAL ELEMANLAR       /20H   DEG.NO.     DEGER//
     1(1H  I 7, F16.6))
C
C     ***********************************************************************
C     GIRIS/CIKIS DEYIMLERININ SONU
C     ***********************************************************************
      END
```

* NOTE. THIS IS THE PROGRAM USED FOR PROBLEMS 10031 & 10032 AND 10033 . FOR PROBLEMS 10021 , 10022 AND 10023 , 10 FORMAT IS CHANGED INTO (I2,6F10.5)

*** SAMPLE DATA ***

```
0.001      2.50        2.50        10031       7        9 1 0 0 0 0 0 0 0 0
  1      .80400   18.10000     .59400      .00080      .49107    1.79300 11.2
  2      .72400   18.10000     .52200      .00060      .45699    1.81900 8.7
  3      .50200   18.10000     .54900      .00032      .47105    1.74700 4.1
  4      .46100   12.90000     .49900      .00036      .44385    1.82100 14.4
  5      .46100   12.90000     .49600      .00021      .44205    1.75800 9.2
  6      .28700   12.90000     .82300      .00013      .52843    1.56700 27.2
  7     1.66200   41.60000     .88500      .00070      .52269    1.43400 8.7
  8     1.98000   41.60000    1.22600      .00070      .43126    1.32500 2.6
  9     1.54000   41.60000    1.27900      .00070      .41361    1.43100 5.5
```

BASAMAKLI REGRESYON

PROBLEM NO.= 10021

DATA SAYISI = 9

DEGISKEN SAYISI = 6

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI

X(1) =	(Activity) =	8.4210
X(2) =	(PI) =	217.8000
X(3) =	(e) =	6.8730
X(4) =	(D_{10}) =	.0045
X(5) =	($\frac{e}{1+e^{?}}$) =	4.2010
Y =	(Log k) =	72.7468

HAM KARELER TOPLAMI

X(1) VS X(1) =	10.984251
X(1) VS X(2) =	267.910300
X(1) VS X(3) =	7.694008
X(1) VS X(4) =	.005165
X(1) VS X(5) =	3.881772
X(2) VS X(2) =	6673.740000
X(2) VS X(3) =	194.612700
X(2) VS X(4) =	.127522
X(2) VS X(5) =	100.821240
X(3) VS X(3) =	6.021209
X(3) VS X(4) =	.003727
X(3) VS X(5) =	3.184798

X(4) VS X(4) =	.000002
X(4) VS X(5) =	.002096
X(5) VS X(5) =	1.973790

X(1) VS Y =	-69.044240
X(2) VS Y =	-1780.083800
X(3) VS Y =	-55.883017
X(4) VS Y =	-.036808
X(5) VS Y =	-33.901228
Y VS Y =	588.734450

DEGISKENLERIN ORTALAMA DEGERLERI

X(1) =	.9356
X(2) =	24.2000
X(3) =	.7636
X(4) =	.0005
X(5) =	.4667
Y =	-8.0829

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	3.105002
X(1) VS X(2) =	64.122100
X(1) VS X(3) =	1.263171
X(1) VS X(4) =	.000936
X(1) VS X(5) =	-.048963
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	28.286100
X(2) VS X(4) =	.018138
X(2) VS X(5) =	-.842960

X(3) VS X(3) =	.772528
X(3) VS X(4) =	.000276
X(3) VS X(5) =	-.023364
X(4) VS X(4) =	.000000
X(4) VS X(5) =	-.000013
X(5) VS X(5) =	.012856
X(1) VS Y =	-.977419
X(2) VS Y =	-19.609600
X(3) VS Y =	-.328659
X(4) VS Y =	-.000273
X(5) VS Y =	.055394
Y VS Y =	.722570

KISMI KORELASYON KATSAYILARI

X(1) VS X(2) =	.971518
X(1) VS X(3) =	.815594
X(1) VS X(4) =	.756965
X(1) VS X(5) =	-.245062
X(2) VS X(3) =	.859192
X(2) VS X(4) =	.689699
X(2) VS X(5) =	-.198480
X(3) VS X(4) =	.447404
X(3) VS X(5) =	-.234444
X(4) VS X(5) =	-.168887
X(1) VS Y =	-.652544
X(2) VS Y =	-.615889
X(3) VS Y =	-.439894

```
   X( 4) VS   Y   =                          -.458112

   X( 5) VS   Y   =                           .574724

Y DEGERININ STANDART HATASI  =                .300534
BASAMAK NO.     1
   REGRESYONA GIREN DEGISKEN          1

   F SEVIYESI =         5.1911
   Y DEGERININ STANDART HAT ASI   =         .2434
   COK YONLU KORELASYON KATSAYISI =          .65254
   SABIT =          -7.78844
           DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI

             X-  1          -.31478          .13816
BASAMAK NO.     2
   REGRESYONA GIREN DEGISKEN          5

   F SEVIYESI =         2.8082
   Y DEGERININ STANDART HAT ASI   =         .2170

   COK YONLU KORELASYON KATSAYISI =          .78030
   SABIT =          -9.38157
           DEGISKEN          KATSAYI   KATSAYI STNDRT. H,,TASI

             X-  1          -.26261          .12703
             X-  5          3.30844          1.97427

BASAMAK NO.     3
   REGRESYONDAN CIKARTILAN DEGISKEN          5

   F SEVIYESI =         -2.3401
   Y DEGERININ STANDART HAT ASI   =         .2880
   COK YONLU KORELASYON KATSAYISI =          .65254
   SABIT =          -7.78844
           DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI

             X-  1          -.31478          .16347

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI =      3

DIYAGONAL ELEMANLAR
   DEG.NO.     DEGER

      1         1.00
      2         .056151
      3         .334806
      4         .427003
      5         .939944
```

TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

OKUMA	HAKIKI	TAHMINI	FARK
1.00	-7.95078	-8.04153	.09075
2.00	-8.06048	-8.01635	-.04412
3.00	-8.38721	-7.94647	-.44073
4.00	-7.84163	-7.93356	.09193
5.00	-8.03621	-7.93356	-.10264
6.00	-7.56543	-7.87879	.31336
7.00	-8.06048	-8.31162	.25114
8.00	-8.58502	-8.41172	-.17329
9.00	-8.25963	-8.27322	.01359

BASAMAKLI REGRESYON

PROBLEM NO.= 10022

DATA SAYISI = 9

DEGISKEN SAYISI = 6

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI

X(1) =	8.4210
X(2) =	217.8000
X(3) =	7.6740
X(4) =	.0045
X(5) =	4.2713
Y =	-70.7251

HAM KARELER TOPLAMI

X(1) VS X(1) =	10.984251
X(1) VS X(2) =	267.910300
X(1) VS X(3) =	8.513382
X(1) VS X(4) =	.005179
X(1) VS X(5) =	3.817812
X(2) VS X(2) =	6673.740000
X(2) VS X(3) =	214.855800
X(2) VS X(4) =	.127909
X(2) VS X(5) =	99.821150
X(3) VS X(3) =	7.365750
X(3) VS X(4) =	.004150
X(3) VS X(5) =	3.545890

X(4) VS X(4) =	.000002
X(4) VS X(5) =	.002124
X(5) VS X(5) =	2.046056

X(1) VS Y =	-67.200221
X(2) VS Y =	-1734.699400
X(3) VS Y =	-60.630444
X(4) VS Y =	-.036069
X(5) VS Y =	-33.499697
Y VS Y =	556.463170

DEGISKENLERIN ORTALAMA DEGERLERI

X(1) =	.9356
X(2) =	24.2000
X(3) =	.8526
X(4) =	.0005
X(5) =	.4745
Y =	-7.8583

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	3.105002
X(1) VS X(2) =	64.122100
X(1) VS X(3) =	1.333076
X(1) VS X(4) =	.000922
X(1) VS X(5) =	-.178700
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	29.145000
X(2) VS X(4) =	.017799

```
X( 2) VS X( 5) =        -3.544310
X( 3) VS X( 3) =          .822386
X( 3) VS X( 4) =          .000271
X( 3) VS X( 5) =         -.096104
X( 4) VS X( 4) =         0.000000
X( 4) VS X( 5) =         -.000035
X( 5) VS X( 5) =          .018944

X( 1) VS    Y  =        -1.025057
X( 2) VS    Y  =       -23.150900
X( 3) VS    Y  =         -.325467
X( 4) VS    Y  =         -.000313
X( 5) VS    Y  =          .065673
Y     VS    Y  =          .680200

KISMI KORELASYON KATSAYILARI

X( 1) VS X( 2) =          .971518
X( 1) VS X( 3) =          .834230
X( 1) VS X( 4) =          .751372
X( 1) VS X( 5) =         -.736798
X( 2) VS X( 3) =          .858026
X( 2) VS X( 4) =          .682180
X( 2) VS X( 5) =         -.687479
X( 3) VS X( 4) =          .429140
X( 3) VS X( 5) =         -.769946
X( 4) VS X( 5) =         -.366719
X( 1) VS    Y  =         -.705340
X( 2) VS    Y  =         -.749417
```

```
   X( 3) VS   Y   =                              -.435161
   X( 4) VS   Y   =                              -.546313
   X( 5) VS   Y   =                   -           .578525
Y DEGERININ STANDART HATASI  =                    .291590
BASAMAK NO.     1
  REGRESYONA GIREN DEGISKEN          2

  F SEVIYESI =          8.9681
  Y DEGERININ STANDART HAT ASI  =          .2063
  COK YONLU KORELASYON KATSAYISI =          .74941
  SABIT =          -7.45902
          DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI

             X-  2          -.01650          .00551
BASAMAK NO.     2
  REGRESYONA GIREN DEGISKEN          3

  F SEVIYESI =          3.5788
  Y DEGERININ STANDART HAT ASI  =          .1764
  COK YONLU KORELASYON KATSAYISI =          .85171
  SABIT =          -7.70979
          DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI

             X-  2          -.03138          .00917
             X-  3           .71661          .37880
BASAMAK NO.     3
  REGRESYONA GIREN DEGISKEN          5

  F SEVIYESI =          3.0536
  Y DEGERININ STANDART HAT ASI  =          .1522
  COK YONLU KORELASYON KATSAYISI =          .91078
  SABIT =          -9.44871
          DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI

             X-  2          -.03025          .00794
             X-  3          1.03160          .37335
             X-  5          3.04016         1.73973

BASAMAK NO.     4
  REGRESYONDAN CIKARTILAN DEGISKEN          5

  F SEVIYESI =          -2.4429
  Y DEGERININ STANDART HAT ASI  =          .2160
  COK YONLU KORELASYON KATSAYISI =          .85171
  SABIT =          -7.70979
          DEGISKEN          KATSAYI   KATSAYI STNDRT. HATASI
```

X- 2	-.03138	.01123
X- 3	.71661	.46394

BASAMAK NO. 5
REGRESYONDAN CIKARTILAN DEGISKEN 3

F SEVIYESI = -1.7894
Y DEGERININ STANDART HAT ASI = .3152
COK YONLU KORELASYON KATSAYISI = .74941
SABIT = -7.45902

DEGISKEN	KATSAYI	KATSAYI STNDRT. HATASI
X- 2	-.01650	.00841

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI = 5

DIYAGONAL ELEMANLAR

DEG.NO.	DEGER
1	.056151
2	1.000000
3	.263791
4	.534629
5	.527371

TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

OKUMA	HAKIKI	TAHMINI	FARK
1.00	-7.69680	-7.75769	.06089
2.00	-7.82390	-7.75769	-.06620
3.00	-8.06048	-7.75769	-.30278
4.00	-7.63827	-7.67188	.03361
5.00	-7.83268	-7.67188	-.16079
6.00	-7.29243	-7.67188	.37945
7.00	-8.06048	-8.14547	.08499
8.00	-8.06048	-8.14547	.08499
9.00	-8.25963	-8.14547	-.11415

BASAMAKLI REGRESYON

PROBLEM NO.= 10023

DATA SAYISI = 9

DEGISKEN SAYISI = 6

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI.

X(1) =	8.4210
X(2) =	217.8000
X(3) =	8.6330
X(4) =	.0045
X(5) =	4.2068
Y =	67.7913

HAM KARELER TOPLAMI

X(1) VS X(1) =	10.984251
X(1) VS X(2) =	267.910300
X(1) VS X(3) =	9.578411
X(1) VS X(4) =	.005165
X(1) VS X(5) =	3.622482
X(2) VS X(2) =	6673.740000
X(2) VS X(3) =	241.723900
X(2) VS X(4) =	.127522
X(2) VS X(5) =	95.187329
X(3) VS X(3) =	9.322337
X(3) VS X(4) =	.004650
X(3) VS X(5) =	3.829376

X(4) VS X(4) =	.000002
X(4) VS X(5) =	.002050
X(5) VS X(5) =	2.011680

X(1) VS Y =	-63.878358
X(2) VS Y =	-1651.111600
X(3) VS Y =	-65.086962
X(4) VS Y =	-.034228
X(5) VS Y =	-31.651676
Y VS Y =	511.067230

DEGISKENLERIN ORTALAMA DEGERLERI

X(1) =	.9356
X(2) =	24.2000
X(3) =	.9592
X(4) =	.0005
X(5) =	.4674
Y =	-7.5323

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	3.105002
X(1) VS X(2) =	64.122100
X(1) VS X(3) =	1.500800
X(1) VS X(4) =	.000936
X(1) VS X(5) =	-.313726
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	32.805300
X(2) VS X(4) =	.018131
X(2) VS X(5) =	-6.618450

X(3) VS X(3) =	1.041371
X(3) VS X(4) =	.000314
X(3) VS X(5) =	-.205927
X(4) VS X(4) =	.000000
X(4) VS X(5) =	-.000062
X(5) VS X(5) =	.045281
X(1) VS Y =	-.448272
X(2) VS Y =	-10.561500
X(3) VS Y =	-.060012
X(4) VS Y =	-.000182
X(5) VS Y =	.035874
Y VS Y =	.437860

KISMI KORELASYON KATSAYILARI

X(1) VS X(2) =	.971518
X(1) VS X(3) =	.834620
X(1) VS X(4) =	.756961
X(1) VS X(5) =	-.836678
X(2) VS X(3) =	.858253
X(2) VS X(4) =	.689699
X(2) VS X(5) =	-.830364
X(3) VS X(4) =	.439179
X(3) VS X(5) =	-.948310
X(4) VS X(5) =	-.416356
X(1) VS Y =	-.384452
X(2) VS Y =	-.426120
X(3) VS Y =	-.088872

```
   X( 4) VS    Y    =                          -.393015

   X( 5) VS    Y    =                           .254771

Y DEGERININ STANDART HATASI  =                  .233949

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI =        0


DIYAGONAL ELEMANLAR
   DEG.NO.      DEGER

      1          1.00
      2          1.00
      3          1.00
      4          1.00
      5          1.00


TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

           OKUMA     HAKIKI          TAHMINI         FARK
```

BASAMAKLI REGRESYON

PROBLEM NO. 10031

DATA SAYISI = 9

DEGISKEN SAYISI = 7

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI

X(1) = (Activity)	8.4210
X(2) = (PI)	217.8000
X(3) = (e)	6.8730
X(4) = (D_{10})	.0045
X(5) = ($\frac{e}{1+e^3}$)	4.2010
X(6) = (γ_d)	14.6950
Y = (k)	91.6000

HAM KARELER TOPLAMI

X(1) VS X(1) =	10.984251
X(1) VS X(2) =	267.910300
X(1) VS X(3) =	7.694008
X(1) VS X(4) =	.005165
X(1) VS X(5) =	3.881772
X(1) VS X(6) =	12.945718
X(2) VS X(2) =	6673.740000
X(2) VS X(3) =	194.612700
X(2) VS X(4) =	.127522
X(2) VS X(5) =	100.821240
X(2) VS X(6) =	337.685300

X(3) VS X(3) =	6.021209
X(3) VS X(4) =	.003727
X(3) VS X(5) =	3.184798
X(3) VS X(6) =	10.767740
X(4) VS X(4) =	.000002
X(4) VS X(5) =	.002096
X(4) VS X(6) =	.007246
X(5) VS X(5) =	1.973790
X(5) VS X(6) =	6.860934
X(6) VS X(6) =	24.297455
X(1) VS Y =	64.125200
X(2) VS Y =	1788.600000
X(3) VS Y =	65.501100
X(4) VS Y =	.037904
X(5) VS Y =	44.182232
X(6) VS Y =	151.879300
Y VS Y =	1362.480000

DEGISKENLERIN ORTALAMA DEGERLERI

X(1) =	.9356
X(2) =	24.2000
X(3) =	.7636
X(4) =	.0005
X(5) =	.4667
X(6) =	1.6327
Y =	10.1777

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	3.105002
X(1) VS X(2) =	64.122100
X(1) VS X(3) =	1.263171
X(1) VS X(4) =	.000936
X(1) VS X(5) =	-.048963
X(1) VS X(6) =	-.803903
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	28.286100
X(2) VS X(4) =	.018138
X(2) VS X(5) =	-.842960
X(2) VS X(6) =	-17.933700
X(3) VS X(3) =	.772528
X(3) VS X(4) =	.000276
X(3) VS X(5) =	-.023364
X(3) VS X(6) =	-.454341
X(4) VS X(4) =	0.000000
X(4) VS X(5) =	-.000013
X(4) VS X(6) =	-.000133
X(5) VS X(5) =	.012856
X(5) VS X(6) =	.001635
X(6) VS X(6) =	.303787
X(1) VS Y =	-21.581866
X(2) VS Y =	-428.120000
X(3) VS Y =	-4.450766
X(4) VS Y =	-.008099
X(5) VS Y =	1.425388
X(6) VS Y =	2.316860

```
    Y      VS     Y      =                     430.195600

KISMI KORELASYON KATSAYILARI

    X( 1) VS X( 2) =                              .971518
    X( 1) VS X( 3) =                              .815594
    X( 1) VS X( 4) =                              .756965
    X( 1) VS X( 5) =                             -.245062
    X( 1) VS X( 6) =                             -.827728
    X( 2) VS X( 3) =                              .859192
    X( 2) VS X( 4) =                              .689699
    X( 2) VS X( 5) =                             -.198480

    X( 2) VS X( 6) =                             -.868679
    X( 3) VS X( 4) =                              .447404
    X( 3) VS X( 5) =                             -.234444
    X( 3) VS X( 6) =                             -.937864
    X( 4) VS X( 5) =                             -.168887
    X( 4) VS X( 6) =                             -.345923
    X( 5) VS X( 6) =                              .026169
    X( 1) VS    Y  =                             -.590507
    X( 2) VS    Y  =                             -.551070
    X( 3) VS    Y  =                             -.244143
    X( 4) VS    Y  =                             -.556191
    X( 5) VS    Y  =                              .606089
    X( 6) VS    Y  =                              .202666

Y DEGERININ STANDART HATASI  =                   7.333106
BASAMAK NO.    1
   REGRESYONA GIREN DEGISKEN        5
```

```
    F SEVIYESI =          4.0644
    Y DEGERININ STANDART HAT ASI  =          6.2354
    COK YONLU KORELASYON KATSAYISI =          .60608
    SABIT =        -41.57303
             DEGISKEN        KATSAYI   KATSAYI STNDRT. HATASI

               X- 5       110.86820          54.99261
BASAMAK NO.     2
    REGRESYONA GIREN DEGISKEN         4

    F SEVIYESI =          3.0240
    Y DEGERININ STANDART HAT ASI  =          5.4918
    COK YONLU KORELASYON KATSAYISI =          .76115
    SABIT =        -27.90563
             DEGISKEN        KATSAYI   KATSAYI STNDRT. HATASI

               X- 4     -13800.35300       7935.88520
               X- 5        96.43615          49.14012

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI =       2

DIYAGONAL ELEMANLAR
    DEG.NO.       DEGER

        1          .412859
        2          .517393
        3          .773844
        4         1.029360

        5         1.029360
        6          .879266

TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

            OKUMA      HAKIKI           TAHMINI          FARK

             1.00     11.20000          8.41098        2.78901
             2.00      8.70000          7.88451         .81548
             3.00      4.10000         13.10450       -9.00450
             4.00     14.40000          9.92942        4.47057
             5.00      9.20000         11.82589       -2.62589
             6.00     27.20000         21.26007        5.93992
             7.00      8.70000         12.84033       -4.14033
             8.00      2.60000          4.02317       -1.42317
             9.00      5.50000          2.32107        3.17892
```

BASAMAKLI REGRESYON

PROBLEM NO. 10032

DATA SAYISI = 9

DEGISKEN SAYISI = 7

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI

X(1) =	8.4210
X(2) =	217.8000
X(3) =	7.6740
X(4) =	.0045
X(5) =	4.2713
X(6) =	14.6950
Y =	155.4000

HAM KARELER TOPLAMI

X(1) VS X(1) =	10.984251
X(1) VS X(2) =	267.910300
X(1) VS X(3) =	8.513382
X(1) VS X(4) =	.005179
X(1) VS X(5) =	3.817812
X(1) VS X(6) =	12.945718
X(2) VS X(2) =	6673.740000
X(2) VS X(3) =	214.855800
X(2) VS X(4) =	.127909
X(2) VS X(5) =	99.821150
X(2) VS X(6) =	337.685300

X(3) VS X(3) =	7.365750
X(3) VS X(4) =	.004150
X(3) VS X(5) =	3.545890
X(3) VS X(6) =	12.047845
X(4) VS X(4) =	.000002
X(4) VS X(5) =	.002124
X(4) VS X(6) =	.007300
X(5) VS X(5) =	2.046056
X(5) VS X(6) =	7.025752
X(6) VS X(6) =	24.297455
X(1) VS Y =	103.559900
X(2) VS Y =	2889.650000
X(3) VS Y =	125.502000
X(4) VS Y =	.062581
X(5) VS Y =	76.314828
X(6) VS Y =	258.039600
Y VS Y =	4232.420000

DEGISKENLERIN ORTALAMA DEGERLERI

X(1) =	.9356
X(2) =	24.2000
X(3) =	.8526
X(4) =	.0005
X(5) =	.4745
X(6) =	1.6327
Y =	17.2666

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	3.105002
X(1) VS X(2) =	64.122100
X(1) VS X(3) =	1.333076
X(1) VS X(4) =	.000922
X(1) VS X(5) =	-.178700
X(1) VS X(6) =	-.803903
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	29.145000
X(2) VS X(4) =	.017799
X(2) VS X(5) =	-3.544310
X(2) VS X(6) =	-17.933700
X(3) VS X(3) =	.822386
X(3) VS X(4) =	.000271
X(3) VS X(5) =	-.09610[illegible]
X(3) VS X(6) =	-.482091
X(4) VS X(4) =	.000000
X(4) VS X(5) =	-.000035
X(4) VS X(6) =	-.000128
X(5) VS X(5) =	.018944
X(5) VS X(6) =	.051669
X(6) VS X(6) =	.303787
X(1) VS Y =	-41.842700
X(2) VS Y =	-871.030000
X(3) VS Y =	-7.002400
X(4) VS Y =	-.015982
X(5) VS Y =	2.563715
X(6) VS Y =	4.305940
Y VS Y =	1549.180000

KISMI KORELASYON KATSAYILARI

X(1) VS X(2) =	.971518
X(1) VS X(3) =	.834230
X(1) VS X(4) =	.751372
X(1) VS X(5) =	-.736796
X(1) VS X(6) =	-.827728
X(2) VS X(3) =	.858026
X(2) VS X(4) =	.682180
X(2) VS X(5) =	-.687479
X(2) VS X(6) =	-.868679
X(3) VS X(4) =	.429140
X(3) VS X(5) =	-.769946
X(3) VS X(6) =	-.964509
X(4) VS X(5) =	-.366719
X(4) VS X(6) =	-.333961
X(5) VS X(6) =	.681083
X(1) VS Y =	-.603306
X(2) VS Y =	-.590821
X(3) VS Y =	-.196181
X(4) VS Y =	-.582933
X(5) VS Y =	.473230
X(6) VS Y =	.198487

Y DEGERININ STANDART HATASI = 13.915726

BASAMAK NO. 1

REGRESYONA GIREN DEGISKEN 1

F SEVIYESI = 4.0059

Y DEGERININ STANDART HAT ASI = 11.8641

COK YONLU KORELASYON KATSAYISI = .60330

SABIT = 29.87561

DEGISKEN	KATSAYI	KATSAYI STNDRT. HATASI
X- 1	-13.47590	6.73297

BASAMAK NO. 2
REGRESYONA GIREN DEGISKEN 3

F SEVIYESI = 5.7123
Y DEGERININ STANDART HATASI = 9.1720
COK YONLU KORELASYON KATSAYISI = .82108
SABIT = 10.10641

DEGISKEN	KATSAYI	KATSAYI STNDRT. HATASI
X- 1	-32.29717	9.43961
X- 3	43.83851	18.34202

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI = 2

DIYAGONAL ELEMANLAR

DEG.NO.	DEGER
1	3.288832
2	.048714
3	3.288832
4	.306924
5	.377821
6	.067965

TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

OKUMA	HAKIKI	TAHMINI	FARK
1.00	20.10000	13.90583	6.19416
2.00	15.00000	12.89485	2.10514
3.00	8.70000	21.42382	-12.72382
4.00	23.00000	20.24920	2.75079
5.00	14.70000	20.07385	-5.37385
6.00	51.00000	42.04532	8.95467
7.00	8.70000	.79309	7.90691
8.00	8.70000	7.57577	1.12422
9.00	5.50000	16.43822	-10.93822

BASAMAKLI REGRESYON

PROBLEM NO. 10033

DATA SAYISI = 9

DEGISKEN SAYISI = 7

DEGISKENIN REGRESYONA GIRECEGI F SEVIYESI = 2.500

DEGISKENIN REGRESYONDAN CIKARILACAGI F SEVIYESI = 2.500

DEGISKENLERIN TOPLAMI

X(1) = 7.4210

X(2) = 217.8000

X(3) = 8.6330

X(4) = .0045

X(5) = 4.2068

X(6) = 14.6950

Y = 307.0000

HAM KARELER TOPLAMI

X(1) VS X(1) = 8.904251

X(1) VS X(2) = 226.310300

X(1) VS X(3) = 8.140411

X(1) VS X(4) = .004465

X(1) VS X(5) = 3.260592

X(1) VS X(6) = 11.514718

X(2) VS X(2) = 6673.740000

X(2) VS X(3) = 241.723900

X(2) VS X(4) = .127522

X(2) VS X(5) = 95.187329

X(2) VS X(6) = 337.685300

```
X( 3) VS X( 3) =                         9.322337
X( 3) VS X( 4) =                          .004650
X( 3) VS X( 5) =                         3.829376
```

```
X( 3) VS X( 6) =                        13.553164
X( 4) VS X( 4) =                          .000002
X( 4) VS X( 5) =                          .002050
X( 4) VS X( 6) =                          .007246
X( 5) VS X( 5) =                         2.011680
X( 5) VS X( 6) =                         6.973219
X( 6) VS X( 6) =                        24.297455
X( 1) VS    Y  =                       224.911700
X( 2) VS    Y  =                      6439.560000
X( 3) VS    Y  =                       295.287500
X( 4) VS    Y  =                          .130942
X( 5) VS    Y  =                       146.022300
X( 6) VS    Y  =                       500.037400
Y     VS    Y  =                     15082.180000
```

DEGISKENLERIN ORTALAMA DEGERLERI

```
X( 1) =                 .8245
X( 2) =               24.2000
X( 3) =                 .9592
X( 4) =                 .0005
X( 5) =                 .4674
X( 6) =                1.6327
    Y =               34.1111
```

ARTIK KARELER TOPLAMI

X(1) VS X(1) =	2.785224
X(1) VS X(2) =	46.722100
X(1) VS X(3) =	1.022022
X(1) VS X(4) =	.000738
X(1) VS X(5) =	-.208181
X(1) VS X(6) =	-.602125
X(2) VS X(2) =	1402.980000
X(2) VS X(3) =	32.805300
X(2) VS X(4) =	.018138
X(2) VS X(5) =	-6.618450
X(2) VS X(6) =	-17.933700
X(3) VS X(3) =	1.041371
X(3) VS X(4) =	.000314
X(3) VS X(5) =	-.205927
X(3) VS X(6) =	-.542606
X(4) VS X(4) =	.000000
X(4) VS X(5) =	-.000062
X(4) VS X(6) =	-.000133
X(5) VS X(5) =	.045281
X(5) VS X(6) =	.104368
X(6) VS X(6) =	.303787
X(1) VS Y =	-28.226850
X(2) VS Y =	-989.840001
X(3) VS Y =	.806280
X(4) VS Y =	-.023240
X(5) VS Y =	2.521980
X(6) VS Y =	-1.225370
Y VS Y =	4610.069000

KISMI KORELASYON KATSAYILARI

X(1) VS X(2) =	.747423
X(1) VS X(3) =	.600105
X(1) VS X(4) =	.630450
X(1) VS X(5) =	-.586226
X(1) VS X(6) =	-.654593
X(2) VS X(3) =	.858253
X(2) VS X(4) =	.689699
X(2) VS X(5) =	-.830364
X(2) VS X(6) =	-.868679
X(3) VS X(4) =	.439179
X(3) VS X(5) =	-.948311
X(3) VS X(6) =	-.964710
X(4) VS X(5) =	-.416356
X(4) VS X(6) =	-.345923
X(5) VS X(6) =	.889863
X(1) VS Y =	-.249102
X(2) VS Y =	-.389211
X(3) VS Y =	.011636
X(4) VS Y =	-.487509
X(5) VS Y =	.174552
X(6) VS Y =	-.032743

Y DEGERININ STANDART HATASI = 24.005387

TAMAMLANAN REGRESYON BASAMAKLARI SAYISI = 0

DIYAGONAL ELEMANLAR

DEG.NO. DEGER

1	1.00
2	1.00
3	1.00
4	1.00
5	1.00
6	1.00

TAHMINI VE HAKIKI DEGERLERIN KARSILASTIRILMASI

OKUMA	HAKIKI	TAHMINI	FARK