CHAPTER V

EXPERIMENTAL INVESTIGATION

5.1 Nature of Apparatus The Blaine air permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of soil of definite porosity. The number and size of the pores in a prepared bed of definite porosity is a function of the size of the particles and determines the rate of air flow through the bed. The apparatus, illustrated in Fig. 1,2,3 consist specifically of the parts described in the following

Permeability Cell The permeability cell consists of a 1.27±0.10 c.m. rigid cylinder inside diamter, constructed of glass (or non-corroding metal). The top of the cell is at right angles to the principal axis of the cell. The bottom of the cell forms an air-tight connection with the top of the manometer. A ledge 1/2 to 1 m.m. in width is an integral part of the cell or firmly fixed in the cell of 6.0 c.m., 6.5 c.m., 7.5 c.m. for clay size, silt size and sand size respectively, from the top of the cell to support the perforated metal disk.

Disk The disk is constructed of brass and is 0.9±0.1 m.m. in thickness, perforated with 30 to 40 holes 1 m.m. in diameter equally distributed over its area. The disk is to fit the inside of the cell snugly.

Plunger The plunger fits into the cell with a clearance of not more than 0.1 m.m. The bottom of the plunger is at right angles to the principal axis. An air vent is provided.either in the center or on one side of plunger. The top of the plunger is provided with a collar in such a way that when the plunger is placed in the cell and the collar brought in contact with the top of the cell, the distance between the bottom of the plunger and the top of the perforated disk will be 1.0±0.1 c.m. for clay size, 1.5±0.1 c.m. for silt size, 2.5±0.1 c.m. for sand size.

Filter Paper The filter paper is medium retentive, corresponding to type 1, grade B, as prescribed in Federal Specification for Paper; Filtering (U.U. P-236). The filter paper disks are circular, with smooth edges, and have the same diameter as the inside of the cell.

Manometer Three U-tube manometers are constructed according to the design indicated in Fig.1, 2, 3, with the use of nominal 0.4, 0.8, 2.0 c.m. inside diameter for clay size, silt size and sand size respectively, standard wall and galss tubing. The top of one arm of the manometer forms an airtight connection with the permeability cell. The manometer arm connected to the permeability cell has a line etched around the tube at 12.5 to 14.5 c.m. below the top of the side outlet and at distances of 1.5 c.m., 7.0 c.m., and 11.0 c.m. above that line. A side outlet is 7.0 c.m., and 11.0 c.m. above that line. A side outlet is provided at 25.0 to 30.5 c.m. above the bottom of the manometer for use in the evacuation of the manometer arm connected to the permeability cell. A positive airtight valve or clamp is provided on the side outlet not more than 5 c.m. from the manometer arm. The manometer is mounted firmly and in such a manner that the arms are horizontal.

Manometer Liquid The manometer is filled to the mid point with a nonvolatile, nonhygroscopic liquid of low viscosity and density, such as dibutylphtalate.

Timer The timer is accurate to 0.5 second for time intervals up to 60 seconds, and to 1 percent for time intervals over 60 seconds.

5.2 Calibration of Apparatus

The calibration of the air permeability apparatus was made with the use of the current lot of National Bureau of Standard cement sample No.114. The standard sample was at room temperature when tested. The bulk volume of the compacted bed was determined by the mercury displacement method as follows:

Placed two filter paper disks in the permeability cell, pressing down the edges with a rod slightly smaller than the cell diameter until the filter disks were flat on the perforated brass disk; then filled the cell with mercury, removing any air bubbles adhering to the wall of the cell. Levelling the mercury with the top of the cell by means of a small glass plate. Removed the mercury from the cell, weighed, and recorded the weight of the mercury. Removed one of the filter disks from the cell. Using a trial quantity of sample, compressed the sample with one filter disk above and one below the sample. Filled the space remaining in the top of the cell with mercury, removing entrapped air, and levelling off the top as before. Removed the murcury from the cell, weighed and recorded the weight of mercury. The bulk volume occupied by the cement was calculated to the nearest 0.005 cu.cm. as follows:

$$V = \frac{W_A - W_B}{D} \tag{10}$$

Where

V = bulk volume of sample in cubic centimeters

W_A = grams of mercury required to fill cell, no sample being in cell

W_B = grams of mercury required to fill the portion of the cell not occupied by the prepared bed of sample in the cell, and

D = density of mercury at temperature of test in grams per cubic centimeters (See Table I)

The weight of the standard sample used for the calibration test was that required to produce a bed of cement having a porosity of 0.500±0.005, and was calculated as follows:

$$W = \rho V(1-E) \tag{11}$$

where

w = grams of sample required

ρ = specific gravity of sample (=3.15 for standard sample)

v = bulk volume of bed of sample in cubic centimeters

ϵ = desired porosity of bed of sample (0.500±0.005 for standard cement sample)

5.3 Preparation of Standard Sample

The contents of a vial of the standard cement sample were enclosed in a 4-Oz. jar and shaken vigorously for 2 minute to fluff the cement and break up lumps or agglomerates.

5.4 Preparation of Bed of Sample

The perforated disk was seated on the ledge in the permeability cell. A filter paper disk was placed on the brass disk and the edges pressed down with a rod slightly smaller than the cell diameter. A quantity of sample determined in section 5.2 and weighed to the nearest 0.01 gm. was to be placed in the cell. The side of the cell was tapped lightly in order to level the bed of sample. A filter paper disk was placed on top of the sample and the sample compressed with the plunger until the plunger collar was in contact with the top of the cell. The plunger was removed slowly and the permeability test was started.

5.5 Permeability Test

The permeability cell was attached to the manometer tube, making certain that an airtight connection was obtained.

The air in one arm of the manometer u-tube was slowly evacuated until the liquid reaches the top mark, and the valve was closed tightly. The timer was started as the bottom of the meniscus of the manometer liquid reached the second (next to the top) mark and was stopped as the bottom of the meniscus of liquid reached the third (next to the bottom) mark. The time interval measured was noted and recorded in seconds. The temperature of test was noted and recorded in degrees Centigrade.

5.6 Permeability Test for Soil Sample

The permeability test for soil sample was made in accordance with the method described in 5.5, except that the definite porosity is not known and the trial values were used to find the minimum possible porosity. Each sample was tested many times to meet this requirement and the time of flow determinations were recorded for calculating the specific surface. Calculation of specific surface value was made according to the following formulas:

$$S = \frac{S_s \rho_s (1-E_s) \sqrt{E^3} \sqrt{t}}{\rho (1-E) \sqrt{E_s^3} \sqrt{t_s}} \qquad (7)$$

when the temperature of the test of the test sample was within $\pm 3^{\circ}$c of the temperature of calibration test of the standard finess sample, and if the temperature of tests was outside of this range the following equation was used

$$S = \frac{S_s \rho_s (1-E_s) \sqrt{\eta_s} \sqrt{E^3} \sqrt{t}}{\rho (1-E) \sqrt{E_s^3} \sqrt{t_s} \sqrt{\eta}} \qquad (8)$$

The apparatus shall be recalibrated in the following cases.

1) At periodic intervals to correct for possible wear on plunger or permeability cell.

2) If any loss in manometer fluid occurs, and

3) If a change was made in the type or quality of the filter paper used for the tests.

Symbols

S = specific surface in sq.cm. per gram of the test sample,

S_s = specific surface in sq.c.m. per gram of the standard sample used in calibration of the apparatus,

t = measured time interval, in seconds, of manometer drop for test sample

t_s = measured time interval in seconds of manometer drop for standard sample used in calibration of the apparatus

η = viscosity of air in poises at the temperature of test of the test sample

η_s = viscosity of air in poises at the temperature of test of the standard sample used in calibration of the apparatus

E = porosity of prepared bed of test sample

E_s = porosity of prepared bed of standard sample used in calibration of apparatus

ρ = specific gravity of test sample, and

ρ_s = specific gravity of standard sample used in calibration of apparatus (=3.15)

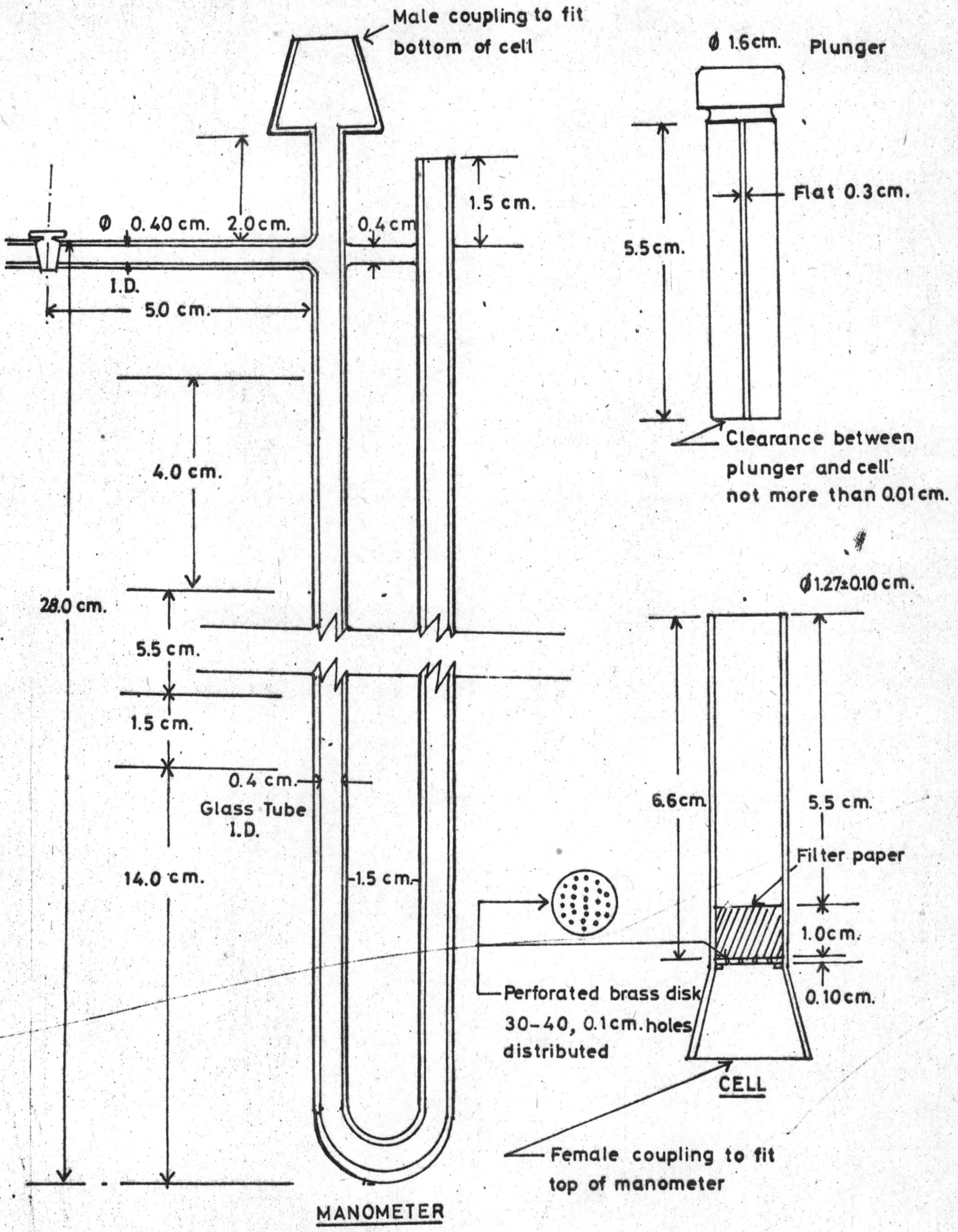

Male coupling to fit bottom of cell
Ø 1.6cm.
Plunger
Ø 0.40 cm.
2.0 cm.
0.4 cm
1.5 cm.
I.D.
5.0 cm.
Flat 0.3cm.
5.5cm.
Clearance between plunger and cell not more than 0.01 cm.
4.0 cm.
28.0 cm.
Ø 1.27±0.10 cm.
5.5 cm.
1.5 cm.
0.4 cm.
Glass Tube I.D.
6.6cm.
5.5 cm.
Filter paper
14.0 cm.
-1.5 cm.-
1.0cm.
0.10cm.
Perforated brass disk 30-40, 0.1cm. holes distributed
CELL
Female coupling to fit top of manometer
MANOMETER

FIG. 1

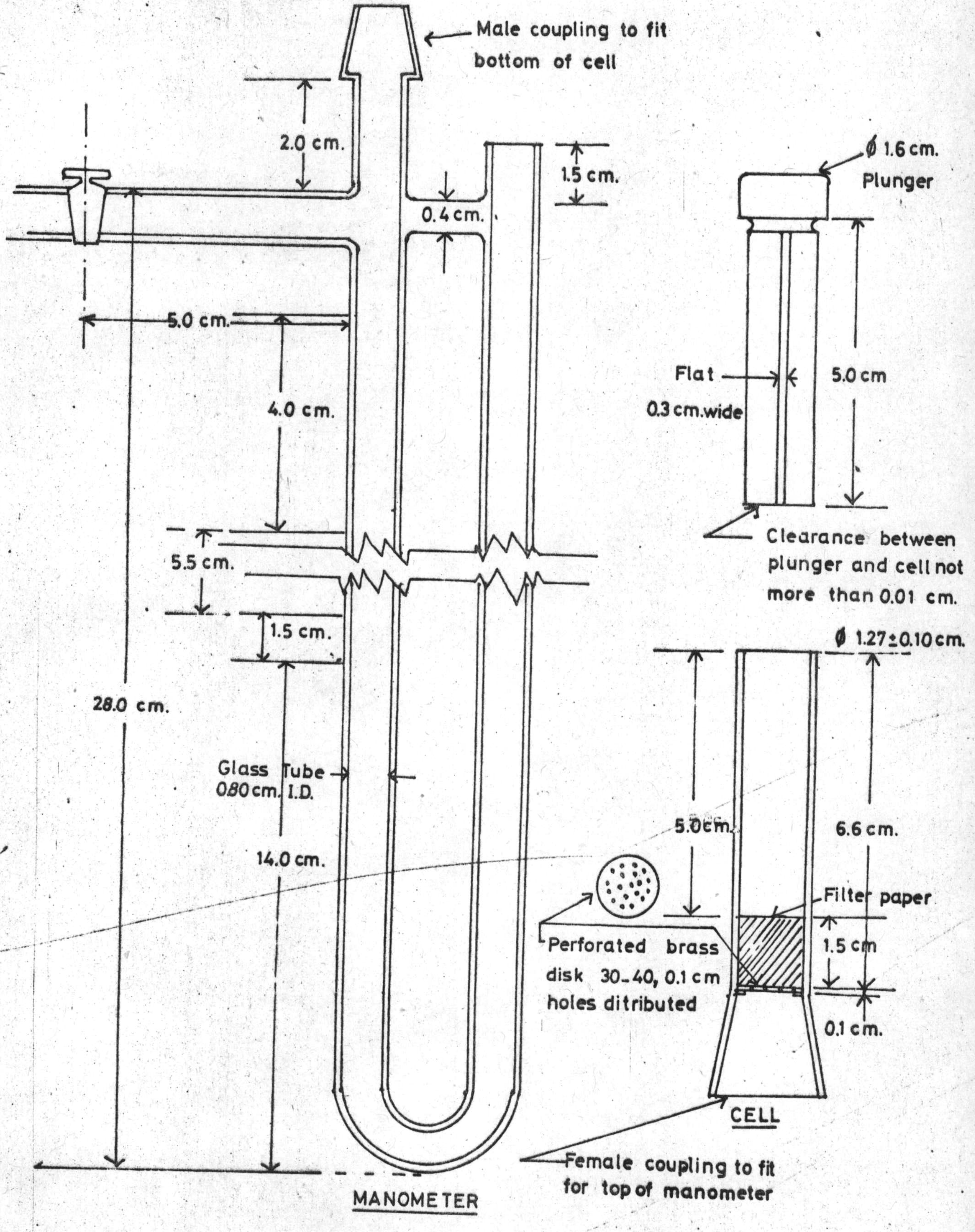

Male coupling to fit bottom of cell
2.0 cm.
1.5 cm.
0.4 cm.
5.0 cm.
4.0 cm.
5.5 cm.
1.5 cm.
28.0 cm.
Glass Tube
0.80 cm. I.D.
14.0 cm.
MANOMETER
Ø 1.6 cm.
Plunger
Flat
0.3 cm.wide
5.0 cm
Clearance between plunger and cell not more than 0.01 cm.
Ø 1.27±0.10 cm.
5.0cm.
6.6 cm.
Filter paper
1.5 cm
0.1 cm.
Perforated brass disk 30-40, 0.1 cm holes ditributed
CELL
Female coupling to fit for top of manometer

FIG. 2

000229

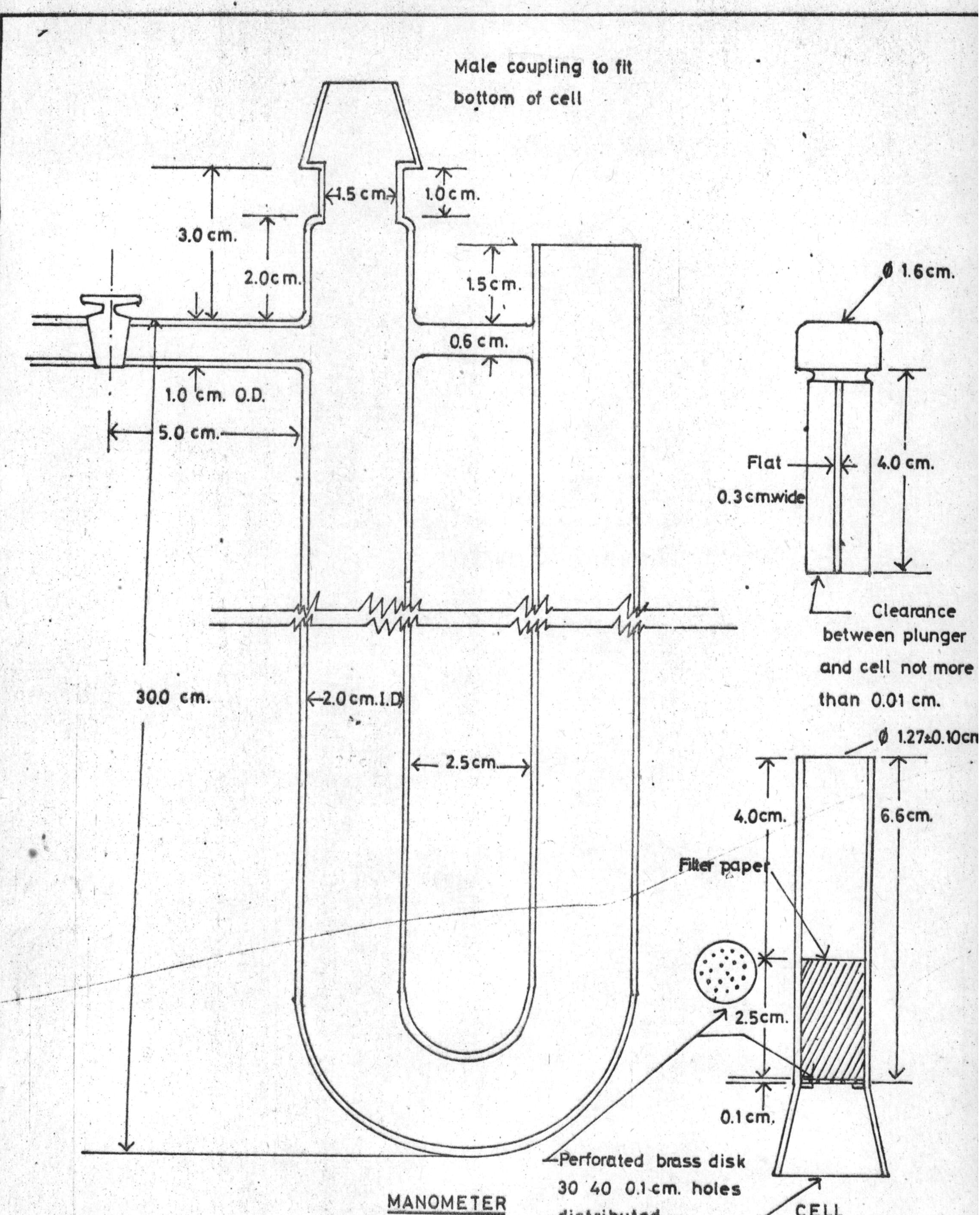

Male coupling to fit bottom of cell
3.0 cm.
2.0cm.
1.5 cm.
1.0cm.
1.5cm.
0.6 cm.
1.0 cm. O.D.
5.0 cm.
30.0 cm.
2.0 cm.I.D
2.5cm.
MANOMETER
Ø 1.6cm.
Flat
0.3 cmwide
4.0 cm.
Clearance between plunger and cell not more than 0.01 cm.
Ø 1.27±0.10cm
4.0cm.
6.6cm.
Filter paper
2.5cm.
0.1cm.
Perforated brass disk 30 40 0.1 cm. holes distributed
CELL
Female coupling to fit top of manometer

FIG. 3

Table I Density of Mercury, Viscosity of Air (η), and $\sqrt{\eta}$ at Given Temperature .

Room Temperature degree Centigrade	Density of Mercury gram per Cubic Centi.	Viscosity of Air, η, Poises	$\sqrt{\eta}$
16	13.56	0.0001788	0.01337
18	13.55	0.0001798	0.01341
20	13.55	0.0001808	0.01344
22	13.54	0.0001818	0.01348
24	13.54	0.0001828	0.01352
26	13.53	0.0001837	0.01355
28	13.53	0.0001847	0.01359
30	13.52	0.0001857	0.01362
32	13.52	0.0001867	0.01366
34	13.51	0.0001876	0.01369

Blaine's Air Permeability Apparatus Calibration
with Standard Cement Sample ($S_s = 3{,}380\ \frac{cm^2}{gm.}$)

Calibrating with Ø0.40 c.m. Glass Tube

Test No.	(1)	(2)	(3)	(4)	(5)	Average
Weight of Cement (gm.)	1.860	1.860	1.860	1.860	1.860	1.860
Volume of Cement (cm^3)	1.180	1.180	1.180	1.180	1.180	1.180
Porosity E_s	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996
Temperature T_s (°c)	28.5	28.5	28.5	28.5	28.5	28.5
Timet t_s (sec)	16.7	16.3	16.1	16.1	16.3	16.3

Calibrating with Ø0.80 c.m. Glass Tube

Test No.	(1)	(2)	(3)	(4)	(5)	Average
Weight of Cement (gm)	2.980	2.980	2.980	2.980	2.980	2.980
Volume of Cement (cm^3)	1.891	1.891	1.891	1.891	1.891	1.891
Porosity E_s	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997
Temperature T (°c)	27.8	27.8	27.50	27.80	27.80	27.74
Time t (Sec.)	100.0	100.3	99.1	98.6	97.8	99.16

Calibrating with Ø2.0 c.m.Glass Tube

Test No.	(1)	(2)	(3)	(4)	(5)	Average
Weight of Cement (gm)	4.585	4.585	4.585	4.585	4.585	4.585
Volume of Cement (cm^3)	2.911	2.911	2.911	2.911	2.911	2.911
Porosity E_s	0.500	0.500	0.500	0.500	0.500	0.500
Temperature T_s (°c)	28.0	28.0	28.3	28.2	28.3	28.26
Time t_s	991.3	1053.1	1011.4	1014.6	1022.3	1018.54

Result from Testing Ø0.40 c.m. Glass Tube

Sample P.354 (G = 2.739)

Test No.	1	2	3	4
Moist Wt. (gm.)	1.10	1.20	1.40	1.50
$\frac{Wn}{Wmoist}$ x100	3.85	3.85	3.85	3.85
Dry Wt. (gm.)	1.05765	1.1538	1.3461	1.4425
Volume (cm^3).	1.198	1.167	1.176	1.236
Porosity E	0.6777	0.6390	0.5821	0.5740
Temperature T (^{o}c)	30.0	31.8	31.7	31.0
Time t (Sec.)	40.27	134.10	437.57	1296.20

Sample 5992 (2.671)

Test No.	1	2	3	4	5
Moist Wt. (gm.)	1.10	1.40	1.60	1.70	1.80
$\frac{Ww}{W\ moist}$ x 100	6.10	6.10	6.10	6.10	6.10
Dry Wt. (gm.)	1.0329	1.3146	1.5024	1.5963	1.6902
Volume (cm3)	1.199	1.199	1.205	1.207	1.213
Porosity E	0.6775	0.5895	0.5332	0.5049	0.4783
Temperature T(^{o}c)	30.2	30.2	30.7	30.9	31.4
Time t (Sec.)	7.0	46.0	82.74	261.82	417.9

Result from Testing 00.40 c.m. Glass Tube (Continued)

Sample No. 2 (G=2.615)

Test No.	1	2
Moist Wt. (gm.)	2.15	2.25
$\frac{Ww}{W\ moist}$ x 100	0.85	0.85
Dry Wt. (gm.)	2.131725	2.230875
Volume (c.m.^{3})	1.206	1.251
Porosity E	0.3241	0.3181
Temperature T(E)	31.3	32.0
Time t (Sec.)	8.90	9.37

Sample No. 3 (G=2.595)

Test No.	1	2
Moist Wt. (gm.)	1.95	2.05
$\frac{Ww}{W\ moist}$x100	1.32	1.32
Dry Wt. (gm.)	1.92426	2.02294
Volume (c.m.^{3})	1.213	1.226
Porosity E	0.3887	0.3641
Temperature T(^{o}c)	31.0	32.0
Time t (Sec.)	15.63	23.33

Result from Testing 00.40 c.m. Glass Tube (Continued)

Sample No. 5 (G=2.645)

Test No.	1	2
Moist Wt. (gm.)	2.10	2.20
$\frac{Ww \times 100}{W\ moist}$	1.17	1.17
Dry Wt. (gm.)	2.07543	2.17426
Volume (c.m.^{3})	1.206	1.226
Porosity E	0.3494	0.3295
Temperature T(^{o}c)	31.5	31.8
Time t (Sec.)	23.47	34.37

Computating the Result

Sample $P_e 354$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.6777	40.27	1	1361.6232	1.731	6.346	14957.329
2	0.6390	134.10	1.00445	1361.6232	1.415	11.580	22410.432
3	0.5821	437.57	1.004315	1361.6232	1.063	20.918	30407.471
4	0.5740	517.20	1	1361.6232	1.021	22.742	31616.319

Sample 5992

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.6775	7.0	1	1396.2882	1.729	2.646	6387.926
2	0.5895	46.0	1	1396.2882	1.103	6.782	10444.997
3	0.5332	82.74	1	1396.2882	0.834	9.096	10592.331
4	0.5049	261.82	1	1396.2882	0.725	16.181	16380.170
5	0.4783	417.9	1	1396.2882	0.634	20.443	18097.098

Computating the Result (Continued)

Sample 674

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w $c.m.^2/gm.$
1	0.6295	24.37	1	1387.9739	1.348	4.937	9237.072
2	0.5704	66.40	1	1387.9739	1.006	8.149	11378.462
3	0.5183	216.08	1	1387.9739	0.775	14.700	15812.491
4	0.4995	398.53	1	1387.9739	0.705	19.963	19534.226

Sample P_f886

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w $c.m.^3/gm.$
1	0.6715	72.22	1.004181	1375.1792	1.675	8.498	19656.347
2	0.6416	111.23	1	1375.1792	1.434	10.547	20798.756
3	0.5909	597.47	1	1375.1792	1.110	24.443	37310.990
4	0.5678	762.93	1.004181	1375.1792	0.990	27.621	37603.986

Computating the Result (Continued)

Sample No. 2

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w cm^2/gm.
1	0.3241	8.90	1	1426.1897	0.273	2.983	1161.430
2	0.3181	9.37	1.004719	1426.1897	0.263	3.061	1153.562

Sample No. 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)x(5)x(6) x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w $c.m.^2$ /gm.
1	0.3887	15.63	1	1437.1815	0.396	3.954	2250.316
2	0.3641	23.33	1.004719	1437.1815	0.346	4.830	2413.123

Sample No. 5

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)x(5)x(6) x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w $c.m.^2$ /gm.
1	0.3494	23.47	1	1410.0136	0.317	4.845	2165.591
2	0.3295	34.47	1.00445	1410.0136	0.282	5.863	2341.643

Result from Testing Ø0.80 c.m. Glass Tube

Sample No.2 Reddish Brown Silty Sand (G=2.615)

Test No.	1	2	3	4	5	6	7
Moist Wt. (gm.)	3.0	3.10	3.15	3.20	3.25	3.30	3.40
$\frac{W_w \times 100}{W_{moist}}$	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Dry Wt. (gm.)	2.9745	3.07365	3.123225	3.1728	3.222375	3.27195	3.3711
Volume (c.m^3)	1.890	1.890	1.890	1.890	1.890	1.890	1.890
Porosity E	0.3982	0.3781	0.3681	0.3580	0.3480	0.3380	0.3179
Temperature T(^{o}c)	33.0	33.0	32.8	32.8	32.50	32.80	33.0
Time t (Sec.)	20.75	21.40	25.75	34.94	40118	44.18	58.76

Sample No. 3

Test No.	1	2	3	4
Moist Wt. (gm.)	3.0	3.10	3.15	3.20
$\frac{W_w \times 100}{W\ moist}$	1.32	1.32	1.32	1.32
Dry Wt. (gm.)	2.9604	3.05908	3.10842	3.15776
Volume (c.m^3)	1.930	1.930	1.930	1.930
Porosity E	0.4089	0.3892	0.3794	0.3695
Temperature T(^{o}c)	30.0	30.0	29.0	29.0
Time t (Sec.)	65.74	85.70	105.02	125.15

Result from Testing 00.80 c.m. Glass Tube (Continued)

Sample No. 5 Light Reddish Brown Silty Sand (G=2.615)

Test No.	1	2	3	4	5
Moist Wt. (gm.)	3.0	3.10	3.20	3.25	3.30
Wwx100 / W moist	1.17	1.17	1.17	1.17	1.17
Dry Wt. (gm.)	2.9649	3.06373	3.16256	3.211975	3.26139
Volume (c.m.^{3})	1.950	1.950	1.950	1.950	1.950
Porosity E	0.4252	0.4060	0.3868	0.3773	0.3677
Temperature T(^{o}c)	27.0	27.8	28.5	29.0	29.0
Time t (Sec.)	44.54	74.40	86.12	106.40	115.32

Sample No.1 Reddish Brown Very Fine Sand(G= 2.662)

TestNo.	1	2	3
Moist Wt. (gm.)	3.0	3.10	3.20
Wwx100 / W moist	0.14	0.14	0.14
DryWt. (gm.)	2.9958	3.09566	3.19552
Volume (c.m.^{3})	1.870	1.870	1.870
Porosity E	0.3982	0.3781	0.3581
Temperature T (^{o}c)	29.5	29.5	29.5
Time t (Sec.)	5.20	6.66	8.50

Result from Testing 00.80 c.m. Glass Tube (Continued)

Sample No. 4

Test No.	1	2	3
Moist Wt. (gm.)	3.10	3.20	3.30
Wwx100 / W moist	1.63	1.63	1.63
Dry Wt. (g:m:)	3.04947	3.14784	3.24621
Volume (c.m.^{3})	1.9038	1.9401	1.9778
Porosity E	0.3965	0.3887	0.3816
Temperature T(^{o}c)	29.0	29.0	29.0
Time t (Sec.)	10.3	13.8	15.1

Computating the Result

Sample No. 2

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec) (sec)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)\ S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface face S_w (c.m.^{2}/gm.)
1	0.3982	20.75	0.9931	578.2329	0.418	4.555	1093.353
2	0.3781	21.40	0.9931	578.2329	0.374	4.626	993.512
3	0.3681	25.75	0.9933	578.2329	0.374	5.074	1028.747
4	0.3580	34.94	0.9933	578.2329	0.334	5.911	1133.941
5	0.3480	40.18	0.9937	578.2329	0.315	6.339	1147.333
6	0.3380	44.18	0.9933	578.2329	0.297	6.647	1133.875
7	0.3179	58.76	0.9931	578.2329	0.263	7.666	1157.765

Sample No. 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec,)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w (c.m.^{2}/gm.)
1	0.4089	65.74	1	582.6894	0.442	8.108	2088.205
2	0.3892	85.70	1	582.6894	0.398	9.257	2146.798
3	0.3794	105.02	1	582.6894	0.377	10.248	2251.218
4	0.3695	125.15	1	582.6894	0.356	11.187	2320.602

Sample No. 5

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x (6)x(7)
Test No	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w (c.m.^{2}/gm.)
1	0.4252	44.54	1	578.233	0.482	6.674	1860.099
2	0.4060	74.40	1	578.233	0.436	8.626	2174.697
3	0.3868	86.12	1	578.233	0.392	9.280	2103.473
4	0.3773	106.40	1	578.233	0.372	10.315	2218.784
5	0.3677	115.32	1	578.233	0.353	10.739	2192.004

Sample No. 1

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w (c.m.^{2}/Sec.)
1	0.3982	5.20	1	568.024	0.418	2.280	541.350
2	0.3781	6.66	1	568.024	0.374	2.581	548.310
3	0.3581	8.50	1	568.024	0.334	2.915	553.033

Computating the Result

Sample No. 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(4)x(5)x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)\, S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)\ \sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w (c.m.^{2}/gm.)
1	0.3965	10.3	1	569.736	0.4137	3.2094	756.455
2	0.3887	13.8	1	569.736	0.3964	3.7148	838.9629
3	0.3816	15.1	1	569.736	0.3812	3.8859	843.9528

Result from Testing Ø2.0 c.m. Glass Tube

Sample No. 2

Test No.	1	2
Moist Wt. (g.m.)	5.04	5.15
$\frac{Ww \times 100}{W\ moist}$	0.85	0.85
Dry Wt. (gm.)	4.99716	5.106225
Volume (c.m.^{3})	2.911	2.911
Porosity E	0.3435	0.3292
Temperature T (^{o}c)	29.0	29.0
Time t (Sec.)	530.13	608.32

Sample No. 3

Test No.	1	2
Moist Wt. (gm.)	4.70	4.80
$\frac{Ww \times 100}{W\ moist}$	1.32	1.32
Dry Wt. (gm.)	4.63796	4.73664
Volume (c.m.^{3})	2.911	2.911
Porosity E	0.3860	0.3730
Temperature T(^{o}c)	30.3	30.5
Time t (Sec.)	996.13	1156.0

Result from Testing Ø2.0 c.m. Glass Tube (Continued)

Sample No. 5

Test No.	1	2
Moist Wt. (gm.)	4.80	4.90
Wwx100 / W moist	1.17	1.17
Dry Wt. (gm.)	4.74384	4.84267
Volume (c.m.^{3})	2.8809	2.911
Porosity E	0.3775	0.3711
Temperature T(^{o}c)	30.3	28.9
Time t (Sec.)	996.24	1106.2

Sample No. 1

Test No.	1	2	3	4	5
Moist Wt. (gm.)	4.70	4.80	4.90	5.00	5.10
Ww x100 / W moist	0.14	0.14	0.14	0.14	0.14
Dry Wt. (gm.)	4.69342	4.79328	4.89314	4.993	5.09286
Volume (c.m.^{3})	2.8299	2.8728	2.8728	2.8787	2.8839
Porosity E	0.3770	0.3732	0.3602	0.3484	0.3366
Temperature T(^{o}c)	30.4	30.4	30.4	30.4	30.9
Time t (Sec.)	76.80	86.02	98.02	115.20	135.60

Result from Testing ø2.0 c.m. Glass Tube (Continued)

Sample No. 4 Light Grey Very Fine Sand

Test No.	1	2	3	4
Moist Wt. (gm.)	4.70	4.80	4.90	5.0
$\frac{Ww}{W \text{ moist}}$ x100	1.63	1.63	1.63	1.63
Dry Wt. (gm.)	4.62339	4.72176	4.82013	4.9185
Volume (c.m.^{3})	2.9512	2.9593	2.9519	2.9623
Porosity E	0.4097	0.3988	0.3847	0.3744
Temperature T(°c)	31.0	31.0	31.0	31.0
Time t (Sec.)	78.48	95.18	127.30	161.18

Sample No. 7 Very Fine Sand Passing No. 80 Sieve - No. 400 Sieve

Test No.	1	2	3	4	5	6
Moist Wt. (gm.)	4.50	4.70	4.80	4.90	5.0	5.10
$\frac{Ww}{W \text{ moist}}$ x100	1.63	1.63	1.63	1.63	1.63	1.63
Dry Wt. (gm.)	4.42665	4.62339	4.72176	4.82013	4.9185	5.01687
Volume (c.m.^{3})	2.911	2.911	2.911	2.911	2.911	2.911
Porosity E	0.4270	0.4016	0.3888	0.3761	0.3634	0.3506
Temperature (°c)	28.9	28.9	27.0	26.0	26.2	26.5
Time t (Sec.)	29.3	36.6	50.23	55.82	58.74	64.86

Computating the Result

Sample No. 2

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w cm.^{2}/gm.
1	0.3435	530.13	1	180.4189	0.307	23.025	1275.323
2	0.3292	608.32	1	180.4189	0.282	24.664	1254.858

Sample No. 3

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.3860	996.13	1	181.8094	0.391	31.562	2243.663
2	03730	1156.0	1	181.8094	0.363	34.0	2243.892

Sample No. 5

(1)m	(2)	(3)	(4)	(5)	(6)m	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.3775	996.24	1	178.3725	0.373	31.563	2099.979
2	0.3711	1106.20	1	178.3725	0.359	33.260	2129.828

Computating the Result (Continued)

Sample No. 1

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.3770	76.80	1	177.2334	0.372	8.764	577.818
2	0.3732	86.02	1	177.2334	0.364	9.275	598.358
3	0.3602	98.02	1	177.2334	0.338	9.901	593.118
4	0.3484	115.20	1	177.2334	0.316	10.733	601.110
5	0.3366	135.60	1	177.2334	0.294	11.645	606.782

Sample No. 4

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5) x(6)x(7)
Test No.	Porosity	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.4097	78.48	1	177.768	0.4442	8.859	699.547
2	0.3988	95.18	1	177.768	0.4189	9.756	726.500
3	0.3847	127.30	1	177.768	0.3878	11.283	777.832
4	0.3744	161.18	1	177.768	0.3662	12.696	826.492

Computating the Result (Continued)

Sample No. 7

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)= (4)x(5)x(6) x(7)
Test No.	Porosity E	Time t (Sec.)	$\sqrt{\frac{\eta_s}{\eta}}$	$K=\frac{\rho_s(1-E_s)S_s}{\rho\sqrt{E_s^3}\sqrt{t_s}}$	$f(E)=\sqrt{\frac{E^3}{(1-E)^2}}$	$\sqrt{t}$	Specific Surface S_w c.m.^{2}/gm.
1	0.4270	29.3	1	177.768	0.4869	5.413	468.523
2	0.4016	36.6	1	177.768	0.4253	6.050	457.409
3	0.3888	50.23	1	177.768	0.3966	7.087	499.653
4	0.3761	55.82	1	177.768	0.3697	7.471	491.000
5	0.3634	58.74	1	177.768	0.3441	7.664	468.807
6	0.3506	64.86	1	177.768	0.3197	8.054	457.728

No. 2 (Reddish Brown Silty Sand)

$G = 2.615$; $W_t = 100$ gm. ; $r_w = 10^{-3}$ gm./m.m.^{3}

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Particle Average Dia. in m.m. (d)	Percent by Weight (%)	Volume of one particle in m.m.^{3} $\pi/6 \times d^3$	Wt. of Solid (W_s) in gm. (2) x W_t	Volume of Solid in m.m.^{3} (4)/ Grw	Number of Soil Particle of Each Dia. (5)/(3)	Surface Area of One Particle in m.m.^{2} (πd^2)	Total Area of Soil in m.m.^{2} (6) x (7)
0.070	10	1.796×10^{-4}	10	3.8241×10^{3}	2.129×10^{7}	0.01540	3278.66×10^{2}
0.066	10	1.505×10^{-4}	10	3.8241×10^{3}	2.541×10^{7}	0.01369	3478.63×10^{2}
0.061	10	1.188×10^{-4}	10	3.8241×10^{3}	3.219×10^{7}	0.01169	3763.01×10^{2}
0.056	10	0.919×10^{-4}	10	3.8241×10^{3}	4.161×10^{7}	0.00986	4102.75×10^{2}
0.050	10	0.654×10^{-4}	10	3.8241×10^{3}	5.847×10^{7}	0.00786	4595.74×10^{2}
0.042	10	0.388×10^{-4}	10	3.8241×10^{3}	9.856×10^{7}	0.00554	5460.22×10^{2}
0.034	10	0.205×10^{-4}	10	3.8241×10^{3}	18.654×10^{7}	0.00363	6771.40×10^{2}
0.025	10	0.081×10^{-4}	10	3.8241×10^{3}	47.211×10^{7}	0.00196	9253.35×10^{2}
0.015	10	0.017×10^{-4}	10	3.8241×10^{3}	224.947×10^{7}	0.00071	$15,971.23 \times 10^{2}$
0.0075	5	0.0022×10^{-4}	5	1.912×10^{3}	869.091×10^{7}	0.00018	$15,643.63 \times 10^{2}$
0.0025	5	0.000082×10^{-4}	5	1.912×10^{3}	23317.073×10^{7}	0.00002	$46,634.14 \times 10^{2}$
			$\Sigma(4) = 100$			$\Sigma(8) =$	$118,952.76 \times 10^{2}$

Specific Surface of Soil $= \dfrac{\Sigma(8)}{\Sigma(4)} = 118,952.76$ m.m.^{2}/gm.

or = 1189.53 c.m.^{2}/gm.

Average Dia $= \dfrac{6}{S_v} = 0.0193$ m.m.

$= 19.3\ \mu$

No. 3 Light Grey Silty Sand $G = 2.595$

$r_w = 10^{-3}$ gm./m.m.^{3} ; Av. Dia. $= 6/S_v$ = 0.00964 m.m.

or = 9.64 μ.

(1) Particle Av. Dia. in m.m. (d)	(2) Percent by Wt. %	(3) Volume of One Particle in m.m.^{3} $\pi/6 \times d^3$	(4) Wt. of Solid in gm. (2)x W_t	(5) Volume of Solid in m.m.^{3} (4)/Gr_w	(6) Number of Soil Particle of Each Dia. (5)/(3)	(7) Surface Area of One Particle in m.m.^{2} (πd^2)	(8) Total Area Of Soil in m.m.^{2} (6)x(7)
0.0695	10	1.7584×10^{-4}	1	0.38536×10^{3}	0.2192×10^{7}	0.01518	33.27456×10^{3}
0.061	10	1.1889×10^{-4}	1	0.38536×10^{3}	0.3241×10^{7}	0.01169	37.88729×10^{3}
0.054	10	0.8248×10^{-4}	1	0.38536×10^{3}	0.4672×10^{7}	0.009165	42.81888×10^{3}
0.045	10	0.4773×10^{-4}	1	0.38536×10^{3}	0.8074×10^{7}	0.006364	51.38294×10^{3}
0.035	10	0.2246×10^{-4}	1	0.38536×10^{3}	1.7158×10^{7}	0.003850	66.0583×10^{3}
0.027	10	0.1031×10^{-4}	1	0.38536×10^{3}	3.7377×10^{7}	0.002291	85.6307×10^{3}
0.019	10	0.0359×10^{-4}	1	0.38536×10^{3}	10.7343×10^{7}	0.001135	121.8343×10^{3}
0.013	5	0.0115×10^{-4}	0.5	0.19268×10^{3}	16.7548×10^{7}	0.000531	88.9680×10^{3}
0.0095	5	0.0045×10^{-4}	0.5	0.19268×10^{3}	42.8178×10^{7}	0.000284	121.60255×10^{3}
0.0065	5	0.0014×10^{-4}	0.5	0.19268×10^{3}	137.6286×10^{7}	0.000133	183.04603×10^{3}
0.0041	5	0.000361×10^{-4}	0.5	0.19268×10^{3}	533.7396×10^{7}	0.0000528	281.8145×10^{3}
0.0025	5	0.0000829×10^{-4}	0.5	0.19268×10^{3}	2349.756×10^{7}	0.0000196	460.5521×10^{3}
			W_t=10 gm.			$\Sigma(8)$ =	2397.9178×10^{3}

$$\text{Specific Surface of Soil} = (8)/\Sigma(4) = \frac{2397.9178 \times 10^3}{10}$$

$$= 2397.9178\times10^2 \ \frac{\text{m.m.}^2}{\text{gm.}}$$

$$\text{or} = 2397.9178 \ \frac{\text{c.m.}^2}{\text{gm.}}$$

No. 5 (Light Reddish Brown Silty Sand) $G = 2.645$

$r_w = 10^{-3}$ gm./mm.^{3} ; Av. Dia. $= 6/S_v$ = 0.010198 mm.

or = 10.198 μ.

(1) Particle Av. Dia. in m.m. (d)	(2) Percent by Wt. %	(3) Volume of One Particle in m.m.^{3} $\pi/6 \times d^3$	(4) Wt. of Solid in gm. (2)xW_t	(5) Volume of Solid in m.m.^{3} (4)/Gr_w	(6) Nos. of Soil Particle of Each Dia. (5)/(3)	(7) Surface Area of One Particle in m.m.^{2} (πd^2)	(8) Total Area of Soil in m.m.^{2} (6)x (7)
0.0695	10	1.7584×10^{-4}	1	0.37807×10^{3}	0.2150×10^{7}	0.015181	32.639×10^{3}
0.0625	10	1.2788×10^{-4}	1	0.37807×10^{3}	0.29564×10^{7}	0.01227	36.296×10^{3}
0.0575	10	0.9958×10^{-4}	1	0.37807×10^{3}	0.37966×10^{7}	0.010391	39.4505×10^{3}
0.0525	10	0.7580×10^{-4}	1	0.37807×10^{3}	0.49877×10^{7}	0.008662	43.20346×10^{3}
0.0465	10	0.5267×10^{-4}	1	0.37807×10^{3}	0.71781×10^{7}	0.006796	48.78237×10^{3}
0.0395	10	0.3228×10^{-4}	1	0.37807×10^{3}	1.17122×10^{7}	0.004904	57.43663×10^{3}
0.0315	10	0.1637×10^{-4}	1	0.37807×10^{3}	2.3095×10^{7}	0.003118	72.01021×10^{3}
0.0215	10	0.0521×10^{-4}	1	0.37807×10^{3}	7.25662×10^{7}	0.001453	105.4387×10^{3}
0.0130	5	0.0115×10^{-4}	0.5	0.189035×10^{3}	16.4378×10^{7}	0.0005311	87.30116×10^{3}
0.0075	5	0.00221×10^{-4}	0.5	0.189035×10^{3}	$85,5362 \times 10^{7}$	0.0001767	151.14246×10^{3}
0.00325	5	0.000180×10^{-4}	0.5	0.189035×10^{3}	1050.1944×10^{7}	0.0000331	347.61434×10^{3}
0.00095	5	0.0000044×10^{-4}	0.5	0.189035×10^{3}	$42,962.500 \times 10^{7}$	0.0000028	1202.9500×10^{3}
			W_t=10 gm.			Σ(8) =	2224.2645×10^{3}

$$\text{Specific Surface} = \frac{2224.2645 \times 10^{3}}{10} = 2224.2645 \times 10^{2} \ \frac{\text{m.m.}^2}{\text{gm.}}$$

$$\text{or} = 2224.2645 \ \frac{\text{cm.}^2}{\text{gm.}}$$

No. 4 Light Grey Very Fine Sand **Passing No. 80**

$G = 2.654$; (Spherical Assumption)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Average Particle Dia. (mm.)	Percent by Wt. %	Volume of One Particle in $m.m.^3$ $\pi/6 \times d^3$	Wt. of Solid in gm. $(2) \times W_t$	Volume of Solid in $m.m.^3$ $(4)/G\gamma_w$	Nos. of Soil Particle of Each Dia. (5)/(3)	Surface Area of One Particle in $m.m.^2$ (πd^2)	Total Area of Soil in $m.m.^2$ (6) x (7)
0.1685	10	25.0595×10^{-4}	1	0.3767897×10^3	0.0150358×10^7	0.0892327	13.417×10^3
0.1525	10	18.5773×10^{-4}	1	0.3767897×10^3	0.0202822×10^7	0.073091	14.824×10^3
0.1400	10	14.3733×10^{-4}	1	0.3767897×10^3	0.0262145×10^7	0.0615999	16.148×10^3
0.1250	10	10.2307×10^{-4}	1	0.3767897×10^3	0.0368293×10^7	0.0491071	18.086×10^3
0.1075	10	6.5073×10^{-4}	1	0.3767897×10^3	0.0579026×10^7	0.0363196	21.030×10^3
0.0950	10	4.4910×10^{-4}	1	0.3767897×10^3	0.0838988×10^7	0.0283642	23.797×10^3
0.0750	10	2.2098×10^{-4}	1	0.3767897×10^3	0.1705085×10^7	0.0176785	30.143×10^3
0.0535	10	0.8021×10^{-4}	1	0.3767897×10^3	0.469754×10^7	0.0089956	42.257×10^3
0.0360	5	0.2444×10^{-4}	0.5	0.1883948×10^3	0.7708461×10^7	0.0040731	31.397×10^3
0.0240	5	0.0724×10^{-4}	0.5	0.1883948×10^3	2.6021381×10^7	0.0018102	47.104×10^3
0.0125	5	0.0102×10^{-4}	0.5	0.1883948×10^3	18.470078×10^7	0.0004910	90.688×10^3
0.0035	5	0.0002245×10^{-4}	0.5	0.1883948×10^3	839.17505×10^7	0.0000384	322.243×10^3
	$\Sigma(2) = 100$		$W_t = 10$gm.			$\Sigma(8) =$	671.134×10^3

$$\text{Specific Surface} = \frac{\Sigma(8)}{W_t} = 671.134 \times 10^2 \ \frac{m.m.^2}{gm.} \quad \text{or} \quad 671.134 \ \frac{c.m.^2}{gm.}$$

$$\text{Av.Dia.} = \frac{6}{S_v} = 33.7 \ \mu$$

No. 4. Light Grey Very Fine Sand Passing No. 80 Sieve

$G = 2.654$ (Cubical Assumption)

(1) Equivalent Cubical Side S (m.m.)	(2) Percent by Wt. %	(3) Volume of One Particle S^3 (m.m.^{3})	(4) Wt. of Solid in gm. W_s (2)xW_t	(5) Volume of Solid in m.m.^{3} (4)/Gr_w	(6) Nos. of Soil Particle of Each Cube. (5)/(3)	(7) Surface Area of One Particle in m.m.^{3} ($6S^2$)	(8) Total Area of Soil in m.m.^{2} (6)x(7)
0.1358	10	$25.0437x10^{-4}$	1	$0.3767897x10^{3}$	$0.0150452x10^{7}$	0.1106496	$16.647x10^{3}$
0.1229	10	$18.5633x10^{-4}$	1	$0.3767897x10^{3}$	$0.0202975x10^{7}$	0.0906264	$18.395x10^{3}$
0.1129	10	$14.3907x10^{-4}$	1	$0.3767897x10^{3}$	$0.0261828x10^{7}$	0.0764784	$20.024x10^{3}$
0.1008	10	$10.2419x10^{-4}$	1	$0.3767897x10^{3}$	$0.036789x10^{7}$	0.0609636	$22.428x10^{3}$
0.0867	10	$6.5171x10^{-4}$	1	$0.3767897x10^{3}$	$0.0578155x10^{7}$	0.0451008	$26.075x10^{3}$
0.0766	10	$4.4946x10^{-4}$	1	$0.3767897x10^{3}$	$0.0838316x10^{7}$	0.0352053	$29.513x10^{3}$
0.0605	10	$2.2145x10^{-4}$	1	$0.3767897x10^{3}$	$0.1701466x10^{7}$	0.0219615	$37.367x10^{3}$
0.0431	10	$0.8006x10^{-4}$	1	$0.3767897x10^{3}$	$0.4706341x10^{7}$	0.0111456	$52.455x10^{3}$
0.0290	5	$0.2439x10^{-4}$	0.5	$0.1883948x10^{3}$	$0.7724264x10^{7}$	0.005046	$38.977x10^{3}$
0.0193	5	$0.0719x10^{-4}$	0.5	$0.1883948x10^{3}$	$2.6202336x10^{7}$	0.0022349	$58.560x10^{3}$
0.0101	5	$0.0103x10^{-4}$	0.5	$0.1883948x10^{3}$	$18.290757x10^{7}$	0.000612	$111.939x10^{3}$
0.0028	5	$0.0002195x10^{-4}$	0.5	$0.1883948x10^{3}$	$858.29066x10^{7}$	0.0000470	$403.397x10^{3}$
			W_t=10 gm.			$\sum$(8) =	$835.777x10^{3}$

$$\text{Specific Surface} = \frac{(8)}{W_t} = 835.777x10^{2}\ \frac{\text{m.m.}^2}{\text{gm.}} \quad \text{or} \quad 835.777\ \frac{\text{cm.}^2}{\text{gm.}}$$

No. 1 Reddish Brown Very Fine Sand (Spherical Assumption)

Passing No. 80 Sieve (G = 2.662)

(1) Average Particle Dia. (mm.)	(2) Percent by Wt. %	(3) Volume of One Particle in m.m.^{3} $\pi/6 \times d^3$	(4) Wt. of Solid in gm. (2)x W_t	(5) Volume of Solid in m.m.^{3} (4)/$G\gamma_w$	(6) Nos. of Soil Particle of Each Dia. (5)/(3)	(7) Surface Area of One Particle in m.m.^{2} (πd^2)	(8) Total Area of Soil in m.m.^{2} (6) x (7)
0.155	10	19.50×10^{-4}	1	0.375657×10^3	0.01926×10^7	0.07551	14.543×10^3
0.141	10	14.684×10^{-4}	1	0.375657×10^3	0.2558×10^7	0.06248	15.982×10^3
0.128	10	10.985×10^{-4}	1	0.375657×10^3	0.03420×10^7	0.051493	17.611×10^3
0.110	10	6.972×10^{-4}	1	0.375657×10^3	0.05388×10^7	0.038029	20.490×10^3
0.0875	10	3.509×10^{-4}	1	0.375657×10^3	0.10706×10^7	0.024062	25.761×10^3
0.075	10	2.210×10^{-4}	1	0.375657×10^3	0.16998×10^7	0.0176785	30.050×10^3
0.0625	10	1.279×10^{-4}	1	0.375657×10^3	0.29371×10^7	0.0122767	36.058×10^3
0.0475	10	0.561×10^{-4}	1	0.375657×10^3	0.669620×10^7	0.007091	47.483×10^3
0.0355	5	0.234×10^{-4}	0.5	0.187829×10^3	0.802688×10^7	0.0039607	31.792×10^3
0.0280	5	0.115×10^{-4}	0.5	0.187829×10^3	1.63330×10^7	0.0024639	40.249×10^3
0.0215	5	0.052×10^{-4}	0.5	0.187829×10^3	3.612096×10^7	0.0014527	52.473×10^3
0.009	5	0.00382×10^{-4}	0.5	0.187829×10^3	49.169895×10^7	0.0002545	125.137×10^3
			W_t = 10gm.			$\Sigma(8)$ =	457.629×10^3

Specific Surface = $\frac{\Sigma(8)}{W_t}$ = 457.629×10^2 $\frac{\text{m.m.}^2}{\text{gm.}}$ or 457.629 $\frac{\text{c.m.}^2}{\text{gm.}}$

Av. Dia. = $\frac{6}{S_v}$ = 49.3 u.

No. 1 Reddish Brown Very Fine Sand **Passing No. 80 Sieve**

$G = 2.662$; (Cubical Assumption)

(1) Equivalent Cubical Side S (m.m.)	(2) Percent by Wt. %	(3) Volume of One Particle S^3 (m.m.^{3})	(4) Wt. of Solid in gm. (W_s) (2)xW_t	(5) Volume of Solid in m.m.^{3} (4)/Gr_w	(6) Nos. of Soil Particle of Each Cube. $\frac{(5)}{(3)}$	(7) Surface Area of One Particle $6S^2$ (m.m.^{2})	(8) Total Surface Area of Soil in m.m.^{2} (6) x (7)
0.1250	10	19.531×10^{-4}	1	0.375657×10^{3}	0.019234×10^{7}	0.09375	18.032×10^{3}
0.1137	10	14.699×10^{-4}	1	0.375657×10^{3}	0.025557×10^{7}	0.07757	$19,825 \times 10^{3}$
0.1032	10	10.991×10^{-4}	1	0.375657×10^{3}	$0,034179 \times 10^{7}$	0.06390	21.840×10^{3}
0,08867	10	6.972×10^{-4}	1	0.375657×10^{3}	0.053881×10^{7}	0.04717	25.416×10^{3}
0.07053	10	3.509×10^{-4}	1	0.375657×10^{3}	0.107055×10^{7}	0.02985	31.956×10^{3}
0.06046	10	2.210×10^{-4}	1	0.375657×10^{3}	0.16998×10^{7}	0.02193	37.277×10^{3}
0.05038	10	1.279×10^{-4}	1	0.375657×10^{3}	0.29371×10^{7}	0.01523	44.732×10^{3}
0.03829	10	0.561×10^{-4}	1	0.375657×10^{3}	0.669620×10^{7}	0.00880	58.927×10^{3}
0.02862	5	0.234×10^{-4}	0.5	0.187829×10^{3}	0.802688×10^{7}	0.00492	39.492×10^{3}
0.02257	5	0.115×10^{-4}	0.5	0.187829×10^{3}	1.63330×10^{7}	0.00306	49.979×10^{3}
0.01733	5	0.052×10^{-4}	0.5	0.187829×10^{3}	3.612096×10^{7}	0.00180	65.018×10^{3}
0.00726	5	0.0038×10^{-4}	0.5	0.187829×10^{3}	49.169895×10^{7}	0.00032	157.344×10^{3}
			W_t =10gm.			$\Sigma(8)$ =	569.838×10^{3}

Specific Surface = $\frac{\Sigma(8)}{W_t}$ = 569.838×10^{2} $\frac{\text{m.m.}^2}{\text{gm.}}$ or 569.838 $\frac{\text{c.m.}^2}{\text{gm.}}$

No. 7 Very Fine Sand (Passing No. 80 - Retaining No. [illegible] Sieve)

G = 2.654

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(m.m.) Av.Spherical Dia. (d)	(m.m.) Equivalent Cubical Side S=0.8061d	Percent by Wt. %	Volume of One Particle in m.m. $(S)^3$	Wt.of Solid (W_s) in gm. (3) xW_t	Volume of Solid in m.m.^{3} $\frac{(5)}{Grw}$	Nos.of Soil Particle of Each Dia. (6)/(4)	Surface Area of One Particle (m.m.^{2}) 6S^2	Total Area of Soil in m.m.^{2} (7) x (8)
0.163	0.1314	10.68	22.687×10^{-4}	1.068	0.4012021×10^{3}	0.0177×10^{7}	0.1035954	18.336×10^{3}
0.127	0.1024	20.49	10.737×10^{-4}	2.049	0.769722×10^{3}	0.0717×10^{7}	0.0629142	45.109×10^{3}
0.0895	0.0721	28.13	3.748×10^{-4}	2.813	1.0567242×10^{3}	0.2819×10^{7}	0.0311904	87.926×10^{3}
0.0635	0.0512	13.94	1.342×10^{-4}	1.394	0.523664×10^{3}	0.3902×10^{7}	0.0157284	61.372×10^{3}
0.0450	0.0363	26.76	0.478×10^{-4}	2.676	1.0052592×10^{3}	2.1031×10^{7}	0.0079056	166.263×10^{3}
		$\sum(3) = 100$		Wt = 10 gm.			$\sum(9) =$	379.006×10^{3}

$$\text{Specific Surface} = \frac{\sum(9)}{W_t} = 379.006 \times 10^2 \ \frac{\text{m.m.}^2}{\text{gm.}} \quad \text{or} \quad 379.006 \ \frac{\text{c.m.}^2}{\text{gm.}}$$

Note Based on cubical assumption

<u>No.7 Very Fine Sand</u> (Passing No. 80 - Retaining No. 400 Sieve)

$G = 2.654$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Passing Sieve	Av. Dia. (m.m.)	Percent by Wt.	Volume of One Particle in m.m. $\pi/6 \times d^3$	Wt. of Solid (W_s) in gm. (3) x W_t	Volume of Solid in m.m.^{3} (5)/Grw	Nos. of Soil Particle of Each Dia. (6)/(4)	Surface Area of One Particle (πd^2)	Total Area of Soil in m.m.^{2} (7) x (8)
No.80-No.100	0.163	10.68	22.685×10^{-4}	1.068	0.4012021×10^{3}	0.018×10^{7}	0.0835025	15.030×10^{3}
No.100-No.140	0.127	20.49	10.730×10^{-4}	2.049	0.769722×10^{3}	0.072×10^{7}	0.0506911	36.498×10^{3}
No.140-No.200	0.0895	28.13	3.755×10^{-4}	2.813	1.0567242×10^{3}	0.281×10^{7}	0.025175	70.742×10^{3}
No.200-No.270	0.0635	13.94	1.341×10^{-4}	1.394	0.523664×10^{3}	0.391×10^{7}	0.0126727	49.550×10^{3}
No.270-No.400	0.0450	26.76	0.477×10^{-4}	2.676	1.0052592×10^{3}	2.107×10^{7}	0.0063642	134.094×10^{3}
		(3)=100		$W_t = 10.0$			$\Sigma(9) =$	305.914×10^{3}

$$\text{Specific Surface} = \frac{\Sigma(9)}{W_t} = 305.914\times10^{2}\ \frac{\text{m.m.}^2}{\text{gm.}} \text{ or } 305.914\ \frac{\text{c.m.}^2}{\text{gm.}}$$

$$\text{Av. Dia} = \frac{6}{S_v} = 0.0739 \text{ m.m. or } 73.9\ \mu$$

<u>Note</u> Based on Spherical assumption

Table 2

Comparision of Air-Permeability Method and Sedimentation for Determination of Specific Surface of Soils

Testing with Ø0.40 c.m. Glass Tube

Description of Soil Sample		Porosity	Air-Permeability Metho		Calculated Specific Surface (Based on Reference No.18) $\frac{m^2}{gm}$	$\frac{S_{cal.}}{S_a}$	Remark
			Specific Surface $\frac{m^2}{gm}$	Mean Value $\frac{m^2}{gm.}$			
P_e354 (Kaolinite)		0.5821	3.04	3.16*	10-20	3.16-6.33	The mark * showed specific surface value taken from max. density of sample.
		0.5740	3.16				
	Montmorillonite 75%						
No.5992	Kaolinite 20%	0.5049	1.64	1.81*	0.75x800+0.20x10 +0.05x80 = 606	≈335	
	Illite 5%	0.4783	1.81				
No.674	Kaolinite 50%	0.5183	1.58	1.95*	0.50x10+0.50x80 = 45	≈23	
	Illite 50%	0.4995	1.95				

Testing with Ø0.40 c.m. Glass Tube

Description of Soil Sample	Porosity	Air=Permeability $m^2/gm.$		Calculated Specific Surface (Based on Reference No.18)	$\frac{Scal}{S_a}$	Remark
		Specific Surface	Mean			
P_f886 (Kaolinite with some quartz)	0.5909	3.73	3.75	10 - 20	2.67-5.33	The mark** showed the specific Surface value in unit of $\frac{c.m.^2}{gm.}$
	0.5678	3.76				
Reddish Brown Silty sand (Passing No. 200 Sieve)	0.3241	1161	1158**	1190**	1.03	
	0.3181	1154				
Light ~~Reddish~~ Grey Silty Sand (Passing No. 200 Sieve)	0.3887	2250	2332**	2398**	1.03	
	0.3641	2413				
Light Reddish Brown Silty Sand (Passing No. 200 Sieve)	0.3494	2166	2254**	2224**	0.99	
	0.3295	2342				

Comparision of Air-Permeability Method and Sedimentation Method for Determination of Specific Surface of Soils

Testing with Ø0.80 c.m. Glass Tube

Description of Soil Sample	Porosity	Air-Permeability Method		Sedimentation Method Specific Surface $c.m.^2/gm.$		$\frac{S_s}{S_a}$	$\frac{S_c}{S_a}$
		Specific Surface $\frac{c.m.^2}{g.m.}$	Mean Value S_a $\frac{d.m.^2}{gm.}$	Spherical Assumption S_s	Cubical Assumption S_c		
Reddish Brown Silty Sand (Passing No. 200 Sieve)	0.3580 0.3480 0.3380 0.3179	1134 1147 1134 1157	1143	1190	-	1.04	-
Light ~~Reddish~~ Grey Silty Sand (Passing No. 200 Sieve)	0.4089 0.3892 0.3794 0.3695	2088 2147 2251 2321	2321*	2398	-	1.03	-

Testing with Ø0.80 c.m. Glass Tube (Continued)

Description of Soil Sample	Porosity	Air-Permeability Meth.		Specific Surface by Sedimentation Meth. ($\frac{c.m.^2}{gm.}$)		$\frac{S_s}{S_a}$	$\frac{S_c}{S_a}$
		Specific Surface $\frac{c.m.^2}{gm.}$	Mean Value(S_a) $c.m.^2/gm.$	Spherical Assumption (S_s)	Cubical Assumption (S_c)		
Light Reddish Brown	0.4060	2175	2172	2224	-	1.02	-
Silty Sand	0.3868	2103					
(Passing No. 200 Sieve)	0.3773	2219					
	0.3677	2192					
Reddish Brown Very Fine	0.3982	541	547	458	570	0.84	1.04
Sand	0.3781	548					
(Passing No. 80 Sieve)	0.3581	553					
Light Grey Very Fine	0.3965	756	813	671	836	0.83	1.03
Sand	0.3887	839					
(Passing No. 80 Sieve)	0.3816	844					

Comparision of Air-Permeability Method and Sedimentation Method for Determination of Specific Surface of Soils

Testing with Ø2.0 c.m. Glass Tube

Description of Soil Sample	Porosity	Air-Permeability Meth.		Specific Surface by Sedimentation Meth.		$\frac{S_s}{S_a}$	$\frac{S_c}{S_a}$
		Specific Surface $\frac{c.m.^2}{gm.}$	Mean Value S_a c.m.^{2}/gm.	Spherical Assumption S_s	Cubical Assumption S_c		
Reddish Brown Silty Sand	0.3435	1275	1265	1190	-	1.06	-
(Passing NO. 200 Sieve)	0.3292	1255					
Light ~~Reddish~~ Grey	0.3860	2244	2244	2398	-	0.94	-
Silty Sand	0.3730	2244					
(Passing No. 200 Sieve)							
Light Reddish Brown	0.3775	2100	2115	2224	-	0.95	-
Silty Sand	0.3711	2130					
(Passing No. 200 Sieve)							

Testing with Ø2.0 c.m. Glass Tube (Continued)

Description of Soil Sample	Porosity	Air-Permeability Meth.		Specific Surface by Sedimentation Meth.		$\frac{S_s}{S_a}$	$\frac{S_c}{S_a}$
		Specific Surface $\frac{c.m.^2}{gm.}$	Mean Value S_a $\frac{c.m.^2}{gm.}$	Spherical Assumption S_s	Cubical Assumption S_c		
Reddish Brown Very Fine Sand (Passing No. 200 Sieve)	0.3770	578	594	458	570	0.77	0.96
	0.3732	598					
	0.3602	593					
	0.3484	601					
	0.3366	607					
Light Grey Very Fine Sand (Passing No. 80 Sieve - Retaining No. 400 Sieve)	0.4270	468	463	306	379	0.66	0.82
	0.4016	457					
	0.3634	469					
	0.3506	458					

Testing with 02.0 c.m. Glass Tube (Continued)

Description of Soil Sample	Porosity	Air-Permeability Meth.		Specific Surface by Sedimentation Meth.		$\frac{S_s}{S_a}$	$\frac{S_c}{S_a}$
		Specific Surface $\frac{c.m.^2}{gm.}$	Mean Value S_a	Spherical Assumption S_s	Cubical Assumption S_c		
Light Grey Very Fine Sand (Passing No. 80 Sieve)	0.4097	700	* 826	671	836	0.81	1.01
	0.3988	727					
	0.3847	778					
	0.3744	826					

Note * = Specific Surface value from the minimum porosity.

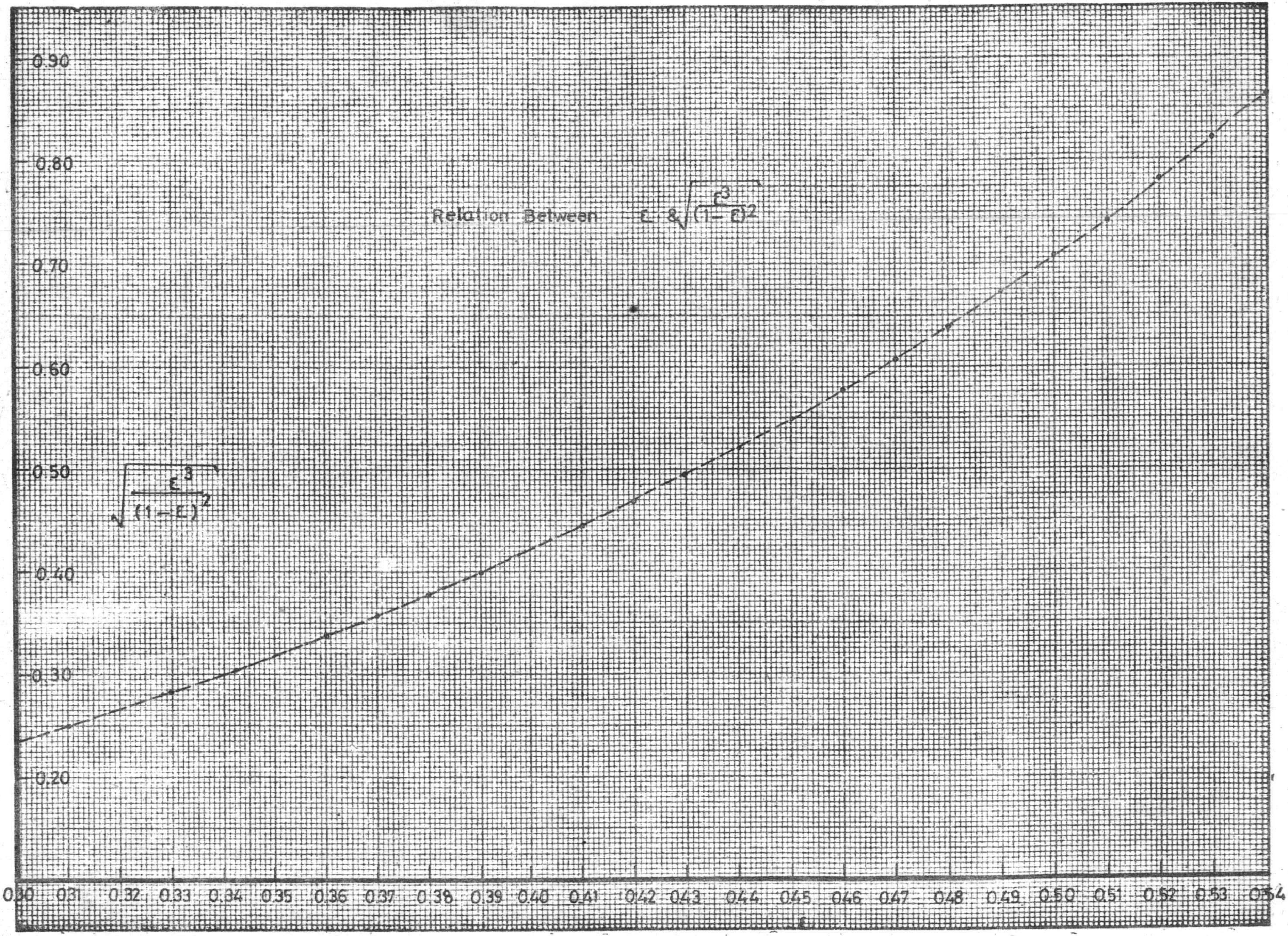
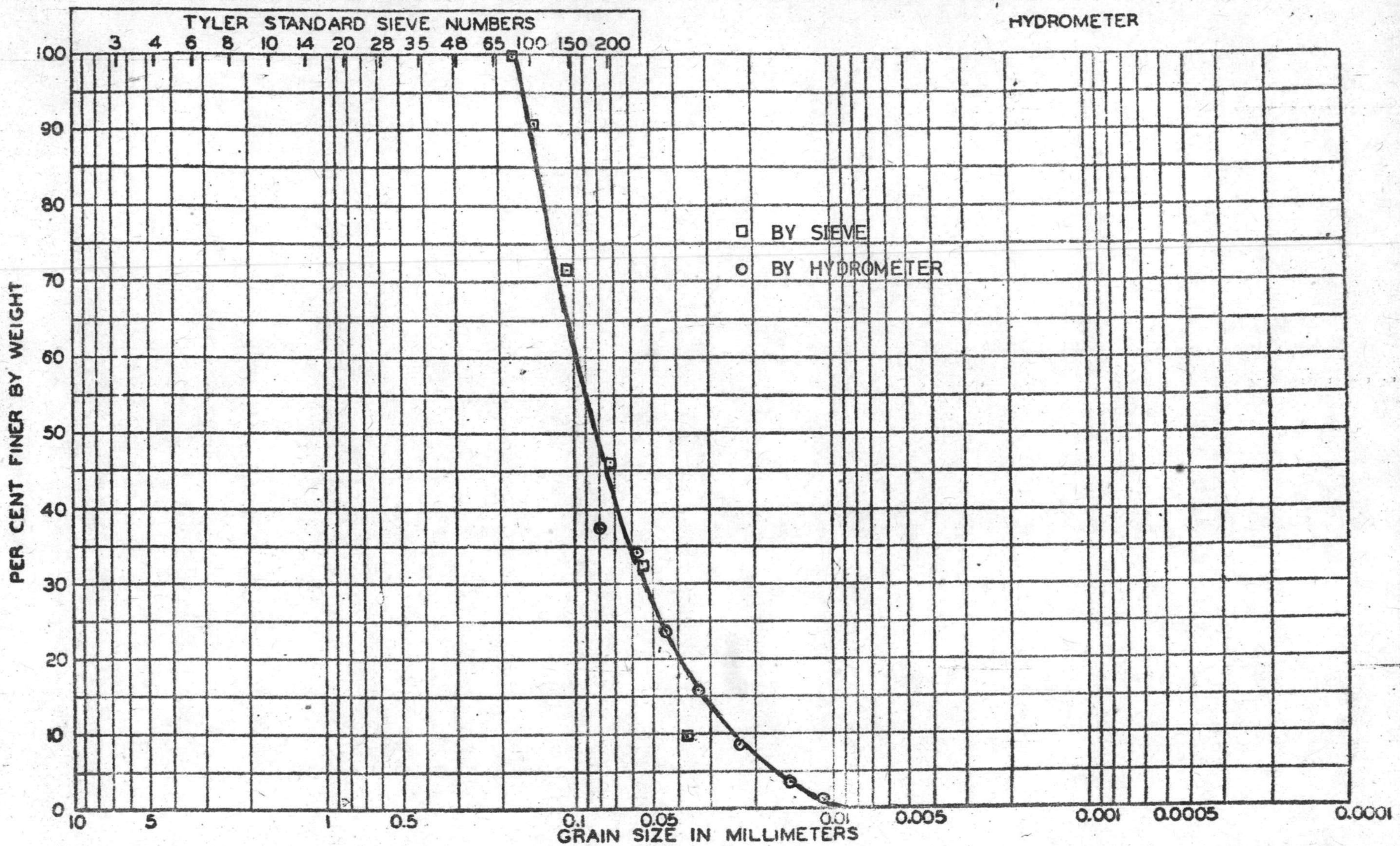

Relation Between ε & $\sqrt{\frac{\varepsilon^3}{(1-\varepsilon)^2}}$
$\sqrt{\frac{\varepsilon^3}{(1-\varepsilon)^2}}$
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.30
0.31
0.32
0.33
0.34
0.35
0.36
0.37
0.38
0.39
0.40
0.41
0.42
0.43
0.44
0.45
0.46
0.47
0.48
0.49
0.50
0.51
0.52
0.53
0.54
ε

FIG. 4



MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

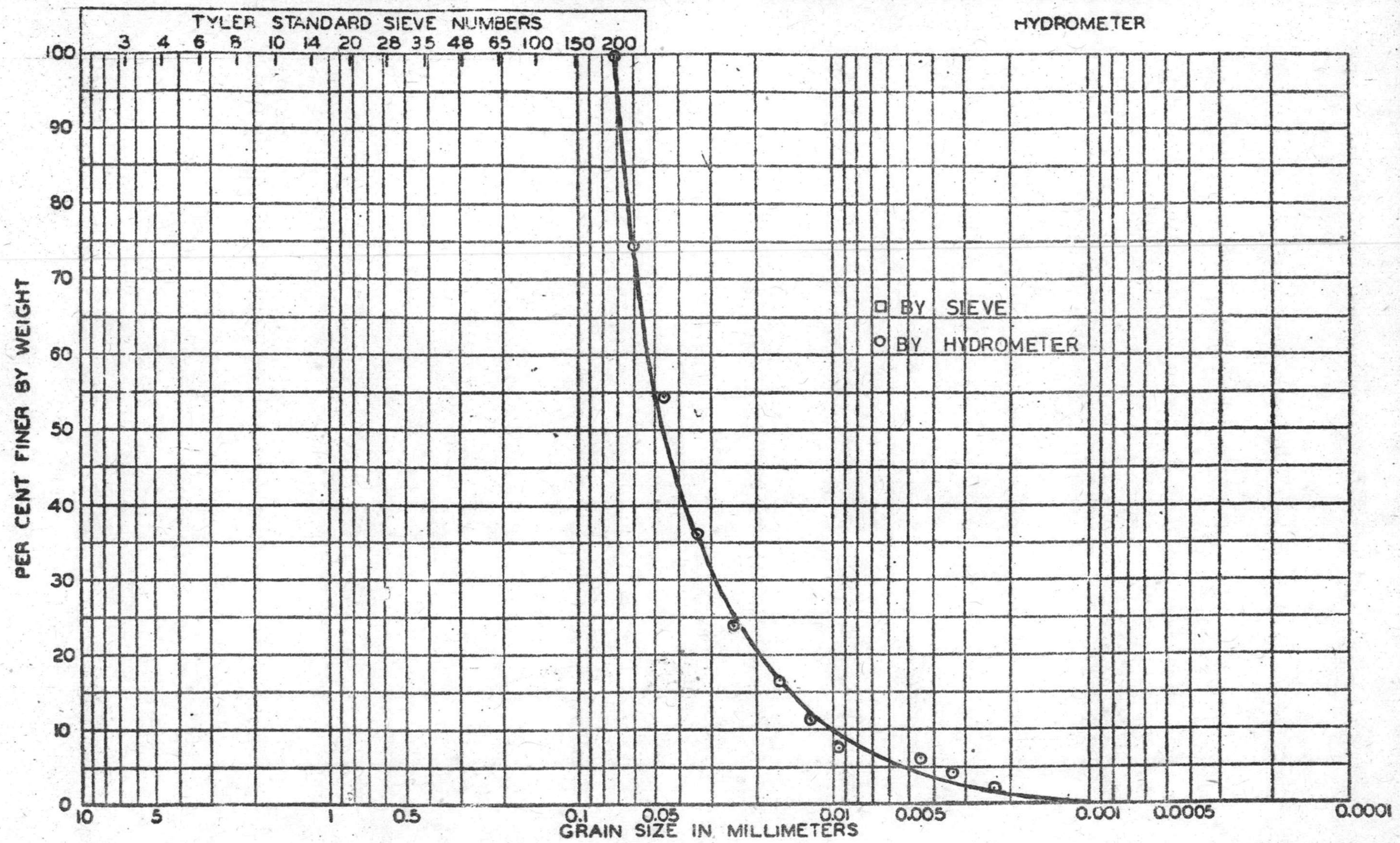
U.S. BUREAU OF SOILS CLASSIFICATION

DESCRIPTION OF SAMPLE Reddish Brown Very Fine Sand Sp. Gr. 2.662 SAMPLE NO. 1

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

SOIL MECHANICS LABORATORY FIG. 5 CHULALONGKORN UNIVERSITY



MEDIUM GRAVEL	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY

U.S. BUREAU OF SOILS CLASSIFICATION

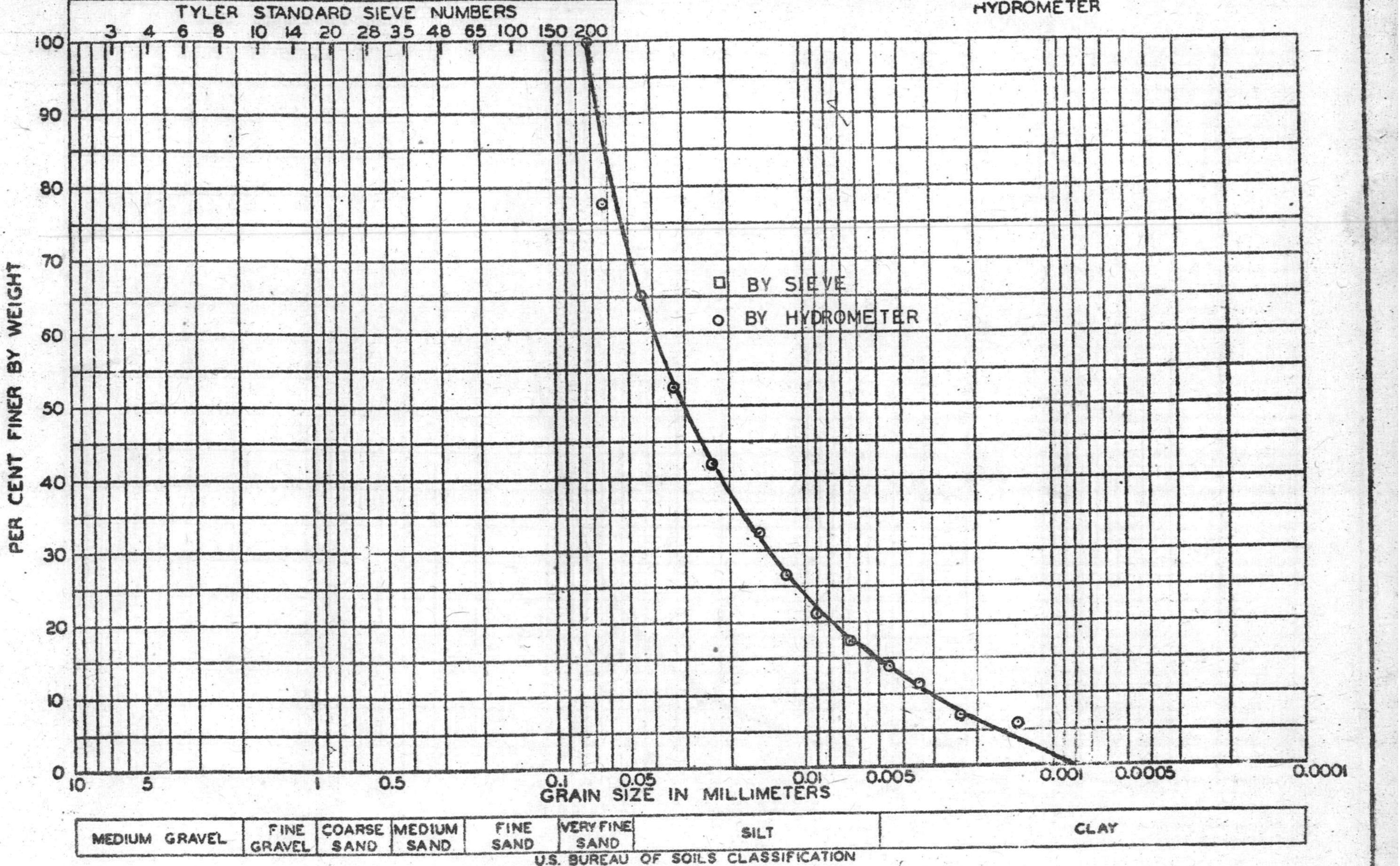
DESCRIPTION OF SAMPLE Reddish Brown Silty Sand Sp.Gr 2.615 SAMPLE NO. 2

DEPTH______ ELEVATION______ REMARKS______

GRAIN SIZE DISTRIBUTION DIAGRAM

FIG. 6

SOIL MECHANICS LABORATORY CHULALONGKORN UNIVERSITY



DESCRIPTION OF SAMPLE Light Grey Silty Sand Sp.Gr. 2.595 SAMPLE NO. 3

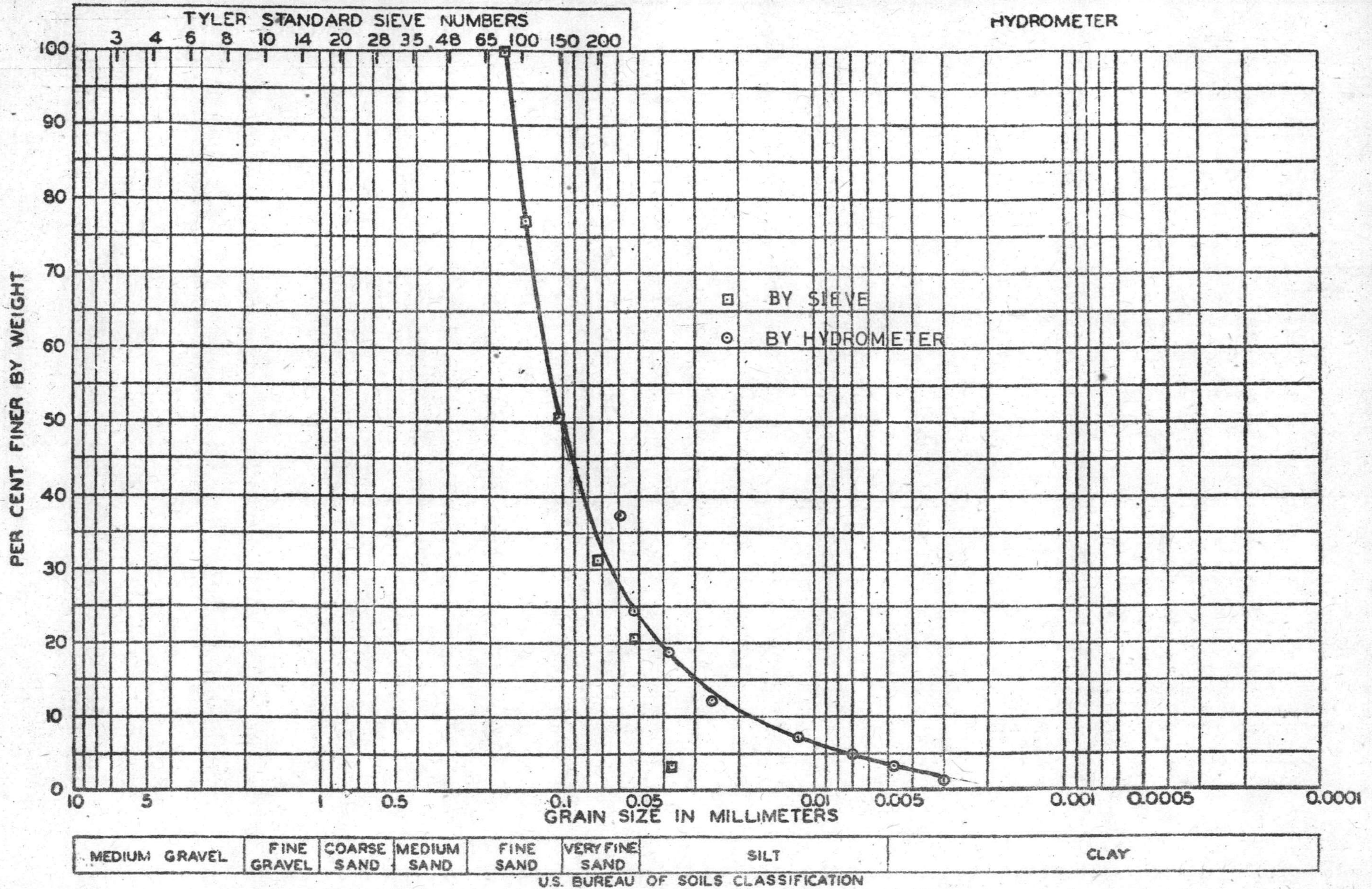
DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

FIG. 7

SOIL MECHANICS LABORATORY

CHULALONGKORN UNIVERSITY

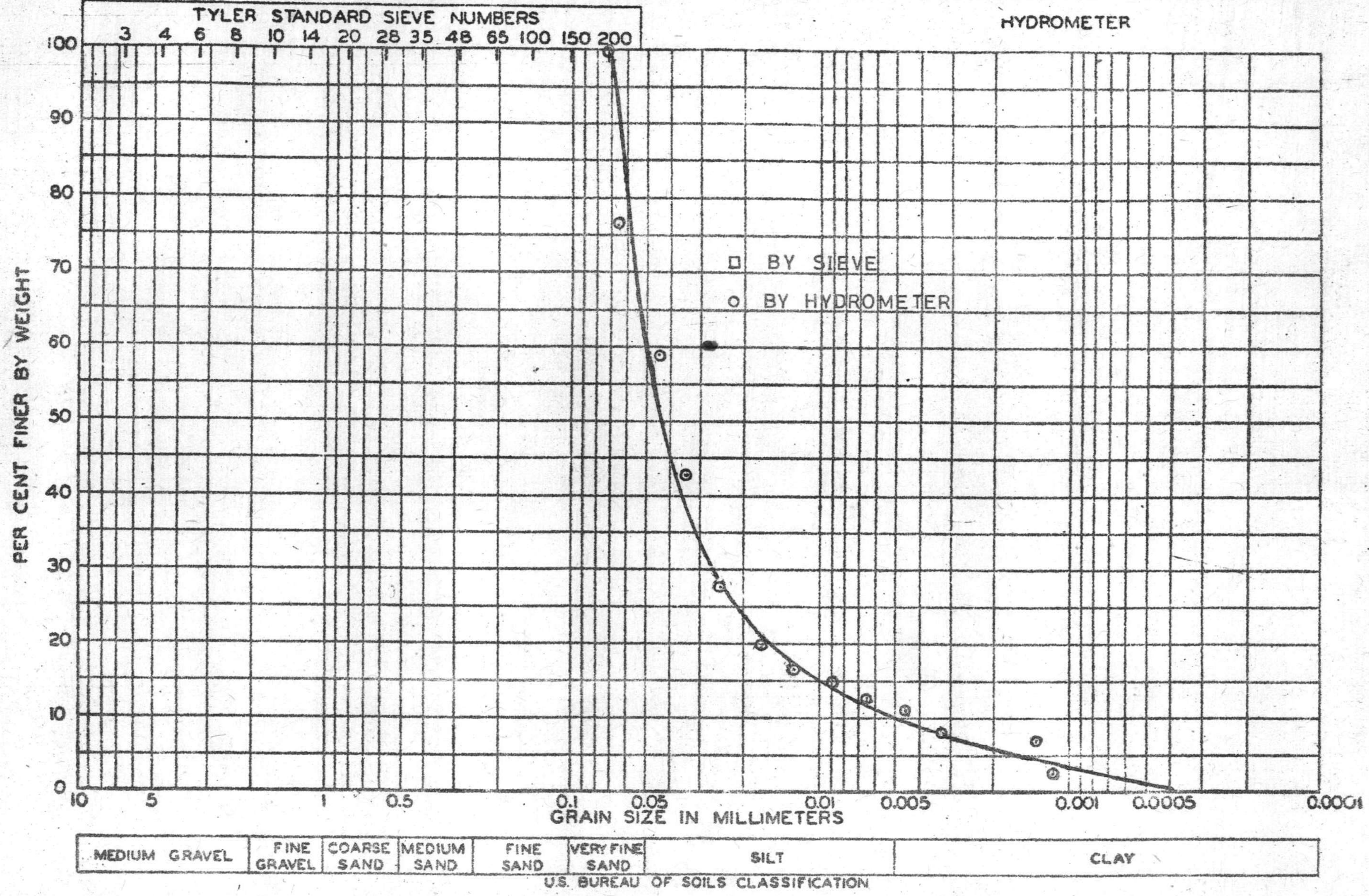


DESCRIPTION OF SAMPLE Light Grey Very Fine Sand Sp.Gr. 2.654 SAMPLE NO. 4

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

SOIL MECHANICS LABORATORY FIG. 8 CHULALONGKORN UNIVERSITY



DESCRIPTION OF SAMPLE Light Reddish Brown Silty Sand Sp. Gr. 2.645 SAMPLE NO. 5

DEPTH ______ ELEVATION ______ REMARKS ______

GRAIN SIZE DISTRIBUTION DIAGRAM

SOIL MECHANICS LABORATORY

FIG. 9

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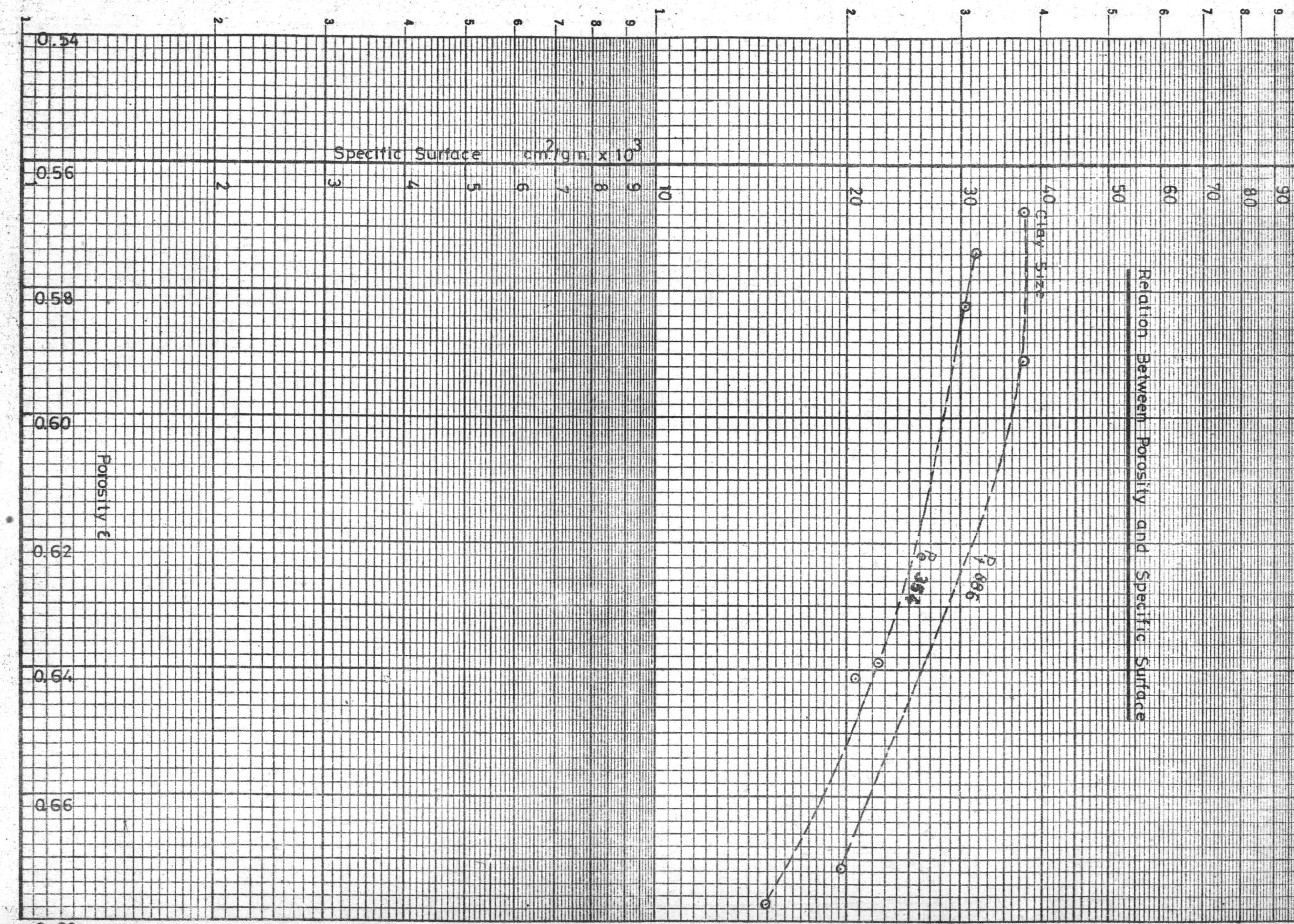

SEMI-LOGARITHMIC
2 CYCLES X 70 DIVISIONS
Relation Between Porosity and Specific Surface
Specific Surface cm²/gm. x 10³
Porosity ε
0.54
0.56
0.58
0.60
0.62
0.64
0.66
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
Clay Size
P7 886
P6 354

FIG.10

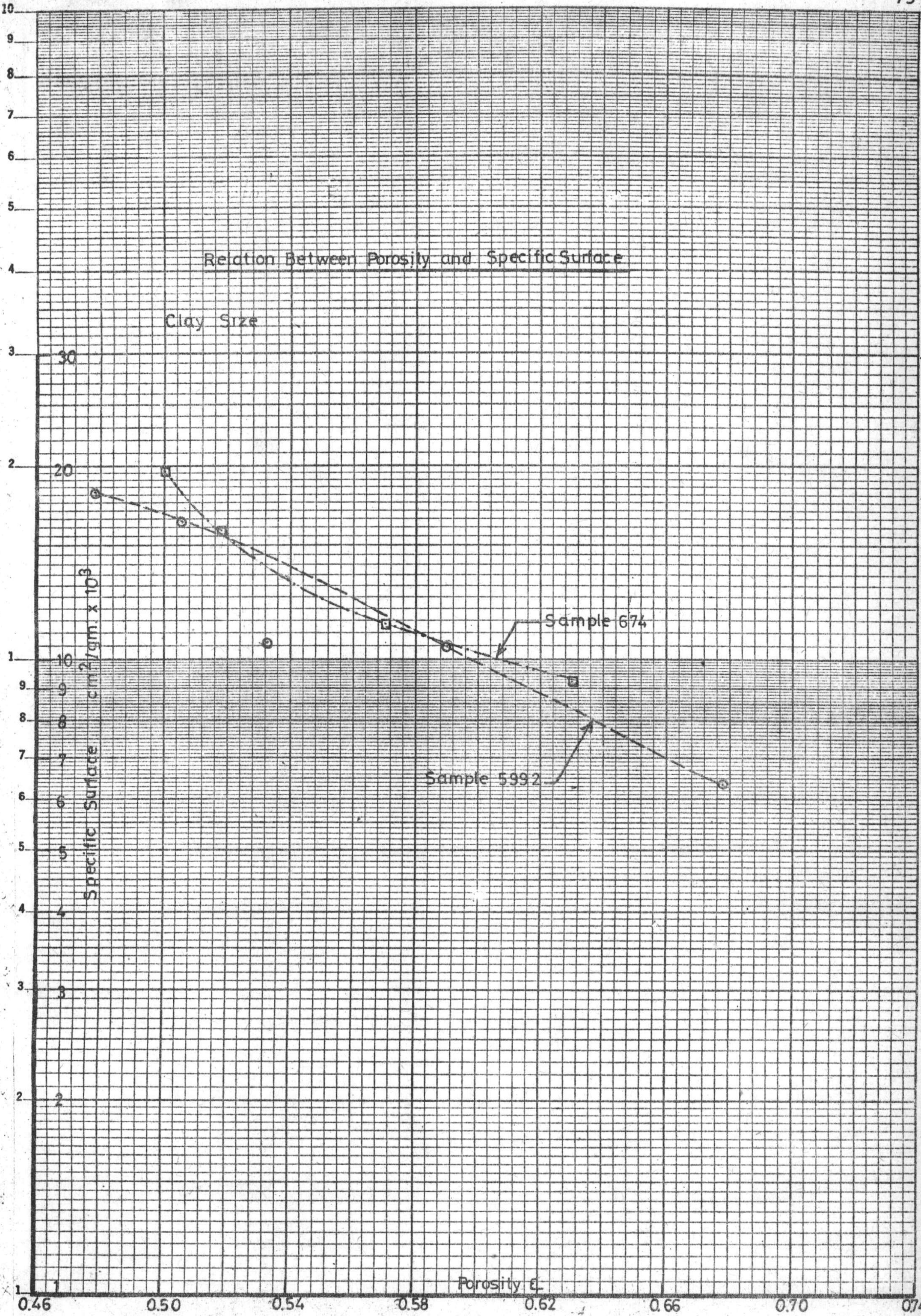
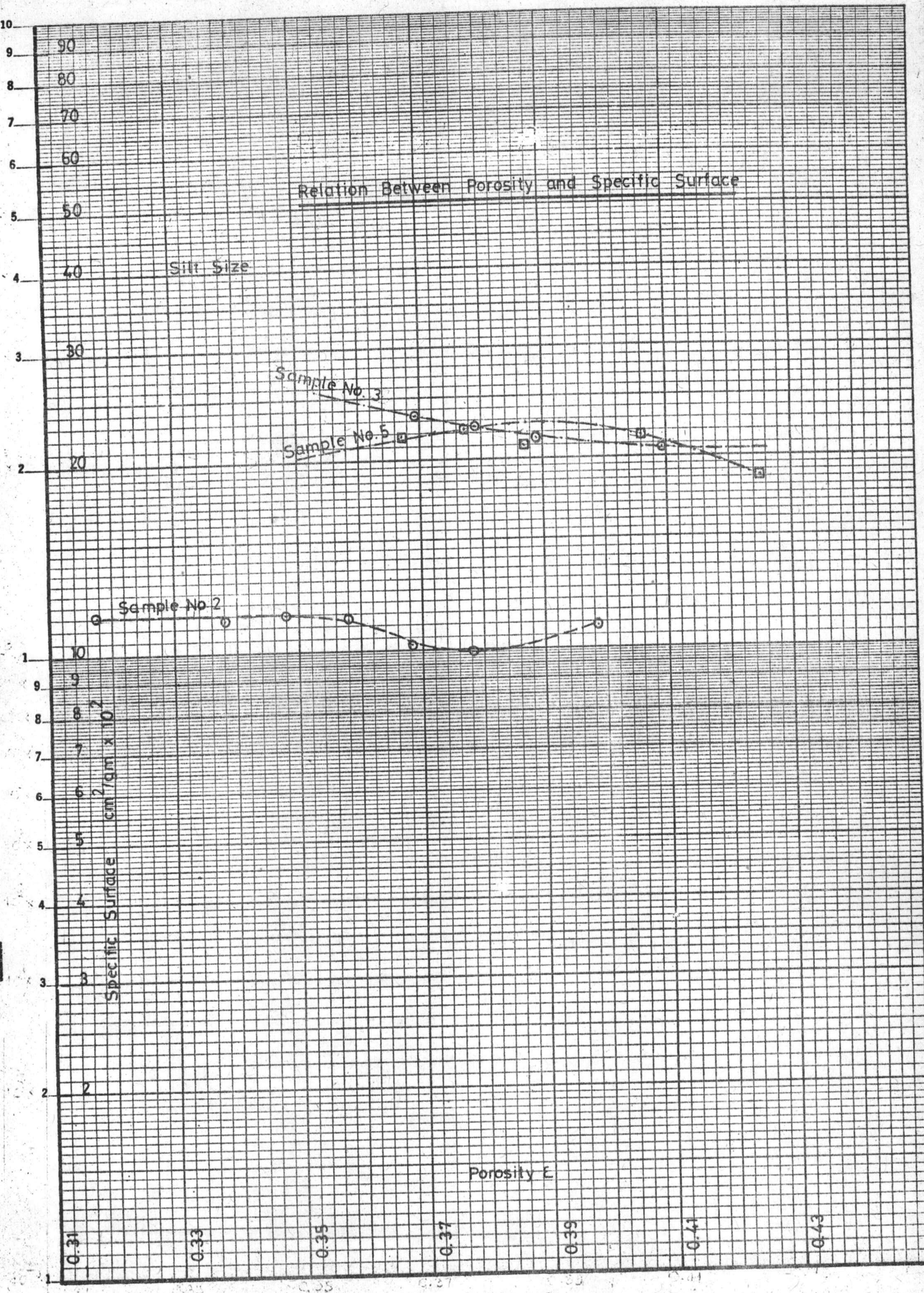

Relation Between Porosity and Specific Surface
Clay Size
Specific Surface cm2/gm. x 10^3
Porosity ε
Sample 674
Sample 5992
1
2
3
4
5
6
7
8
9
10
20
30
0.46
0.50
0.54
0.58
0.62
0.66
0.70
0.74

FIG.11



Relation Between Porosity and Specific Surface

FIG.12

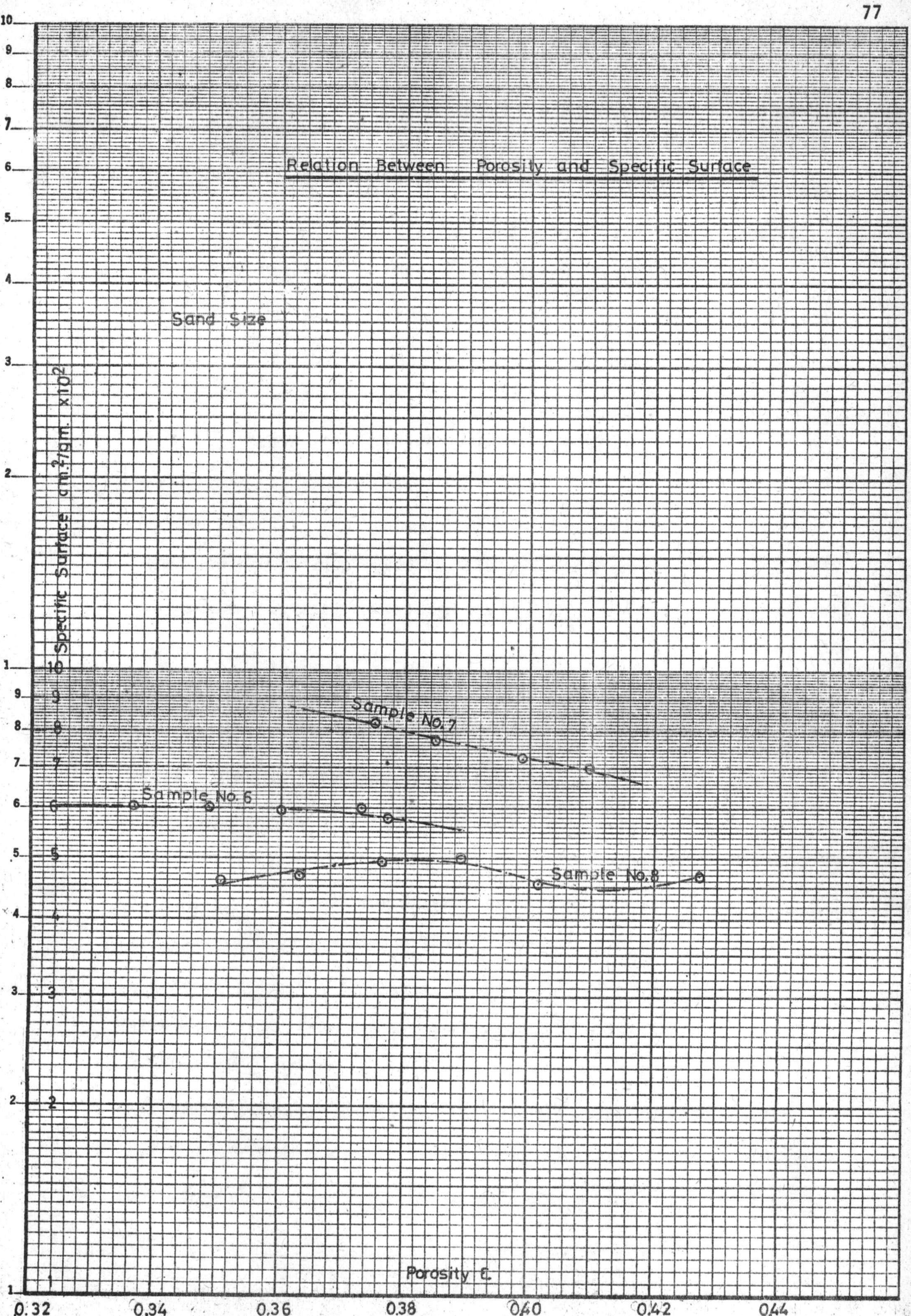

Relation Between Porosity and Specific Surface
Sand Size
Specific Surface cm.²/gm. x10²
Sample No.7
Sample No.6
Sample No.8
Porosity ε
0.32
0.34
0.36
0.38
0.40
0.42
0.44
1
2
3
4
5
6
7
8
9
10
SEMI-LOGARITHMIC
2 CYCLES X 70 DIVISIONS

FIG. 13

Discussion

In the first series of experiments, the very fine soil samples were tested with the developed apparatus 0.4 c.m. in diameter and the space in cell 1.0 c.m. for sample length. The results from the experiment in term of the specific surface are very different from the typical value[18] (1969) of the clay minerals. The main reason may be the compacted bed of clay minerals have the very small pores diameter and the flow of gas pass through these pores do not follow the Poiseulle's law. Because it has been realized that, with compacted beds of very fine particle and gases near atmospheric pressure or with coarse particles and gases at reduced pressures, the size of the pore or void spaces becomes small in comparison with the mean free path of the molecules of the gas which may be caused to flow through the bed. When this condition previals in capillary tubes the rate of gas flow is greater than that given by Poiseuille's law. This is attributed to 'slippage' at the capillary walls. If the mean free path is much greater than the capillary diameter, viscosity plays no part in flow, since molecules collide only with capillary walls, and not with one another. Such 'free molecule' or Knudsen flow is a process of diffusion. The comparison of air-permeability results and the typical value for determination of specific surface is shown in Table 2. In this Table the sample P_e354 (Kaolinite) and P_f886 (Kaolinite with some quartz) give the ratio $\frac{S_c}{S_a}$ about three for the closest agreement with the typical value but sample No.5992 and sample No.674 give much larger ratio of $\frac{S_c}{S_a}$. This may be caused by the constituent of a mixture which were more different in size and also the percentages of the very small particle was much more than the bigger one. The arrangement of the structure of the mixture should be looser than the arrangement of each size of particle by itself alone. Therefore, the permeability of the mixture should be higher and the specific surface values obtained, should be lower. In the second series of experiments, the fine soil samples in range of silt size were tested with the developed apparatus 0.80 c.m. inside diameter glass tubing and the sample length in permeability cell of 1.50 c.m.. In this range, it was found that the ratio $\frac{S_c}{S_a}$ did not vary in wide range and the average value of this ratio was about 1.03. The corresponding result in this range was due to the similarity of the soil sample shape. The range of pore shapes of this type of soil was such that the shape factor (C_s) was reasonably constant, and that the tortuosity was also not very susceptible to variations in pore geometry. Another effective factor was that the uniformity of pore size was implied, if a pore space was represented by a bundle of capillaries of widely varying radius, the mean hydraulic radius $R_h = \frac{E}{S_v(1-E)}$ was not the correct mean value for permeability calculation; and the Kozeny equation was then no longer valid. The difference of the calculated value and the experimental value should be very large. In the last series of experiments, the coarse grained soil samples in ranges of sand size were tested with the developed apparatus 2.0 c.m. inside diamter glass tubing and the space in permeability cell of 2.50 c.m. was provided for the sample. The results of the sedimentation and sieve analyses in the present work had been calculated, using both Andreasen cube and the spherical dimensions. In the Andreasen method the particle was expressed as the length of the side of the cube of the same volume as the Stoke's law sphere. The Andreasen dimension was 0.8061 times the spherical dimension[16]. The assumption of the calculating result was that the mean particle diameter of 'd/2' was assigned to the small proportion of particles below 'd'. From an examination of the results, there was a close agreement of the value obtained by the air-permeability and the sedimentation methods when the latter were calculated by the cubical dimension. The mean ratio $\frac{S_a}{S_s}$ was about 1.24 and this value showed the surface factor of sand which was different from silt. For light grey very fine sand passing No.80 sieve and retaining No.400 sieve the result from the experiment was less close agreement with the result from sieve analysis because of the uncertainty of percentage retained of the soil fraction on the sieve having the smaller aperture than the sieve No. 200. The results of the testing by three size of apparatus with the same soil samples, the surface area values obtained were shown to be independent of the dimensions of the u-tube manometer. The time of flow rate should be considered to prevent the prevailing of the turbulent flow. Carman P.C.[7,16] (1938) had shown that for values of $\frac{V}{A\,\eta\,(1-E)\rho_{s_w}}$ greater than 2.0 the Kozeny-Carman equation did not hold owing to turbulent flow and that for extremely low values of this ratio the permeability-porosity relation was not true. The flow rates used in all the tests should be within the limits $1\text{-}3\times10^{-4}$ for the ratio $\frac{V}{A\,\nu\,(1-E)\rho S_w}$ where ν is the kinematic viscosity of fluid in stokes. The advantages of varied size of the u-tube manometer is as follows: when the coarse grained soil is tested, the bigger size would give enough time for the operator to measured the time of the falling of manometer liquid with more accuracy and the time is saved when the fine grained soil is tested with the smaller size of apparatus. The plotting of specific surface value versus porosity in Fig. 10, 11, 12, 13, shows a distinct scatter about a mean value of S_w at each porosity. The value over a limited porosity range gives the impression that S_w is independent of porosity. This range may reasonably regard as the normal range of porosities. It might also be expected that as the porosity approaches the normal range the pore texture becomes more uniform, and therefore the values of the calculated specific surface tend to close to constant. Some soil samples No. 3, 674, and 5992 show no tendency for specific surface to become constant at low porosities. This may be due to the soil particles. Carman and Malherbe[10] (1950) has explained that harder particles either show a slower rate of change of specific surface throughout, or approach a slower rate of change in the 'normal' range, but softer particles show the change much more rapidly with porosity over the whole porosity range. The reason for the rapid increase in S_w at low porosities is not self-evident. It was thought at first that the soil particles were crushed into smaller fragments, thus producing a real increase in S_w. In any case it seems reasonable to assume that porosities below the normal range can only be produced by an abnormal porous texture, so that values of

S_w below the normal range as well as above it, are suspect. For uniform equi-dimensional particles the 'normal' porosity range is = 0.4-0.5 and for non-uniform particles, it can be less and for acicular, platy or skeletal particles it can be considerably higher than this range.

Care should be exercised during the experimental stage on the followings:

1) Weighing the sample when use the manometer of 0.40 c.m. and 0.80 c.m. diameter since the difference of weight ±0.10 gram may cause the considerable difference of specific surface.

2) The accuracy in determining the bulk volume which will be varied with the weight of the sample. The precision of the volume ±0.01 cu.c.m. may cause the difference of specific surface about ±0.5 %.

3) The mode of compaction may give the variation of the testing time. The segregation of the fine particle from the coarse particle introduces the possibility of causing uneven compression. This would give a lower permeability than an evenly compressed sample.

4) The porosity of the sample may have significant effect on the specific surface. Hence, the porosity of the sample should be calculated not only from the accurate value of weight and volume but also it is necessary to use an accurate value of the specific gravity of the particles.

Determination of the surface area of a particle requires the study of processes of different kinds; in choosing a particular method of measurement. Consideration should be given to the nature of the process being studied and it relation to the various methods of measurement available. For example, where the process is essentially one of surface behavior as in wetting or adsorption, then an adsorption method of measuring the surface area of the solid bears the closest relation to the practical conditions under investigation. Where purely physical interaction of the solid particles are being considered, as in the case of rheological studies of mixtures of highly viscous liquid and mineral particles, then the air-permeability method is probably of more value than most other methods. It is assumed in the air-permeability method that the bed of particle behaves as a bundle of capillaries. Consequently, only the surface of the continuous paths through the material will contribute to the measured specific surface area. This area is not the same as that measured by adsorbing a gas on to the surface of the particles where all the surface accessible to gas molecules of the type used will contribute. There will therefore be a general trend for results obtained from the adsorption of nitrogen to be larger than those obtained by a permeability method. This differences may be accentuated if the particle has an appreciable 'internal' surface due to cracks, internal pores and other irregularities. In addition, the permeability methods may not measure the full 'external' surface of the particle because of the formation of blind pores during compaction of the bed. In very fine particles a further complication arises since, as has been shown by Carman P.C.[19] (1950), it is very difficult to compact a fine particles to give a bed of low void-fraction; with the more porous type of bed, there may be serious lack of uniformity in the compacted bed. And in all cases the area measured by the gas adsorption method was larger than the air-permeability method.