TR-82

LABORATORY ANALYSIS OF SOIL SAMPLES FROM KOLAR SUB-BASIN OF RIVER NARMADA

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE-247 667 (UP)
INDIA

1990

CONTENTS

PREFACE

The present report is a part of the project concerned with transfer of the System Hydrologique European (SHE)- Hydrological Modelling System to the National Institute of Hydrology, Roorkee and is intended to deal with formulation of water and land resources development strategies through numerical modelling. The project is financed by Agreement ALA 86/19. Hydrological Computerized Modelling System, signed between the Commission of the European Communities (C.E.C) and the Government of India. Under this project besides transfer of SHE model technology, six N.I.H. Scientists have also been trained in theoretical and practical aspects of the SHE, at Danish Hydraulic Institute, Denmark.

At the third meeting of the Project Steering Committee held on June 9, 1989 at National Institute of Hydrology, Roorkee, it was recommended that a programme of simple field measurements and sampling be carried out in Kolar basin followed by laboratory analysis with the aim of reducing uncertainity in the soil parameter values for the SHE simulations.

This report prepared by Dr S M Seth, Scientist F and Project Coordinator with the assistance of scientific staff of NIH and support of WRDTC describes the results of laboratory analysis of soil samples carried out in NIH and WRDTC. It also includes reproduction of relevant information regarding equipment and test procedures, which would be quite useful as a reference material.

Satish Chandra
(SATISH CHANDRA)
DIRECTOR

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The project ALA 86/19 'Hydrological Computerized Modelling System (SHE) signed between Government of India and Commission of European Communities (CEC) in June/July 1987, is funded by the CEC and involves transfer of technology in respect of SHE Modelling system to National Institute of Hydrology, by the Danish Hydraulic Institute (DHI), Denmark and its SHE partners, for application to hydrological problems. In view of the large scale water resources development activity in the Narmada Basin and the availability of data, 6 sub-basins of the Narmada, namely: Kolar, Barna, Sher, Ganjal, Hiran, and Narmada upto Manot were selected as focus basins for simulation studies after discussions with M.P. Irrigation Department. The available data for the first 3 basins were used for training at DHI of 3 scientists of NIH during 1988, and the second 3 basins for training of scientists during 1989. Though the available data provided reasonable information regarding rainfall, discharge, topography, evaporation, land use, etc., there was relative lack of direct information on soil and vegetation properties, root zone depths, and vegetation growth and cropping pattern, soil depths and moisture profiles, and channel cross sectional dimensions. For the simulation work of the 6 basins using SHE Model, such information was obtained indirectly from the reports and papers of neighboring areas to the extent required. For the first 3 sub-basins, namely: Sher, Kolar, and Barna in the initial simulations retention curve for soil was constructed based on data given in ICAR Report (1982) and the values of saturated soil conductivity (for saturated and unsaturated zones) and soil moisture content were also assumed on the basis of information from literature. In December 1988, it was proposed that a sample programme of field measurement be taken up in one of the basins with the aim of improving the parameter basis for soil, vegetation, and basin response.

During the third meeting of Steering Committee held on June 9, 1989 at Roorkee, the matter of field measurement was further discussed and it was decided that such measurements could be planned in Kolar basin with the aim of reducing uncertainty in the soil parameter values for the SHE simulation and also for providing necessary experience to NIH staff in making field measurements. Detailed specifications were drawn up to help in the preparations for the field programme highlighting various resources in terms of man power, equipment, etc. The main thrust of the field programme particularly in respect to soil parameters and relationships was concentrated on the evaluation of the following:

i) Unsaturated zone saturated hydraulic conductivity (for vertical flow);

ii) Unsaturated zone moisture content/hydraulic conductivity relationship;

iii) Unsaturated zone moisture content/tension relationship;

iv) Saturated zone hydraulic conductivity (for horizontal flow);

v) Soil depth and profile;

vi) Root zone depth.

It was decided to conduct in situ infiltration tests for obtaining information about saturated hydraulic conductivity. For determining unsaturated zone moisture content/tension relationship, laboratory analysis using standard laboratory equipment consisting of pressure soil apparatus, was recommended.

The present report is confined to description of laboratory analysis of the soil samples (disturbed as well as soil cores) collected at different points in Kolar basin. The details of field investigations have been discussed in separate technical report.

2.0 SOIL SAMPLING

During the field investigation programme from Jan. 10-25, 1990 by NIH Scientists and Scientific staff with the active participation of Consultant Staff and Staff of M.P. Irrigation Department, a total of 12 sites distributed in the Kolar basin upto Satrana gauging site (area 828 sq.km) were investigated and soil cores and disturbed samples were taken. Besides soil sampling activity, infiltration tests were also carried out and information was obtained regarding other physical features. The undisturbed soil samples were taken by driving core pipes of inner dia 3.8 cm and length 23.5 cms into the soil. The samples were sealed on both sides by molten wax and were brought to Roorkee for laboratory analysis. At each of the 12 sites about 3 kg disturbed soil sample was taken for use in laboratory analysis in Roorkee for determining particle size distribution, soil moisture vs. tension relationship and permeability. The names of the sites are listed in Table 1.

TABLE 1
Name of Sites and Schedule of Collection of Soil Samples

Sample No.	Site Code	Location	Date of Sampling	Remarks
1.	3C	Sagoni	13.1.90	
2.	1C	Khajuri	20.1.90	
3.	2B	Left Rosturm of Dam	15.1.90	
4.	1A	Satrana	11.1.90	
5.	3A	Brijesh Nagar	19.1.90	
6.	4C	Khari	23.1.90	
7.	1B	Bardha	12.1.90	
8.	2A	Saras	18.1.90	
9.	4D	Khamkhera	22.1.90	

10.	4B	Bamladar	24.1.90
11.	2C	Downstream of Dam (Birpur)	10.1.90
12	3B	Semli Jadid	17.1.90

Dr (Ms) M Styczen, DHI, Denmark also participated in the field investigation programme in Kolar basin from 15-20 Jan. 1990. In her report covering various aspects of soil and soil properties, she had also commented on the difficulties/non-representativeness of core samples in black clay soils, since the black clay soil becomes compressed with the hammering done leading to much higher density than the natural soil. It was noticed in the preliminary sieve analysis carried out at the Quality Control Lab of M.P. Irrigation Department that clay content determined by simple sieve analysis was very less and completely wrong, due to aggregation of particles. She, therefore, advised use of sedimentation analysis after proper dispersion of the soil for particle size distribution of black clay soils.

3.0 PARTICLE SIZE DISTRIBUTION

For determining percentage of various size of particles in the soil samples collected from various points in Kolar basin, the facilities of NIH Laboratory were utilized. The loose (disturbed) samples were oven dried. Since the soil in this area consist of both coarse and fine grains, sieve analysis as well as sedimentation analysis was used. 200 gm of oven dried soil sample was washed through 75 micron size sieve. The material retained on the sieve was used for sieve analysis after over drying by arranging the various sieves one over the other in order of their mesh openings and the whole assembly was shaken in a sieve shaking machine. The proportion of the soil sample retained on each sieve was weighed and the percentage was calculated on the basis of total weight of dried soil samples taken.

The material passing through 75 micron size was subjected to sedimentation analysis using hydrometer method. The details of procedure for both sieve analysis as well as hydrometer analysis extracted from the book: 'Soil Mechanics and Foundations' by B C Punmiya are given in Appendix 1.

The results of particle size analysis using both sieve analysis as well as hydrometer analysis were plotted to get a particle size distribution curve with the percent finer (N %) as the ordinate and the particle dia as the abscissa with the diameter being plotted on a logarithmic scale. Particle size distribution curves for the 12 samples used in the present analysis are shown at Fig. 1 to 12. From the particle size distribution curves, the percentages of clay, silt, sand, and gravel in the respective samples were ascertained as shown in the figures. The values of the 4 constituents for each of the samples determined by this analysis are given in Table 2.

Name of Site:
SAGONI

Soil Sample
Code No. N-1

% (by weight) cf:

Clay = 40.79
Silt = 32.22
Sand = 26.51
Gravel = 0.48

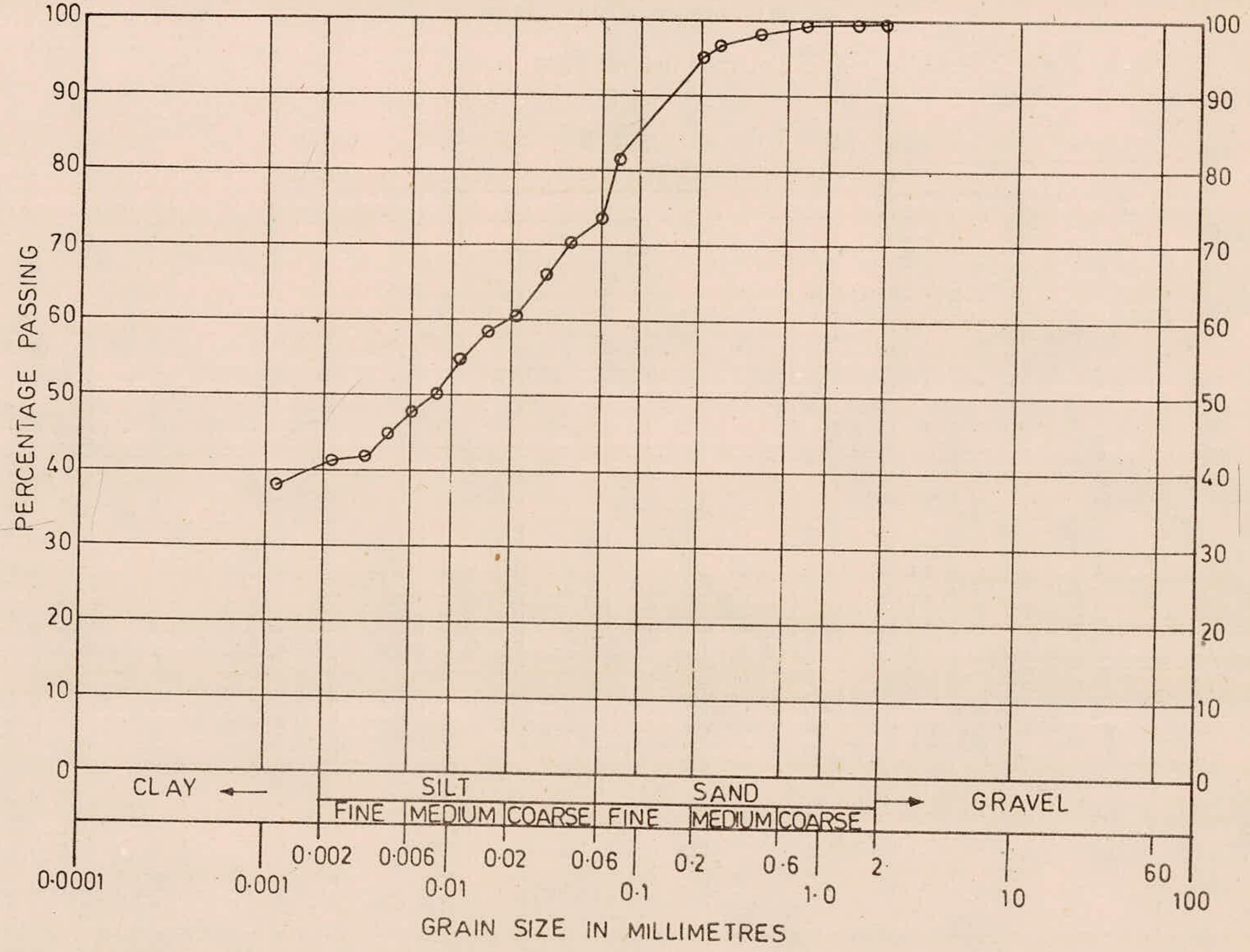


Fig. 1 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO 1

Name of Site:
KHAJURI

Soil Sample
Code No. N-2

<u>% (by weight) of:</u>

Clay = 17.20
Silt = 14.85
Sand = 54.73
Gravel = 13.22

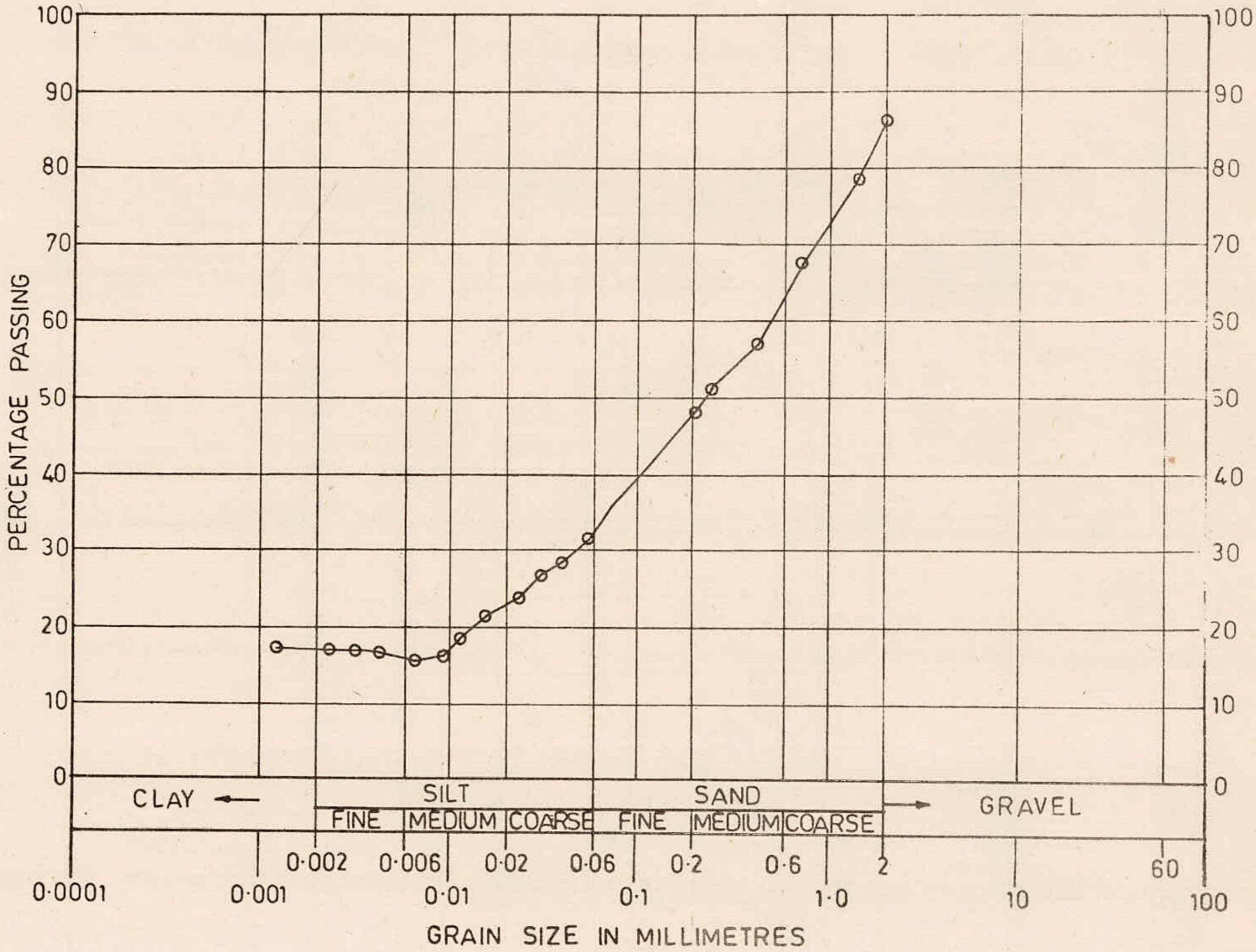


Fig. 2 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.2

Name of Site:
LEFT ROSTRUM OF DAM

Soil Sample
Code No. N-3

<u>% (by weight) of:</u>

Clay = 25.84
Silt = 27.04
Sand = 35.24
Gravel = 11.88

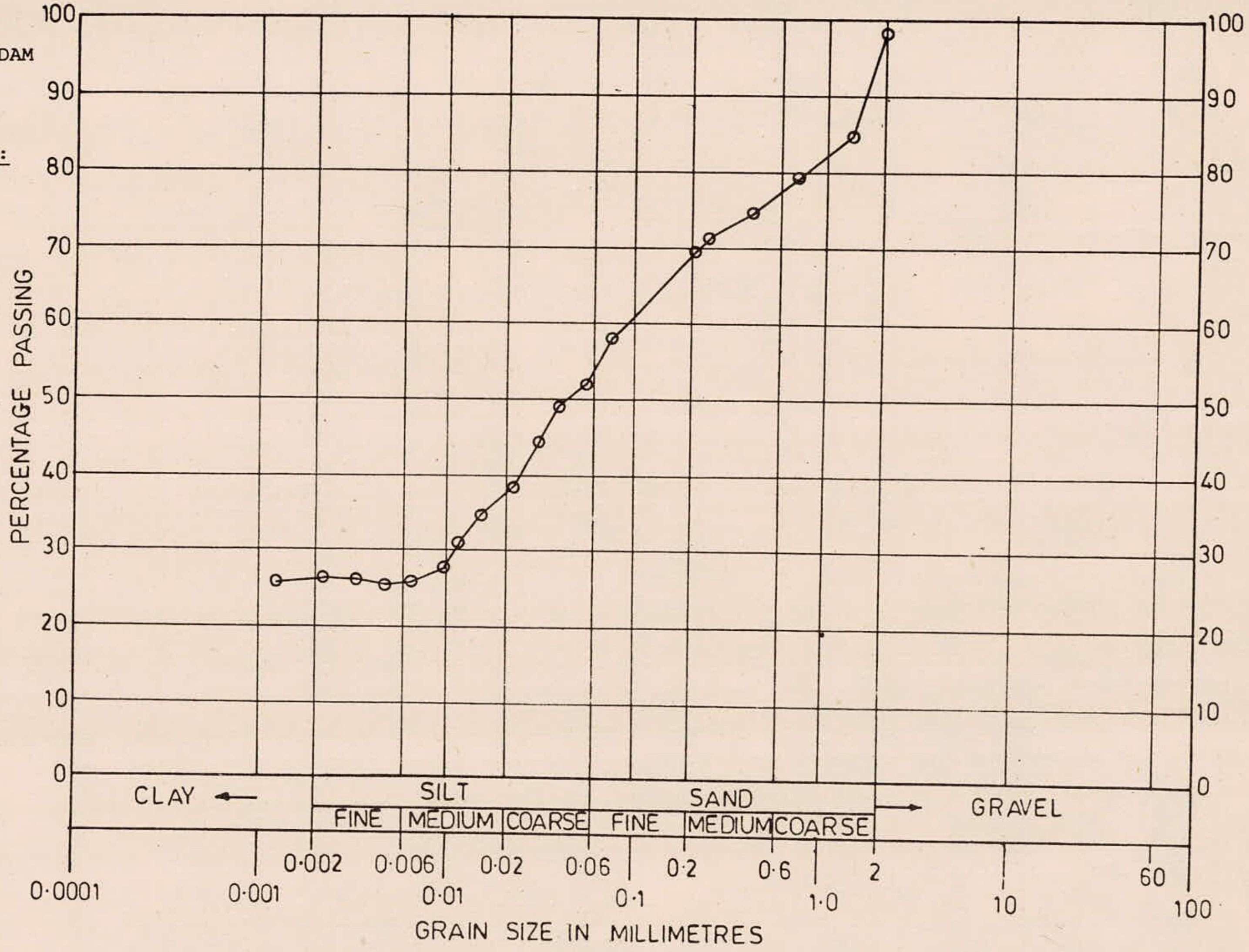


Fig. 3 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.3

Name of Site:
SATRANA

Soil Sample
Code No. N-4

% (by weight) of:

Clay = 21.0
Silt = 45.0
Sand = 19.5
Gravel = 14.5

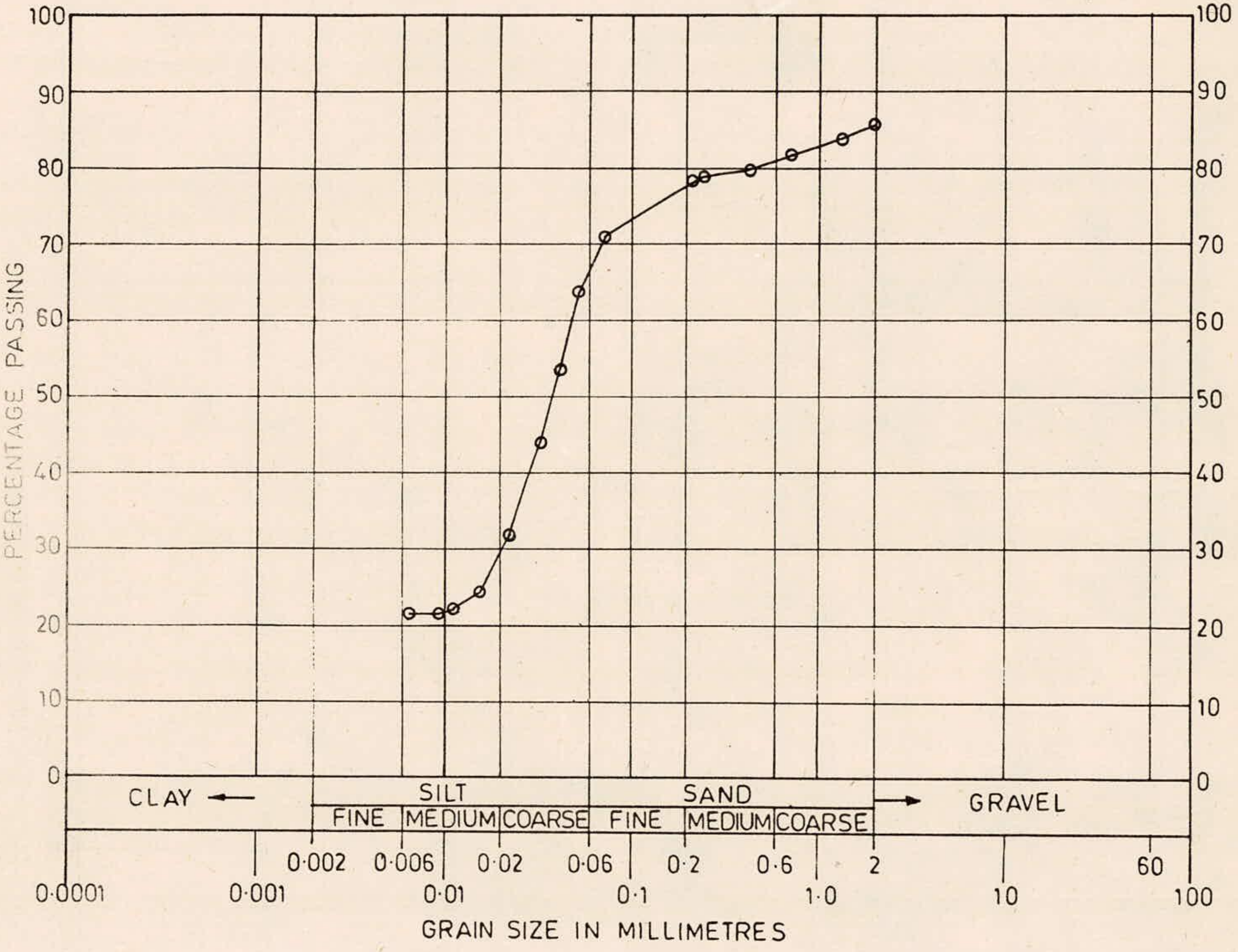


Fig. 4 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.4

Name of Site:
BRIJESH NAGAR

Soil Sample
Code No. N-5

% (by weight) of:

Clay = 45.0
Silt = 39.5
Sand = 12.9
Gravel = 2.6

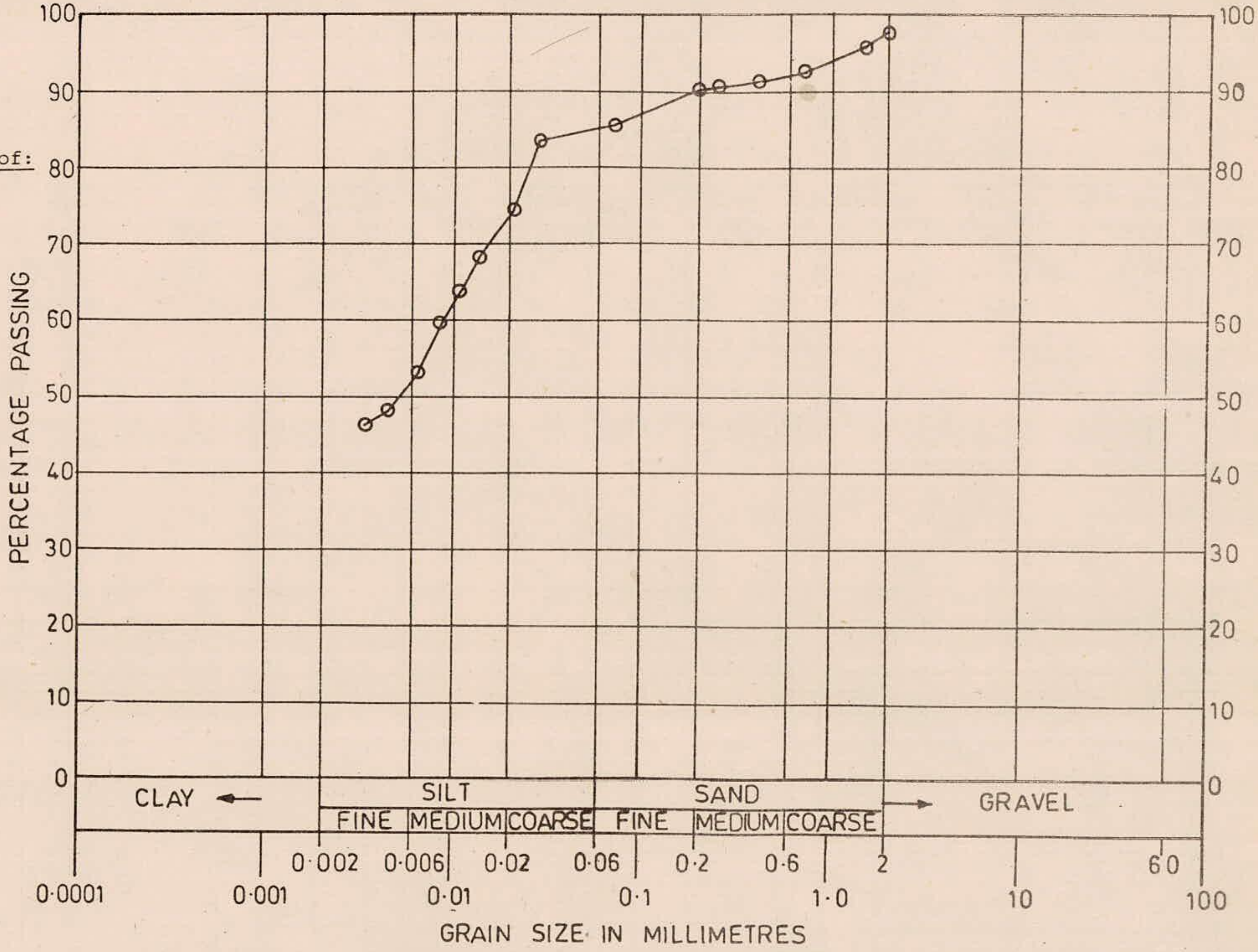


Fig. 5 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.5

Name of Site:
KHARI

Soil Sample
Code No. N-6

% (by weight) of:

Clay = 56.4
Silt = 40.1
Sand = 2.82
Gravel = 0.68

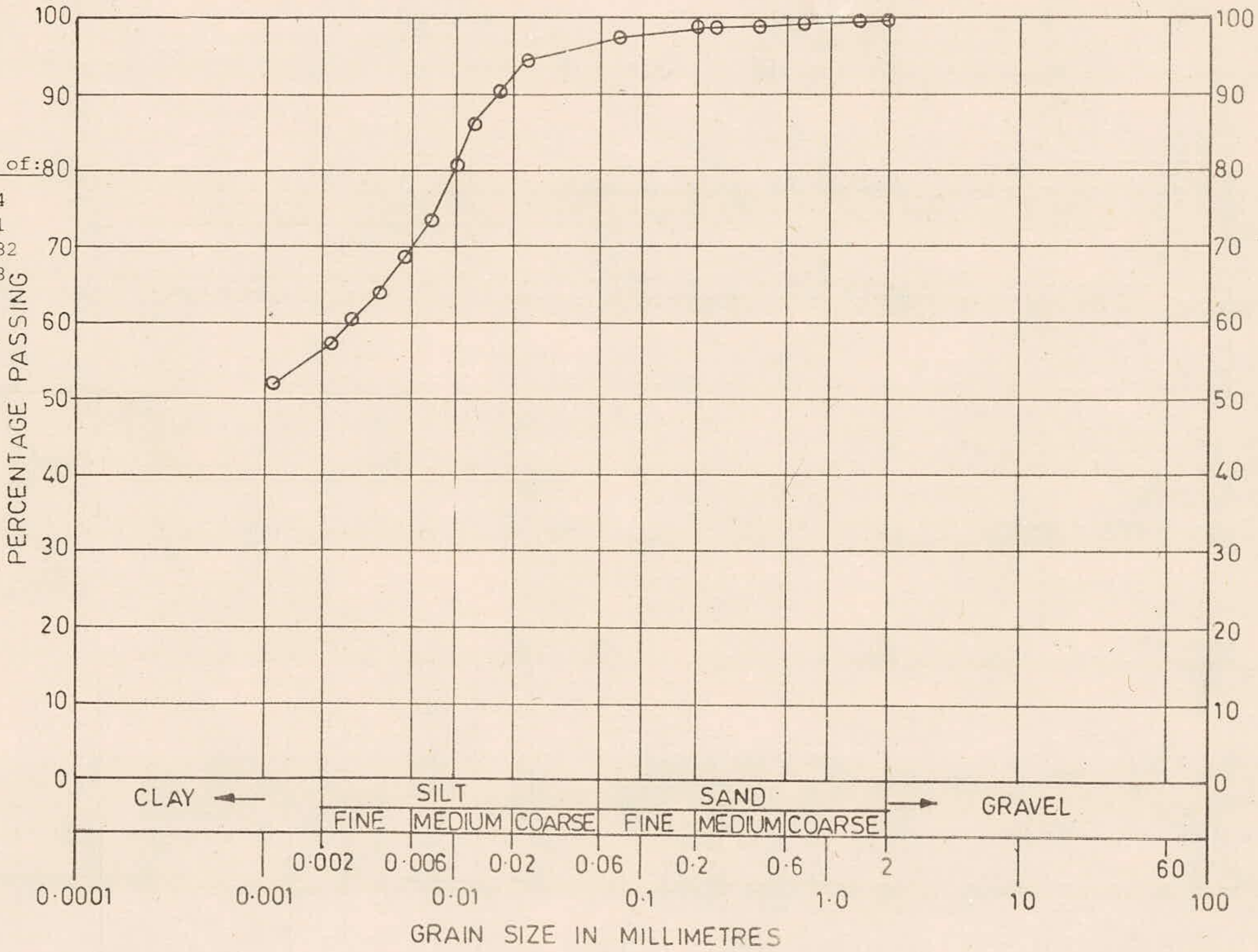


Fig. 6 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.6

Name of Site:
BARDHA

Soil Sample
Code No. N-7

% (by weight) of:

Clay = 55.6
Silt = 33.9
Sand = 8.03
Gravel = 2.47

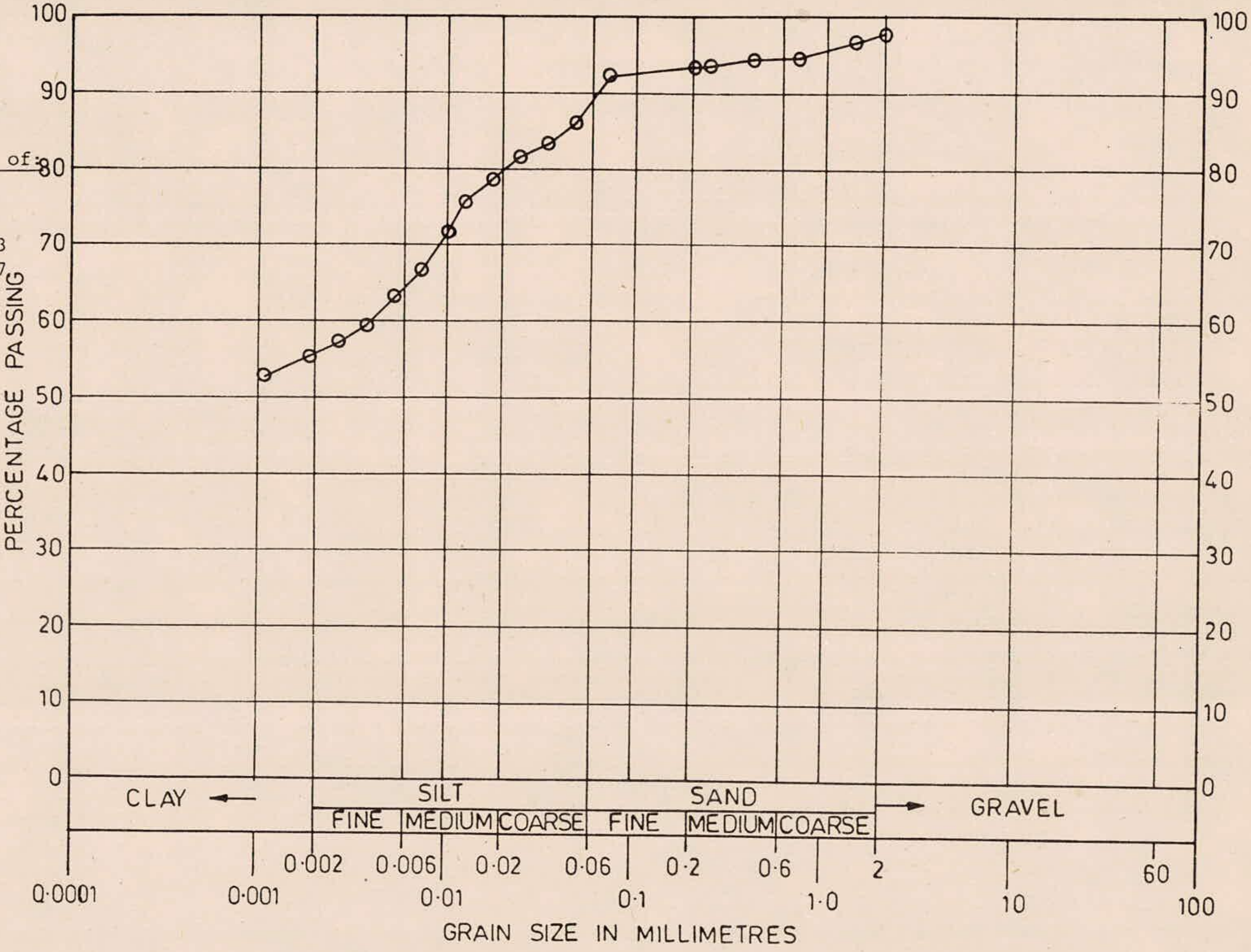


Fig. 7 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.7

Name of Site:
SARAS

Soil Sample
Code No. N-8

% (by weight) of:

Clay = 39.1
Silt = 33.6
Sand = 21.32
Gravel = 5.98

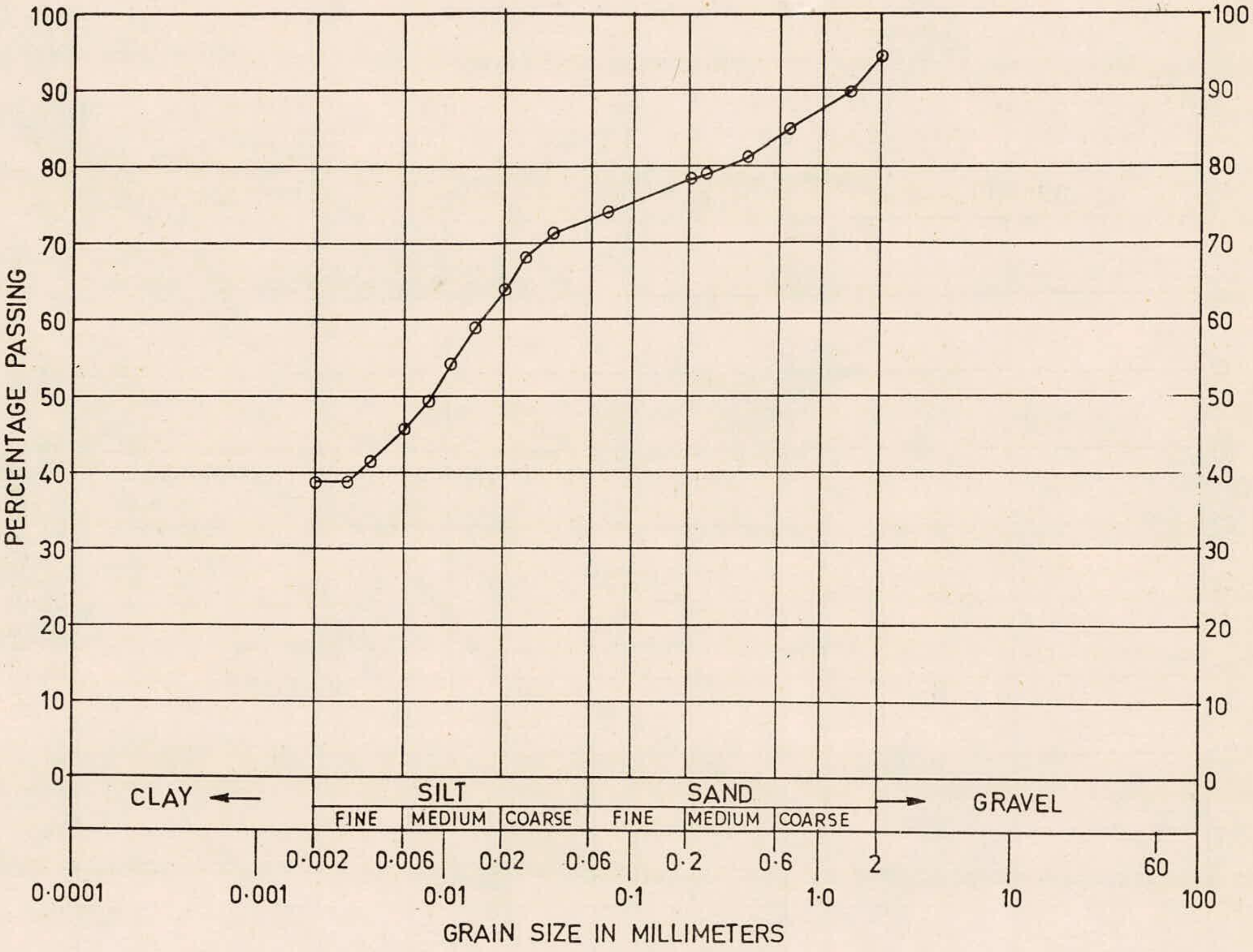


Fig. 8 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.8

Name of Site:
KHAMKHERA

Soil Sample
Code No. N-9

% (by weight) of:

Clay = 36.37
Silt = 27.13
Sand = 22.21
Gravel = 14.29

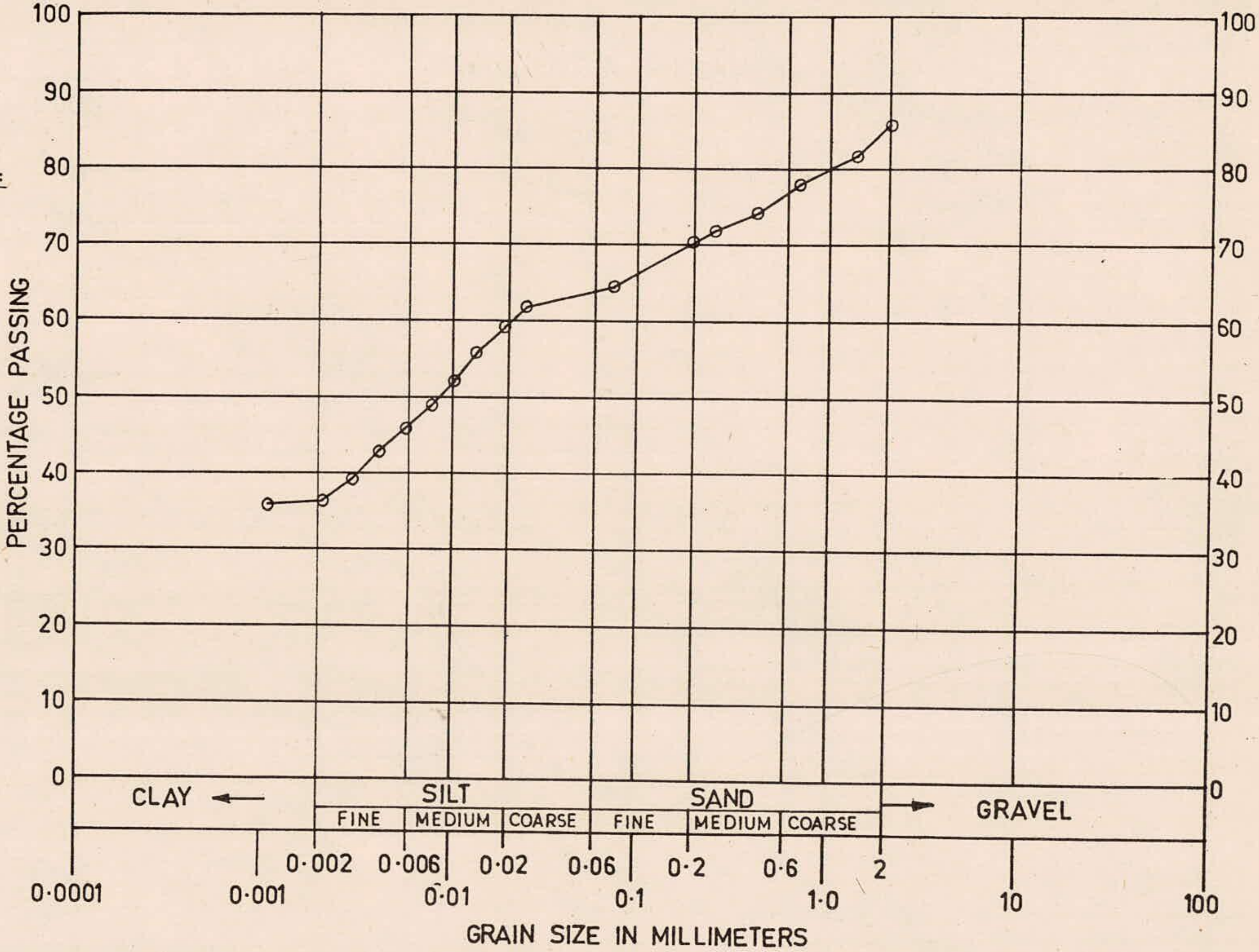


Fig. 9 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.9

Name of Site:
BAMLADAR

Soil Sample
Code No. N-10

% (by weight) of:

Clay = 29.0
Silt = 27.5
Sand = 8.29
Gravel = 35.21

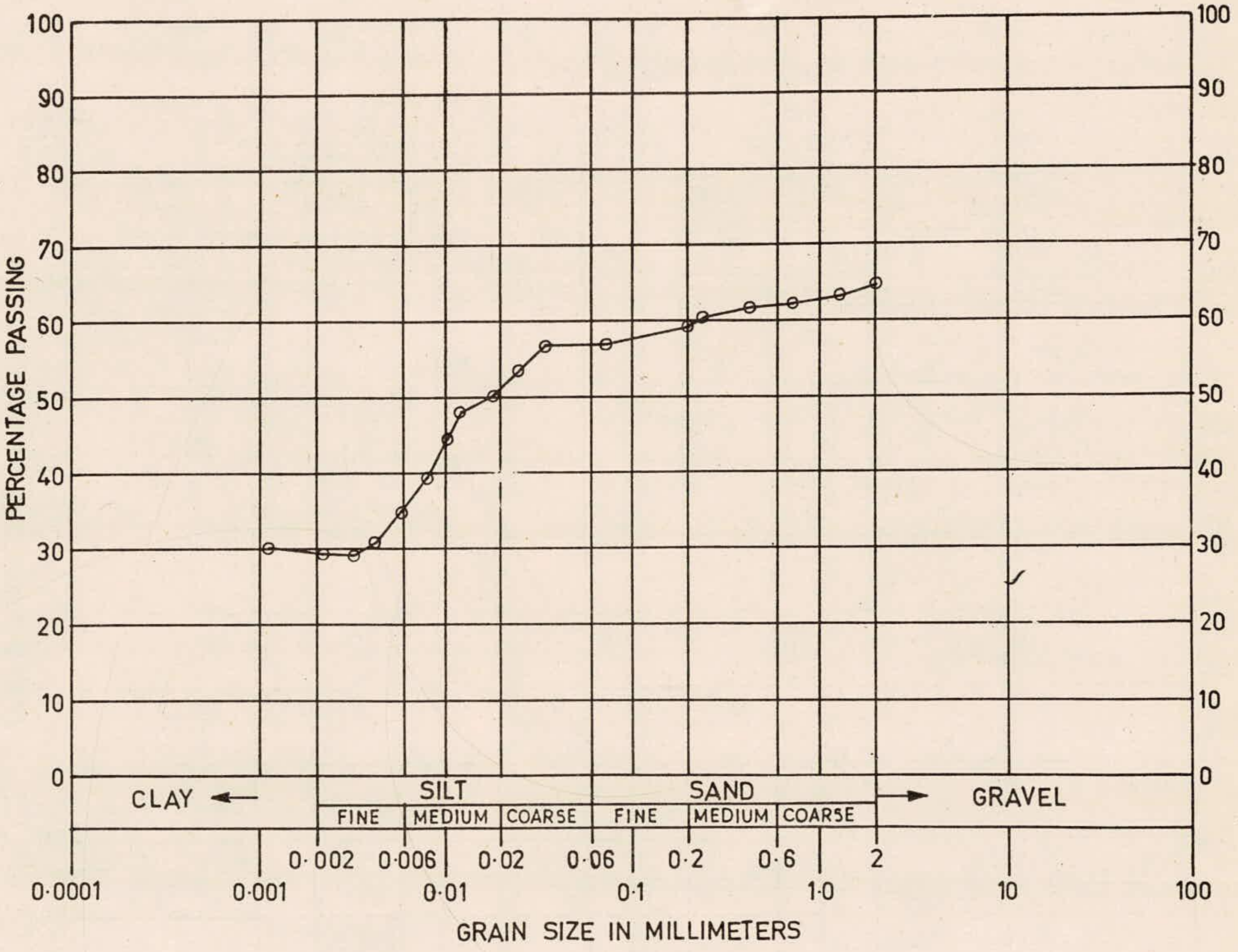


Fig. 10 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO.10

Name of Site:
DOWNSTREAM OF
DAM (BIRPUR)

Soil Sample
Code No. N-11

% (by weight) of:

Clay = 12.5
Silt = 40.0
Sand = 20.75
Gravel = 26.75

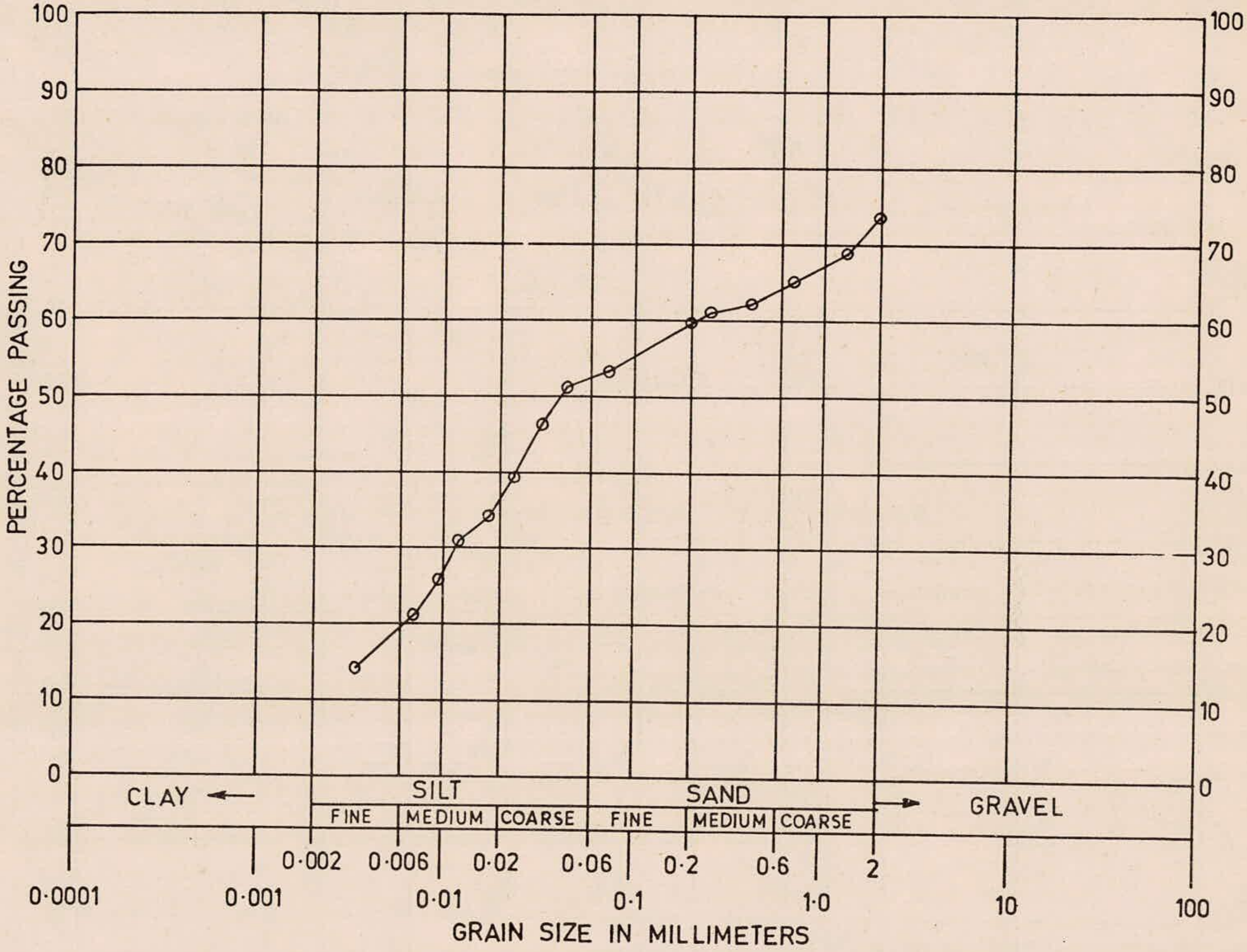


Fig. 11 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO. 11

Name of Site:
SEMLI JADID

Soil Sample
Code No. N-12

% (by weight) of:

Clay = 69.0
Silt = 27.75
Sand = 2.86
Gravel = 0.39

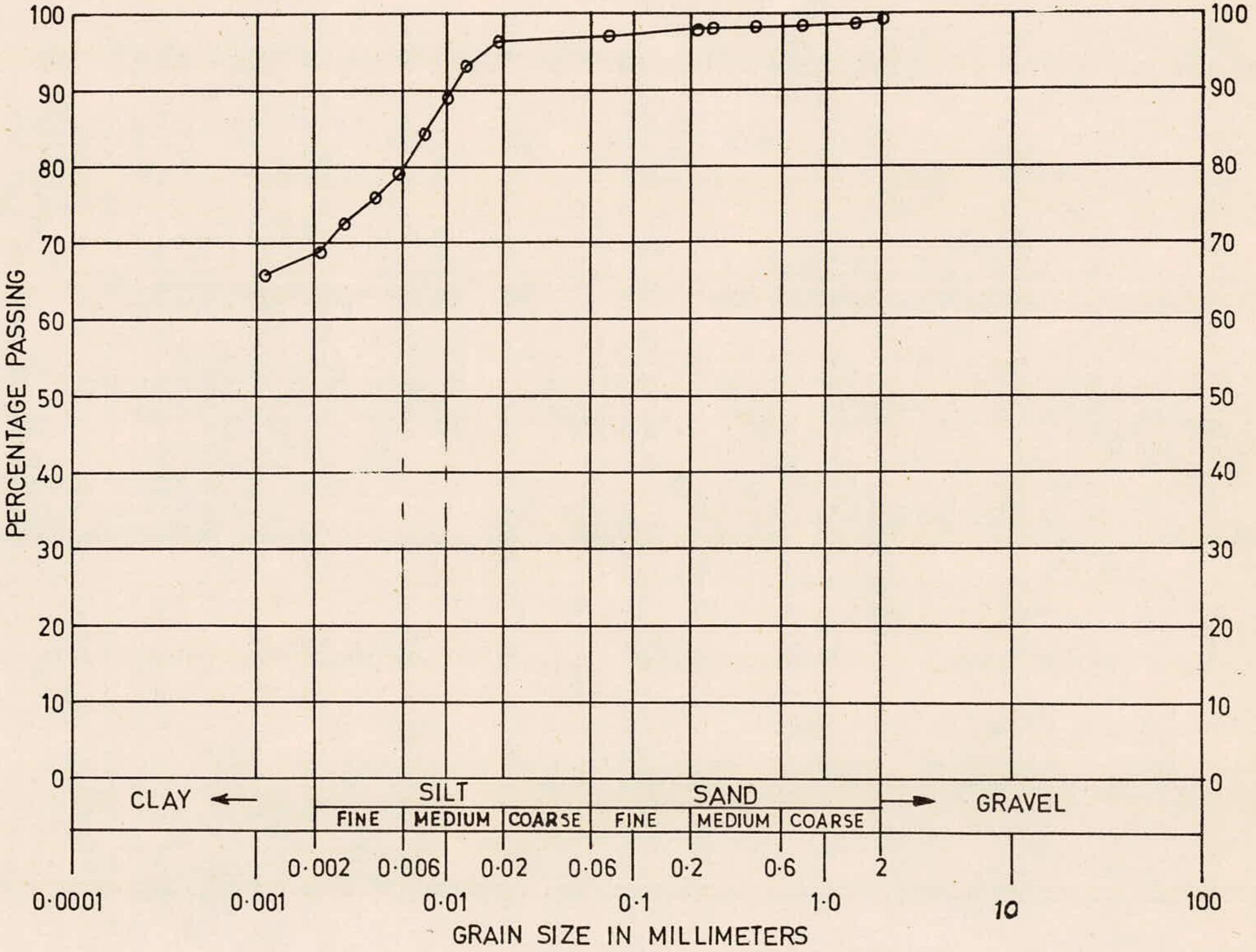


Fig. 12 : PARTICLE SIZE ANALYSIS OF SOIL SAMPLE NO. 12

TABLE 2
Particle Size Analysis

Sl. No.	Sample No.	Particle size distribution percent by weight			
		Clay	Silt	Sand	Gravel
1.	N1	40.79	32.32	26.51	0.48
2.	N2	17.20	14.85	54.73	13.22
3.	N3	25.84	27.04	35.24	11.88
4.	N4	21.0	45.0	19.50	14.5
5.	N5	45.0	39.5	12.90	2.60
6.	N6	56.4	40.1	2.82	0.68
7.	N7	55.6	33.9	8.03	2.47
8.	N8	39.1	33.6	21.32	5.98
9.	N9	36.37	27.13	22.21	14.29
10.	N10	29.0	27.5	8.29	35.21
11.	N11	12.5	40.0	20.0	26.75
12.	N12	69.0	27.75	2.86	0.39

4.0 PERMEABILITY

The permeability is defined as the property of a coarse material which permits the passage or seepage of water through its interconnected voids. Gravel's are high permeable while stiff clay is the least permeable. The various factors affecting permeability include grain size, properties of the pore fluid, void ratio of the soil, structural arrangement of the soil particles, entrapped air and foreign matter, and adsorbed water in clayey soils.

For the determination of the coefficient of permeability for the 12 disturbed samples collected from Kolar basin in the laboratory at National Institute of Hydrology, the falling head permeability test was used.

The details of tests extracted from the book: 'Soil mechanics and Foundations' by B C Punmiya are given in Appendix 2. In view of clayey nature of the soil of the Kolar basin, the laboratory determination of coefficient of permeability is considerably affected by air entrapment and adsorption of water. No arrangements of facilities were available in the laboratory for completely saturating the soil samples by vacuum saturation of such samples for measuring the permeability. As such, the saturation to the extent possible was achieved by allowing the water to flow through the sample for a long time (24 hours).

The density of the soil cores collected from field from the sites from which disturbed samples were collected were determined in the WRDTC laboratory. It was seen that for each sample, the density determined: (i) considering the inner volume of the pipe sampler, (ii) considering the volume of dried sample after shrinkage, etc. (iii) considering the sample prepared in WRDTC lab after removal of gravel and used for determination of moisture content at saturation, were considerably different. For permeability determination of sample No 1, samples were prepared for 3 different dry densities. However, subsequently all other 11 samples were prepared for the dried density of 1.3 gm/cc and used for determination of the coefficient of permeability by falling head method. The results of samples for density of 1.3 gm/cc are given in Table 3.

TABLE 3
Permeability Values

Sample No	Dry Density (gm/cc)	Permeability (cm/sec.)
1	1.30	3.90×10^{-6}
2	1.30	610.0×10^{-6}
3	1.30	306.9×10^{-6}
4	1.30	30.92×10^{-6}
5	1.30	0.783×10^{-6}
6	1.30	5.063×10^{-6}
7	1.30	12.912×10^{-6}
8	1.30	4.690×10^{-6}
9	1.30	1.590×10^{-6}
10	1.30	1.643×10^{-6}
11	1.30	6.717×10^{-6}
12	1.30	0.350×10^{-6}

For most of the samples used for determination of permeability after completion of the test, the sample was weighed for determining the moisture content of the sample to get an idea of the degree of saturation achieved in the test for determination of permeability. The values of moisture content for the samples are given Table 4.

TABLE 4
Degree of Saturation in Permeability Test

Sample No	Water Content After Completion of Test
1	33.75%
2	–
3	43.02%
4	–
5	33.81%
6	34.49%
7	39.73%
8	37.67%
9	34.36%
10	33.77%
11	36.57%
12	37.24%

5.0 ANALYSIS IN WRDTC LABORATORY

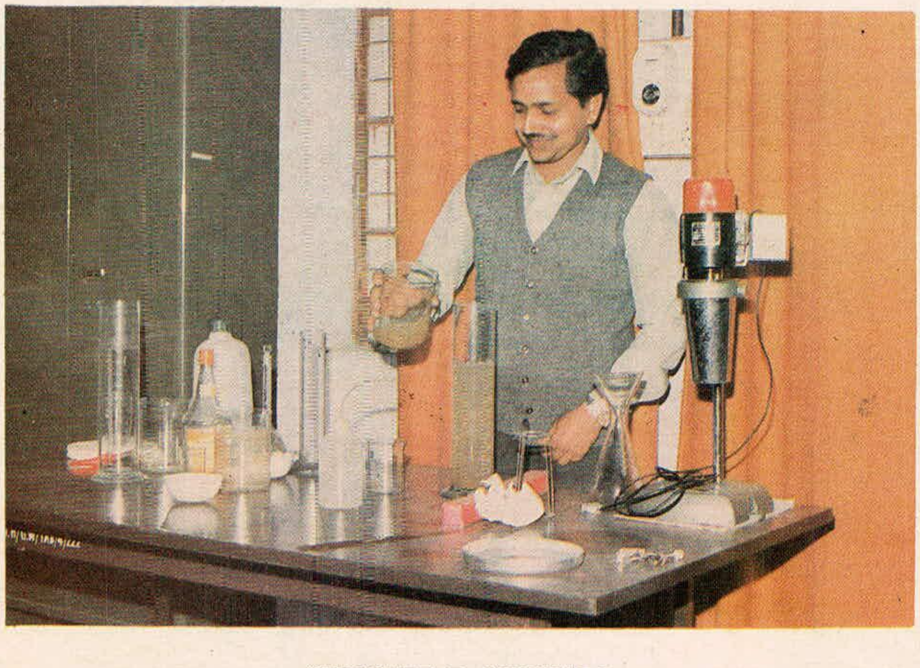
The Water Resources Development Training Centre, University of Roorkee, Roorkee was approached on 18th December 1989 for utilization of their laboratory to determine soil moisture retention behaviour of soil samples against payment of testing charges for this purpose. In response to this, it was informed by Dr S K Tripathi, Reader, WRDTC that testing charges would be Rs.1000/- per sample and it was agreed by them that for each soil sample, moisture retention would be estimated for pressures of 0.5, 1.0, 2.0, 3.0, and 15.0 bars. It was also agreed by WRDTC to determine the density of core samples obtained for the corresponding sites in Kolar basin using 1.5 inch pipe samples.

The Interim Report of the moisture retention of 3 samples, namely: soil samples Nos. 1, 2, & 3 was received from WRDTC on March 9, 1990. These 3 typical samples represent yellow, red, and black soils and were sent to WRDTC with a view to utilize their results for most of the samples in Kolar basin assuming that all other 9 samples would be nearer to one of three samples in their moisture retention behaviour. In the results provided by WRDTC, the dry bulk density in gm/cc was estimated by 3 methods. In the first method, the core samples prepared for estimating the moisture content at 0.5 bar, i.e. saturation stage was used. In the second approach, the weight of dried soil core was taken while the volume was taken as the inside volume of the pipe sampler. In the third approach, the weight of dried core samples was taken and the volume was taken as that of the dried core after shrinkage in view of predominance of clay content. The interim results for sample Nos. 1, 2, & 3 also included the semi-logarithmic relationship between moisture content (percent by weight) and pressure applied in bars. The Interim Report for these 3 samples given by WRDTC is also enclosed. The pressure plate apparatus was used for the soil moisture retention characteristic by WRDTC. The details of such apparatus extracted from literature of M/s Eijkelkamp Agrisearch Equipment, The Netherlands is given at Appendix 3.

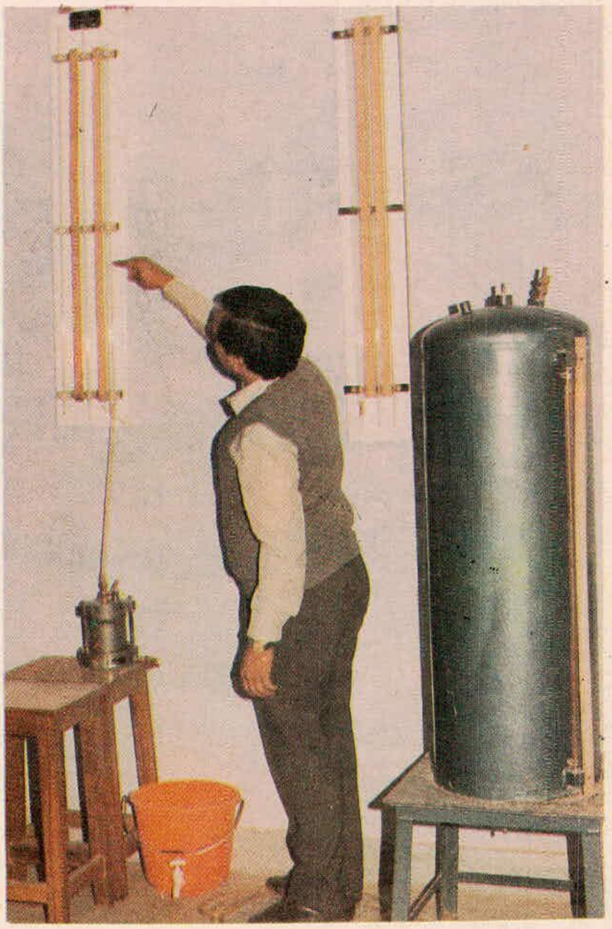
The testing of remaining samples continued in WRDTC. During May 1990 an interim report of results of 10 samples was sent to NIH.

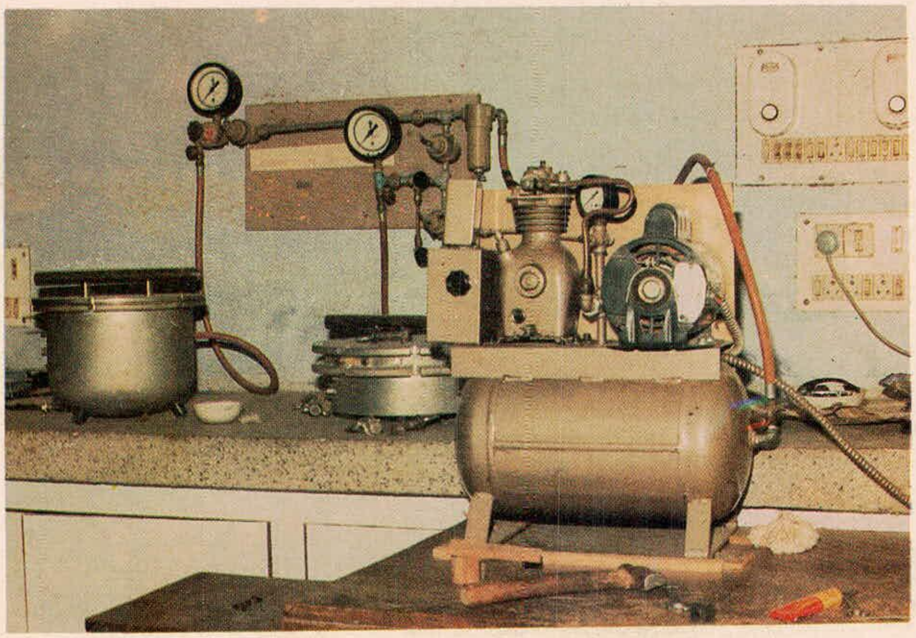
The testing of all the 12 samples have since been completed. The final report has also been received from WRDTC and relevant portions of this report are appended at Appendix 4. The final report also included following catalogues of M/s Soil Moisture Equipment Corporation, U.S.A.:

(i) Catalogue No 1080 - Installation Instructions for the PM Hinge
(ii) Operating Instructions for the Model 500-A PM Compressor
(iii) Catalogue No 1500 - Operating Intructions for the 15 Bar Ceramic Plate Extractor.
(iv) Catalogue No 1600 - Operating Instructions for the 5 Bar Pressure Plate Extractor.



HYDROMETER ANALYSIS





PRESSURE PLATE APPARATUS

These catalogues have been reproduced in Appendix 5 after obtaining permission from the manufacturer.

The results of sample N7 in particular appeared to be gross overestimates. The value of moisture content at saturation was determined again by repetition of the test. It was found that earlier estimated value of 56.25% by weight gets reduced to 46% by weight. This indicates range of variability possible in laboratory results of moisture retention characteristics.

In this report broad classification of 12 samples has been given as follows:

TABLE 5
Classification of Samples

(i) Based on soil moisture % (by weight) recorded at 0.1 bar.

Sl. No.	Soil Moisture Range (%)	Sample No.
1.	25	N2
2.	25-30	--
3.	30-35	N3, N4, N8, N11, N12
4.	35-40	N5
5.	40-45	N1, N9
6.	45-50	N6, N10
7.	50	N7

(ii) Based on Soil Moisture % (by weight) recorded at 15 bar.

Sl. No.	Soil Moisture Range (%)	Sample No.
1.	10	N2
2.	10-13	N3
3.	13-16	N4
4.	16-19	N7
5.	19-22	N5, N6
6.	22-25	N1, N8, N10, N12
7.	25	N9, N11

The inconsistency in these two groupings has been attributed to the variation in mineralogical composition and organic matter content of the soil samples.

6.0 DISCUSSION OF RESULTS

In the tests carried out in WRDTC Laboratory, the dry bulk densities determined using three approaches, indicated significant differences. Furthermore, the tests for soil moisture retention characteristics were carried out after removing the gravel content. As such for conversion of results obtained on weight basis, the question arises as to which value of bulk density should be adopted and also whether presence of gravel should be accounted for by applying suitable corrections. Such and related questions were probed to the extent possible as described in following paragraphs:

6.1 Variation with (Clay + Silt) Content

(a) The values of infiltration rate at 24 hours (as given below) determined by field investigations were plotted against (clay + silt) content of the soil sample (Fig. 13). It is seen that except for sample N10, all other samples had nearly similar values. There is a general decreasing trend of infiltration values with increase in (clay + silt) content.

TABLE 6
Infiltration Rate at 24 Hour (cm/hr) for Twelve Samples

Sample No.	Infiltration Rate (cm/hr.)
N1	1.649
N2	3.14
N3	1.21
N4	0.04
N5	0.497
N6	3.31
N7	5.15
N8	1.188
N9	0.678
N10	25.137
N11	2.862
N12	1.294

(b) The values of soil moisture content (% by weight) as obtained in WRDTC Lab. for 0, 3 and 15 bar pressures were plotted against (clay + silt) content as determined in NIH Lab. without applying any correction for gravel content (Fig. 14 to 16). There is a general increasing trend in all three cases, but no specific pattern emerges.

(c) The values of soil moisture content (% by weight) as obtained for 0, 3 and 15 bar pressures were plotted against (clay + silt) content after applying correction for gravel content removal while conducting test in WRDTC Lab (Fig. 17 to 19). Besides general increasing trend, it is also seen that samples N2 and N3 behave in a different manner while all other 10 samples having (clay + silt) more than 60% by weight appear in a cluster. On this basis three categories are distinguished viz. (clay + silt), (i) less than 40%, (ii) between 40 to 60%, (iii) more than 60% by weight.

(d) The values of dry bulk densities (gm/cc) based on three approaches indicate significant variations. In order to see the effect of this variation, the moisture retention curves were plotted for: (i) moisture content (% by weight), (ii) moisture content (% by volume) using density value as determined for WRDTC sample used for 0 bar pressure, (iii) moisture content (% by volume) using density value determined for pipe core volume as shown in Fig.20 to 22 respectively.

When percent by weight is considered, the following three groupings are indicated by plot in Fig. 20.

1. Sample N2
2. Samples N3 and N4
3. Samples N1, N5, N6, N7, N8, N9, N10, N11, N12

For cases of conversion on volume basis using bulk densities, the groupings indicated by plots in figure 21 & 22 are as follows:

Group	Fig. 21	Fig. 22
1	N2, N3	N2, N3, N4, N7
2	N1, N4, N5, N6 N7, N8	N1, N5, N6, N8, N11, N12
3	N9, N10, N11, N12	N9

It is thus seen that there are broadly 3 groups in the soil samples collected. However, it is difficult to give definite divisions in these 3 groups. Based on the results of WRDTC laboratory, after testing all 3 samples namely: N1, N2, and N3, representing respectively, Black, Red, and Yellow soils, the soil moisture retention curves were suitably adapted for updating of simulation in Kolar Basin. The moisture retention characteristics representing relationship between moisture tension (pressure in bars) and moisture content (percent by volume) was taken as follows:

TABLE 7

Retention Curves Adopted for Updating Studies

Pressure (Bar)	Moisture Content (% by volume*)		
	Sample No		
	1	2	3
0	0.621	0.403	0.438
0.5	0.546	0.285	0.345
1.0	0.54	0.28	0.342
2.0	0.538	0.278	0.34
3.0	0.537	0.277	0.337
15.0	0.533	0.272	0.33

* Density = 1.53 gm/cc.

These values broadly represent 3 groups of the soil samples. It is, therefore, considered appropriate that simulation runs based upon 3 soil samples would be adequate. However, in order to study the effect of differences between the moisture retention curve, sensitivity study should be carried out on single column basis. This course of action was adopted in carrying out further

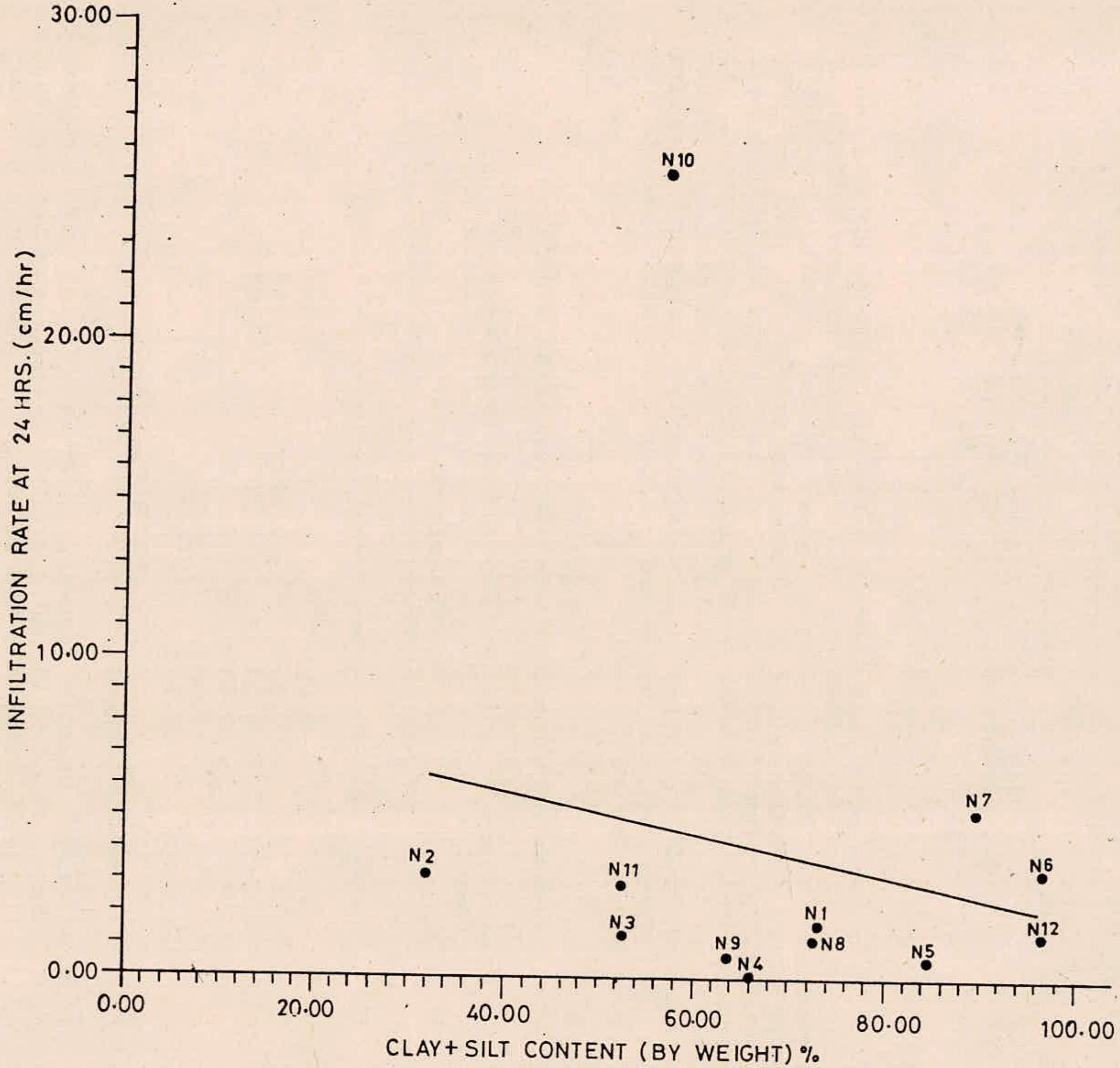


FIG.13 - PLOT OF INFILTRATION RATE AT 24 Hrs.

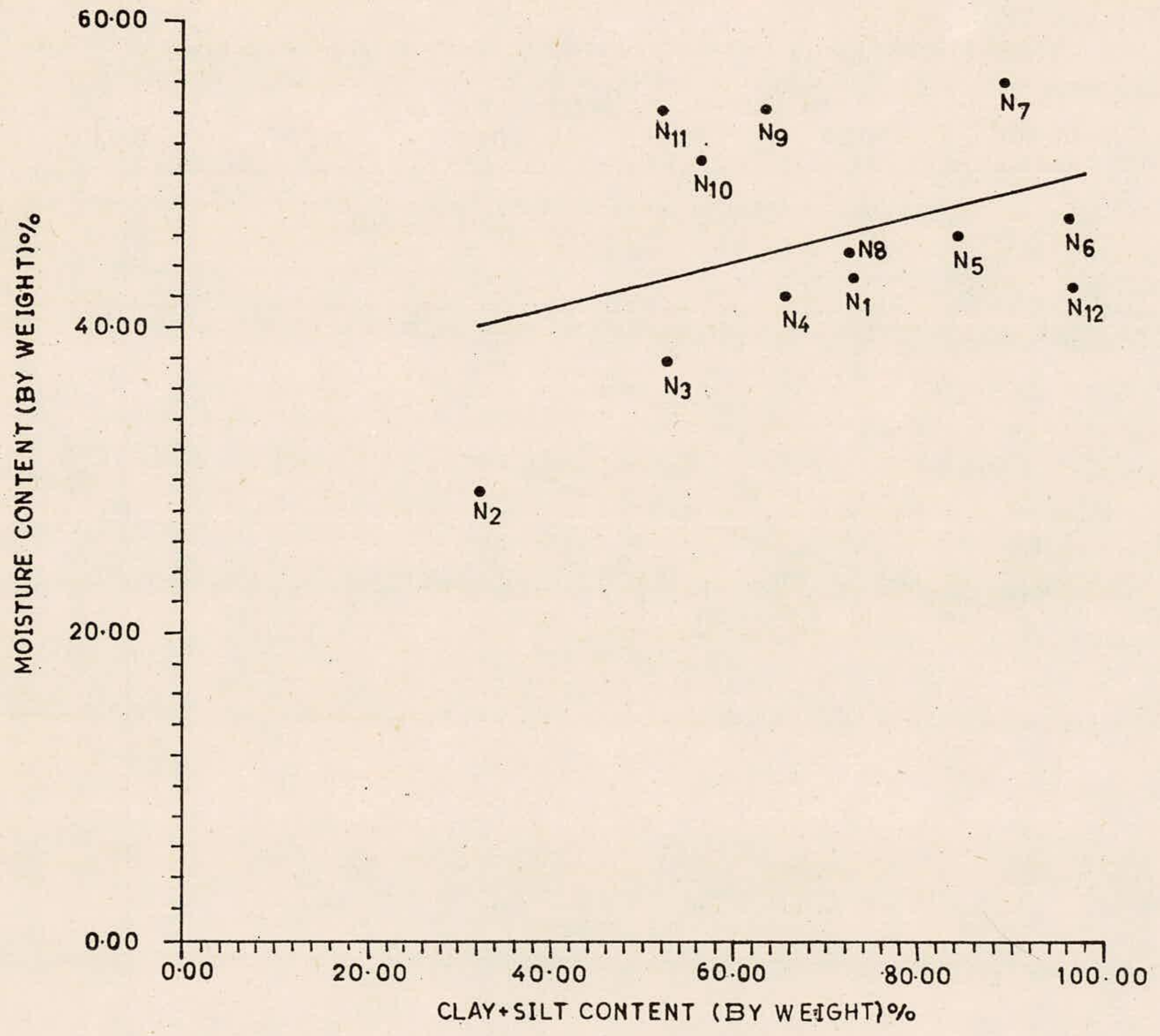


FIG. 14: —PLOT OF ORIGINAL VALUES OF CLAY & SILT AT PRESSURE (ZERO BARS)

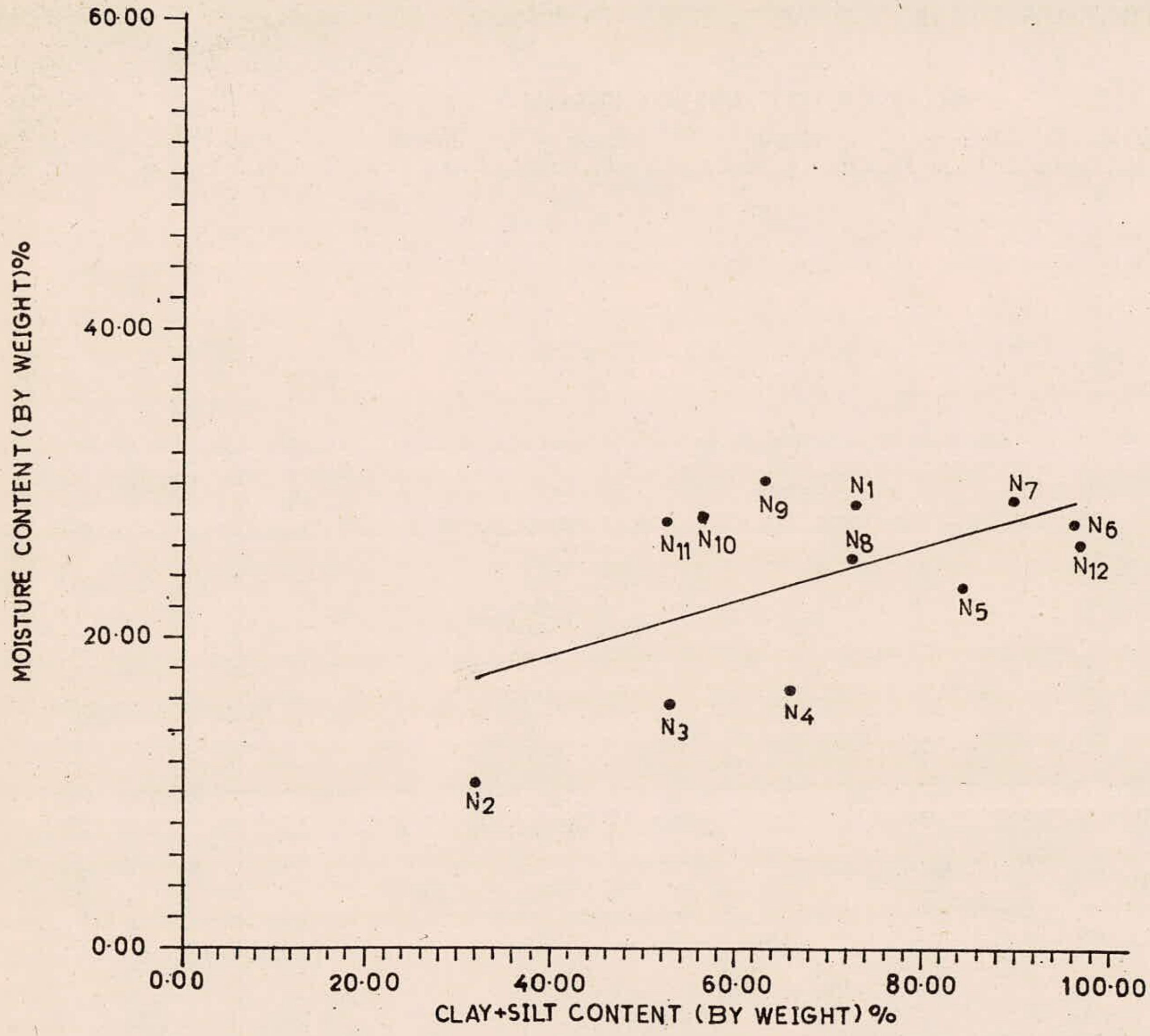


FIG.15 – PLOT OF ORIGINAL VALUES OF CLAY & SILT AT PRESSURE (3 BARS)

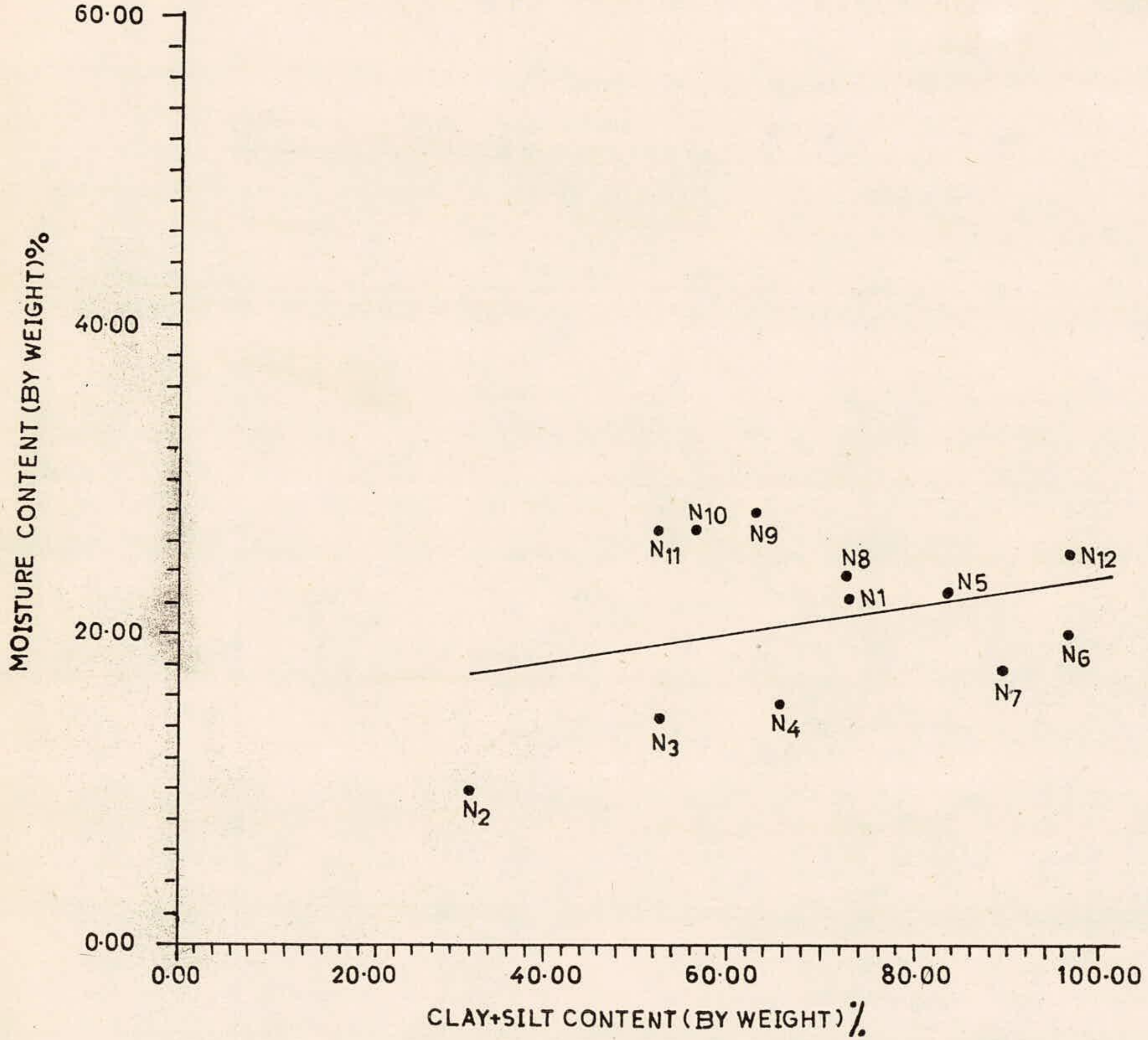


FIG. 16 — PLOT OF ORIGINAL VALUES OF CLAY & SILT AT PRESSURE (15 BARS)

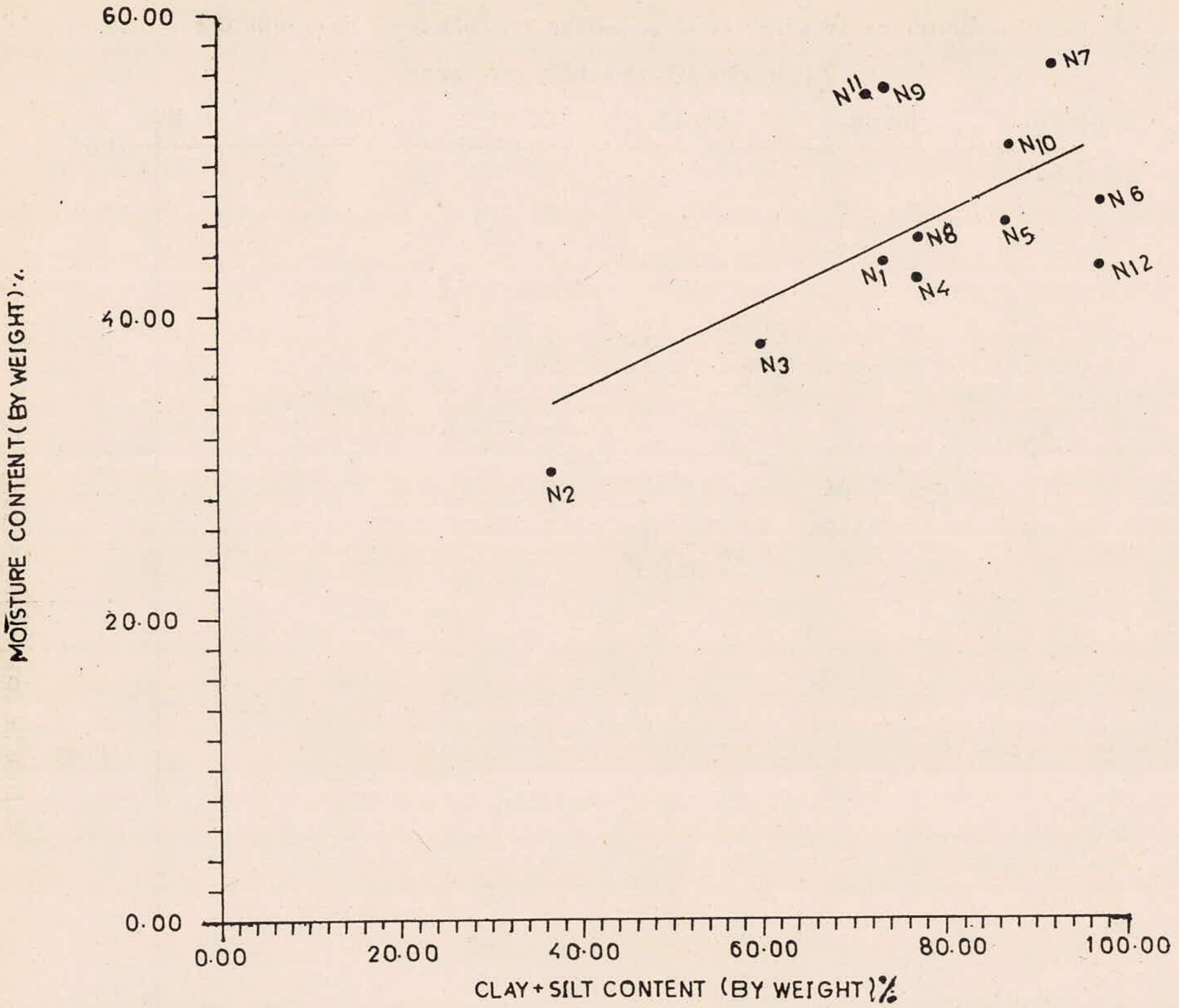


FIG. 17 : PLOT OF REVISED VALUES OF CLAY & SILT AT PRESSURE (ZERO BARS)

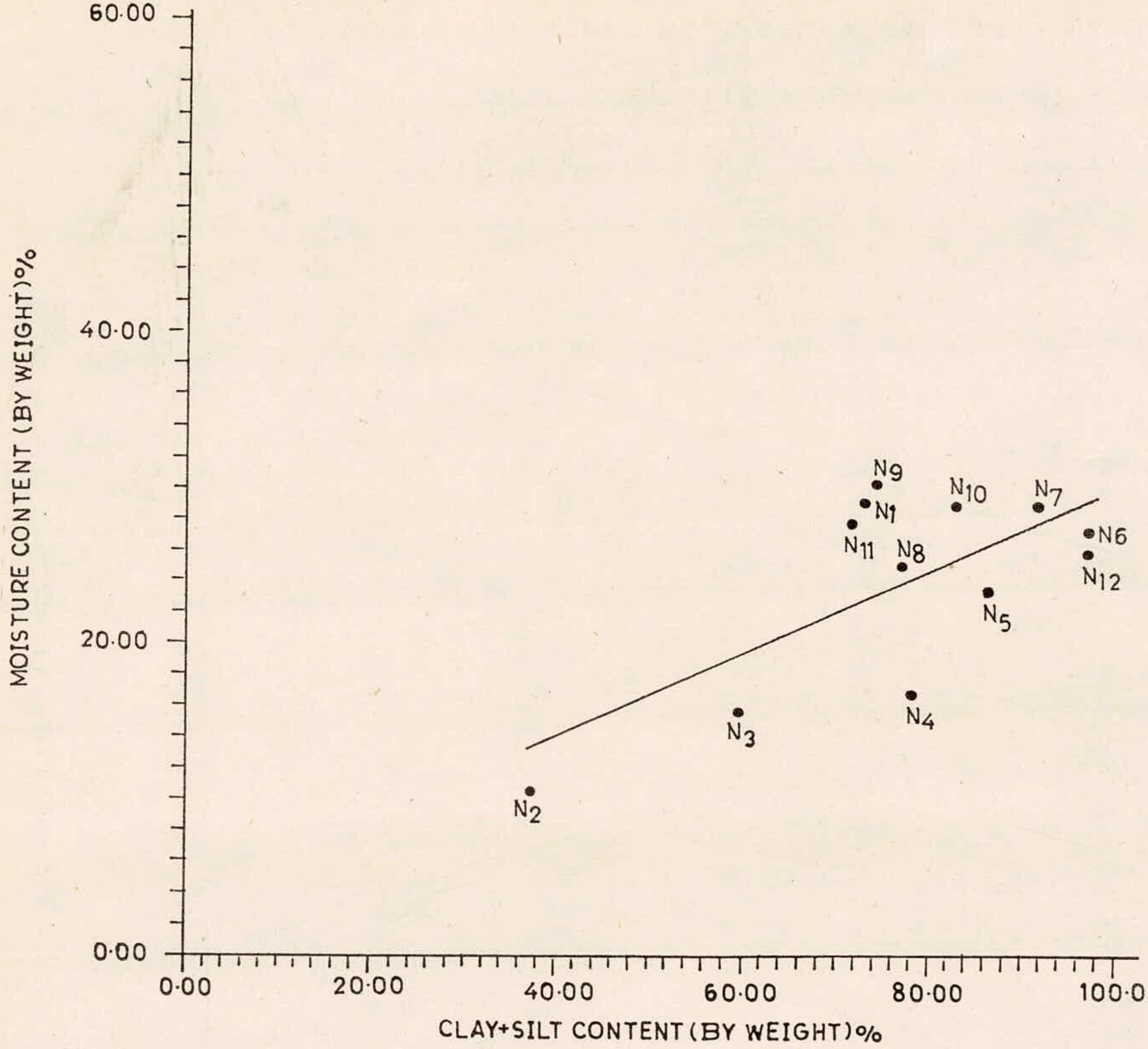


FIG. 18: PLOT OF REVISED VALUES OF CLAY & SILT AT PRESSURE (3 BARS)

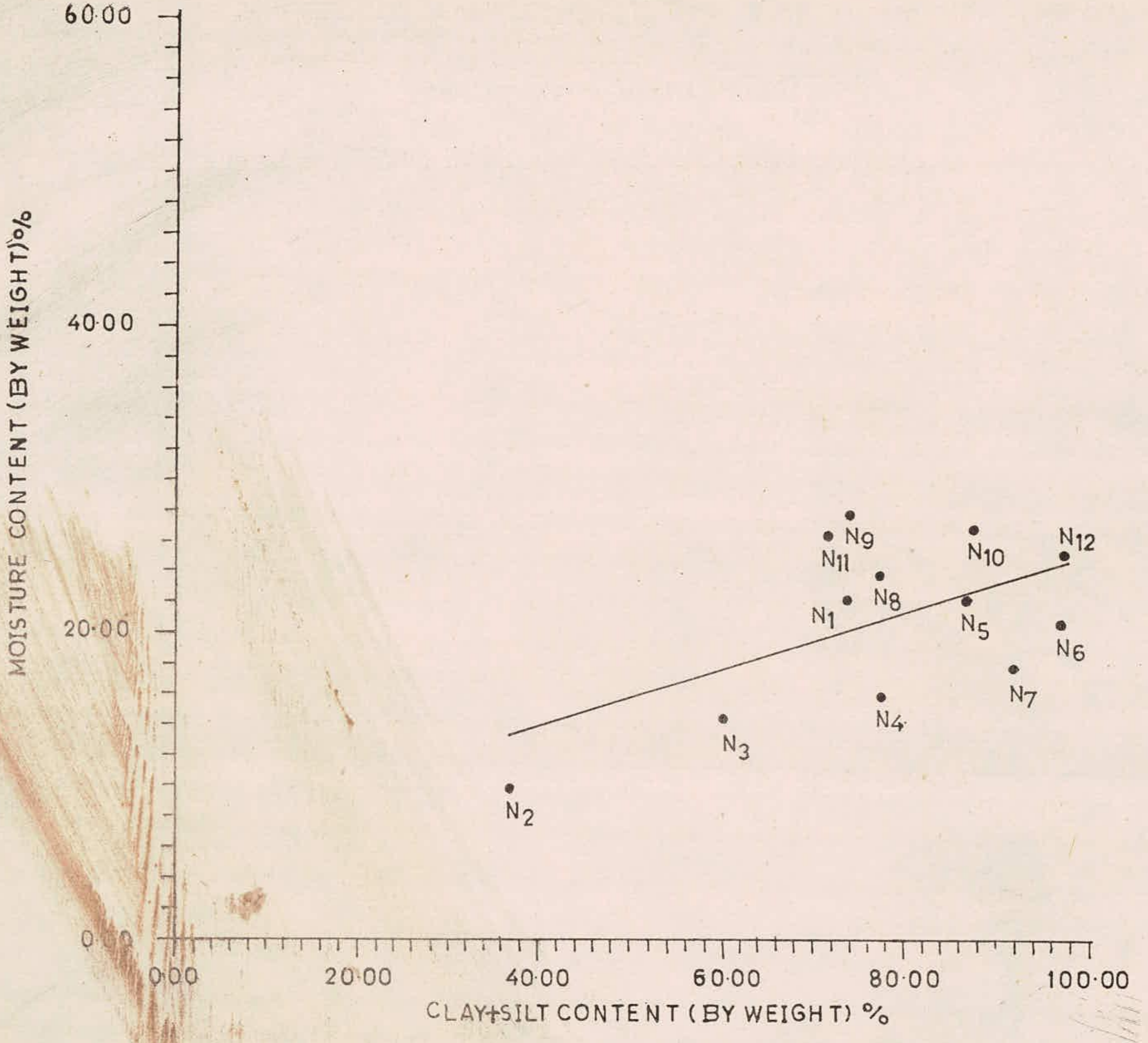


FIG.19: PLOT OF REVISED VALUES OF CLAY & SILT AT PRESSURE (15 BARS)

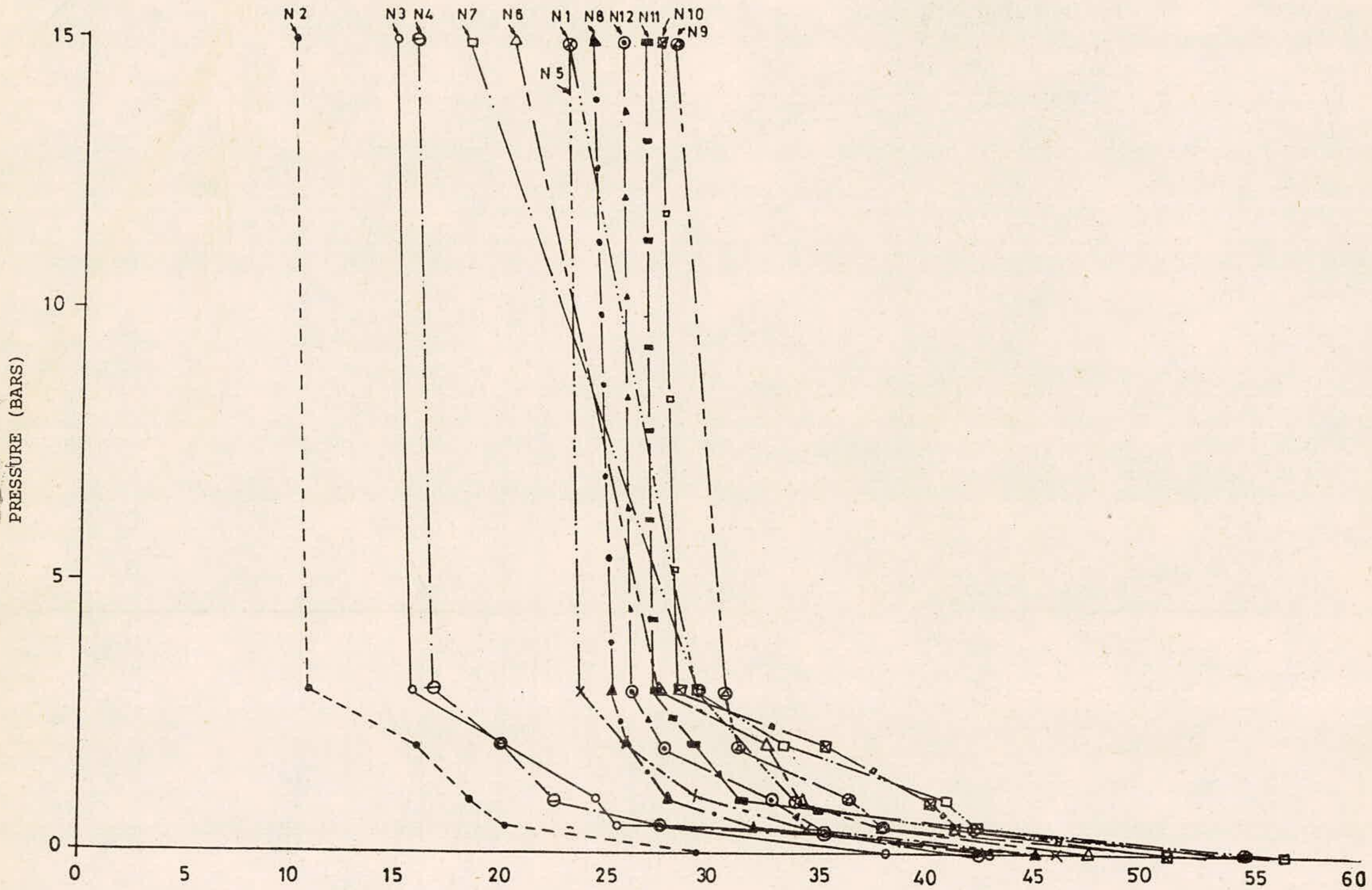


Fig.20 : MOISTURE CONTENT BY WEIGHT %

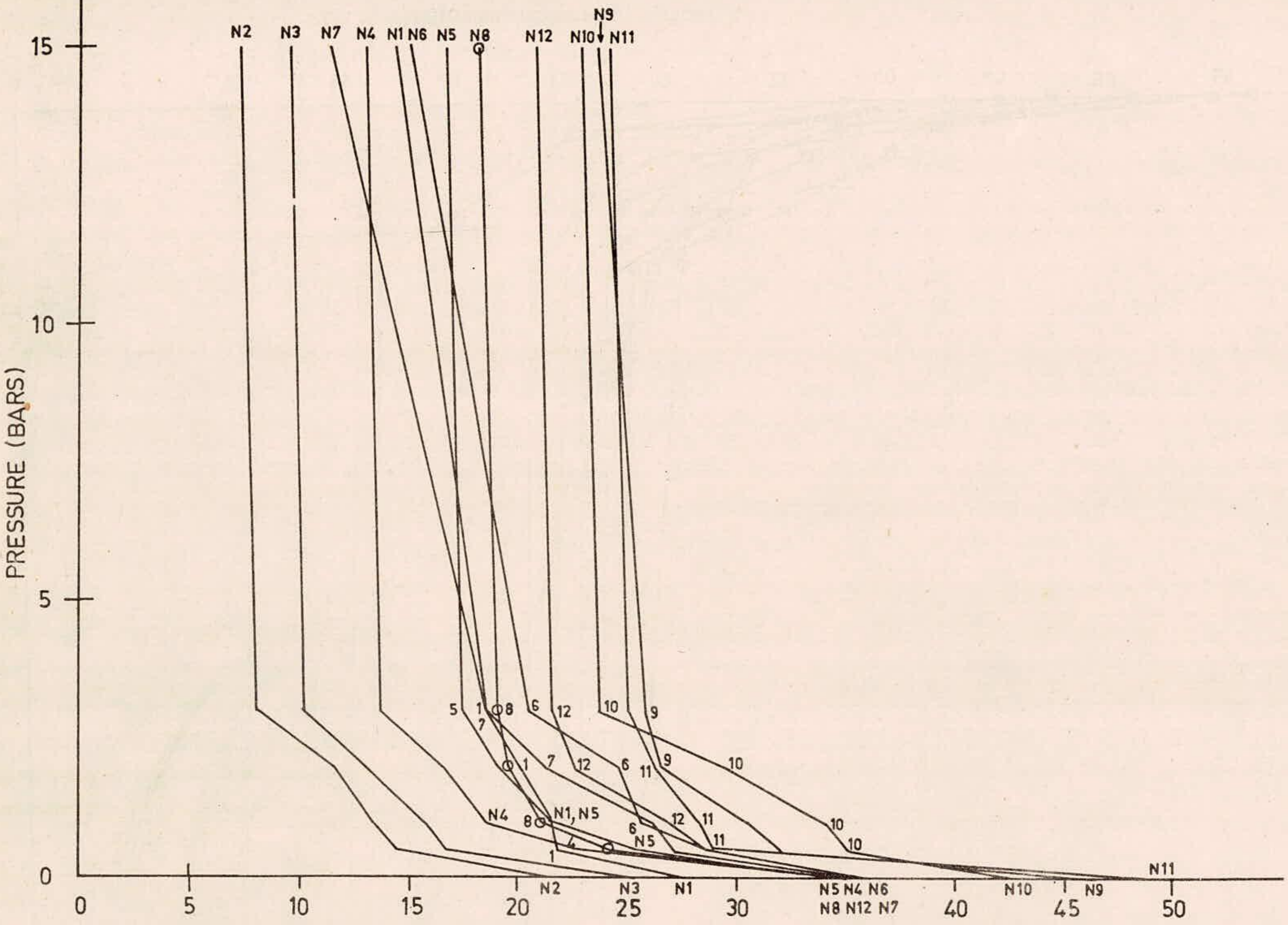


FIG. 21- MOISTURE CONTENT BY VOLUME % BASED UPON FIRST DENSITY.

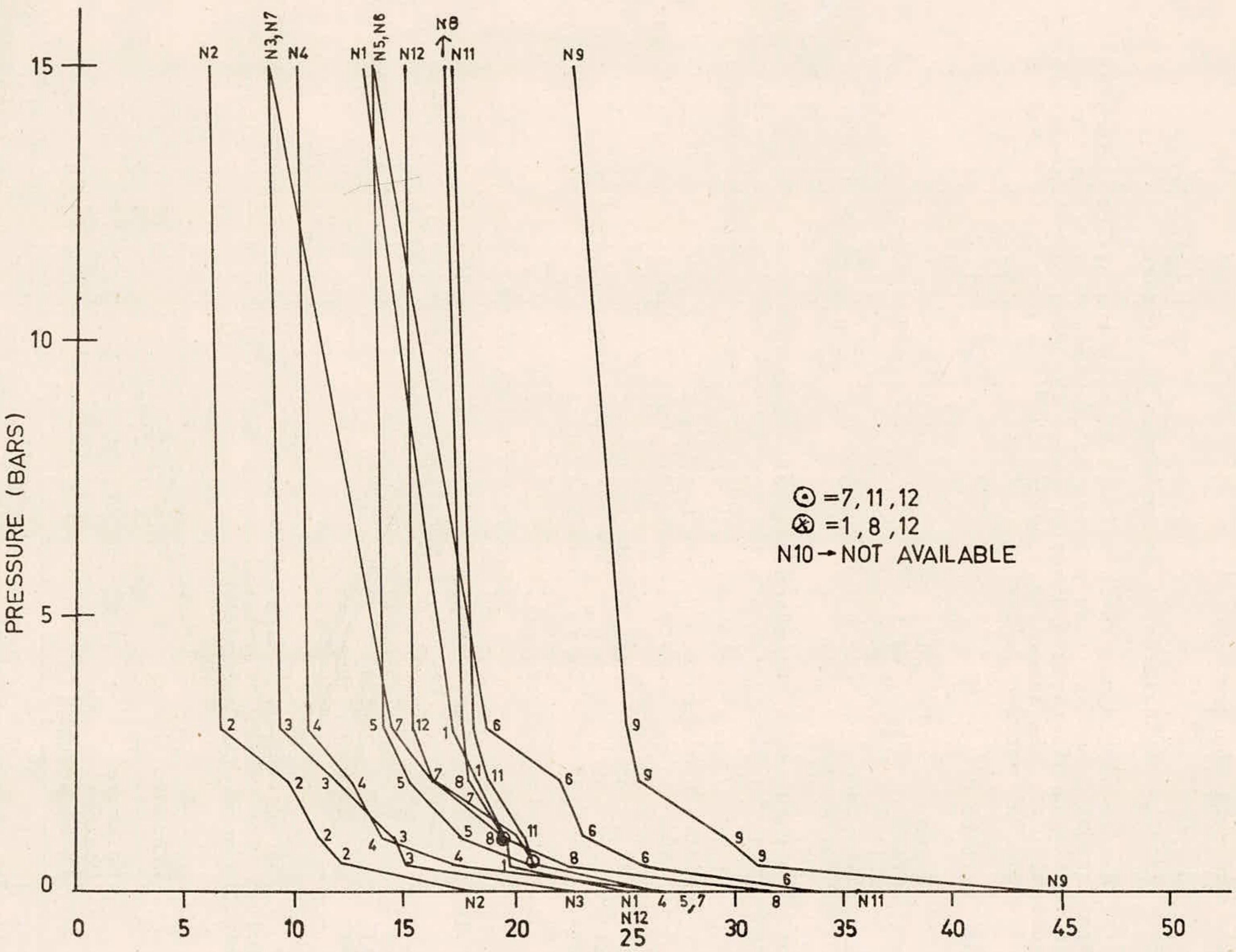


FIG. 22-MOISTURE CONTENT BY VOLUME % BASED UPON THIRD DENSITY.

studies regarding updating of Kolar simulation and effect of land use and soil changes.

6.2 Results of Analysis of Barna Sample in Denmark

A soil sample was taken to Denmark with the aim of studying the shrinking and swelling properties of black clay soils for use in modelling of cracks and macropores. The results of laboratory analysis of the sample as communicated in a note by Dr (Ms) M Styczen, DHI were as follows:

a) Texture

Humus - 1.1 %
Clay - 40.1 %
Silt - 36.7 %
Fine Sand - 17.4 %
Coarse sand - 4.7 %

b) The results of retention analysis were:

	Bulk Density (gm/cc)	Porosity	Moisture Content, Weight Percent					
			At Sample	pF1.0 (0 bar)	pF2.0 (0.1 bar)	pF2.5 (0.31bar)	pF3.0 (1 bar)	pF4.2 (15.54 bar)
1)	1.43	45.9	24.1	36.6	33.0	29.7	26.7	19.3
2)	1.25	52.7	25.0	35.7	31.9	28.5	25.2	18.7
Av:	1.34	49.3	24.6	36.2	32.5	29.1	26.0	19.0

Bulk	Moisture Content, Volume Percent					
	At Sample	pF1.0 (0 bar)	pF2.0 (0.1 bar)	pF2.5 (0.31bar)	pF3.0 (1 bar)	pF4.2 (15.54 bar)
1)	34.5	52.5	47.3	42.5	38.3	27.6
2)	31.4	44.8	40.0	35.8	31.6	23.4
Av:	33.0	48.6	43.7	39.1	35.0	25.5

The retention characteristics of Barna sample were also tested for sake of comparison, in WRDTC lab. The following results were obtained:

Pressure (bar)	0	0.5	1.0	2.0	3.0	15.0
Moisture Content (% by weight)	39.62	36.47	34.32	32.23	28.80	25.73

The results are approximately comparable, considering that 1 bar = 1018 cm and pF = $\log_{10}$ (pressure in m). There is overestimation in case of WRDTC results.

7.0 CONCLUSIONS

On the basis of the laboratory analysis carried out in NIH Laboratory and by WRDTC, the following broad conclusions can be made:

1) There is considerable difference of behaviour in moisture retention characteristic among the 12 samples. On the basis of range of soil moisture (percent by weight) recorded at 0.5 bar and 15 bar, these samples could be grouped under 7 categories.

2) The study of effect of variation with (clay + silt) content indicates broadly 3 categories among the 12 soil samples. These conclusions remain valid even when effect of removal of gravel is accounted for.

3) When the effect of bulk density is introduced by considering moisture content (percentage by weight), the moisture retention characteristic could be broadly grouped under 3 categories.

4) The consideration of 3 types of soils while carrying out updating of Kolar simulation is adequate even after analysis of results of 12 samples and studies could be made only on single column basis as sensitivity analysis to consider effect of variability of retention characteristics of soils.

5) Detailed guidelines/manual is necessary for both for taking out the samples in field and carrying out their laboratory analysis. It would be desirable to analyse mineral and organic matter content as well.

ACKNOWLEDGEMENTS

The laboratory investigation work was carried out with active cooperation of Water Resources Development Training Centre, University of Roorkee, Roorkee and Soil Laboratory of National Institute of Hydrology. Many individuals have directly and indirectly contributed in various stages of this study, in particular, thanks are due to Mr. B Storm, Dr J C Bathurst, Dr. M Erlich, Dr (Ms.) M Styczen, Mr. G H Jorgensen (Members of Consultant Staff), Dr S K Tripathi, WRDTC, Dr B Soni, Sc.'E', Shri S K Jain, Sc.'C', (NIH Staff) and the Staff in Drawing Section, NIH for preparation of various drawings is also acknowledged.

<><><><><><><><><><><><><>

APPENDIX - 1

PROCEDURE FOR SIEVE ANALYSIS AND HYDROMETER ANALYSIS

[Reproduced with the Permission from the Book: 'Soil Mechanics and Foundations', by Dr B C Punmiya, published by M/s Standard Book House, Delhi, 1982]

PARTICLE SIZE DISTRIBUTION

The percentage of various sizes of particles in a given dry soil sample is found by a particle-size analysis or ***mechanical analysis.*** By mechanical analysis is meant the separation of a soil into its different size fractions. The mechanical analysis is performed in two stages : (*i*) sieve analysis, and (*ii*) sedimentation analysis or wet mechanical analysis.

The first stage is meant for coarse-grained soils only, while the second stage is performed for fine-grained soils. In general, a soil sample may contain both coarse-grained particles as well as fine particles, and hence both the stages of the mechanical analysis may be necessary. The sieve analysis is, however, the true representative of grain size distribution, since the test is not affected by temperature etc.

SIEVE ANALYSIS

In the BS and ASTM standards, the sieve sizes are given in terms of the number of openings per inch. The number of openings per square inch is equal to the square of the number of the sieve. In the Indian Standard (IS : 460—1962), the sieves are designated by the size of the aperture in mm. Table 3·1 gives a list of sieves and their openings, for IS, BS and ASTM specifications.

The complete sieve analysis can be divided into two parts—the *coarse analysis* and *fine analysis*. An oven-dried sample of soil is separated into two fractions by sieving it through a 4·75 mm IS sieve. The portion retained on it (+4·75 mm size) is termed as the *gravel fraction* and is kept for the coarse analysis, while the portion passing through it (—4·75 mm size) is subjected to fine sieve analysis. The following set of sieves are used for coarse sieve analysis : IS : 100, 63, 20, 10 and 4·75 mm. The sieves used for fine sieve analysis are : 2 mm, 1·0 mm, 600, 425, 300, 212, 150 and 75 micron IS sieves.

Sieving is performed by arranging the various sieves one over the other in the order of their mesh openings—the largest aperture sieve being kept at the top and the smallest aperture sieve at the bottom. A receiver is kept at the bottom and a cover is kept at the top of the whole assembly. The soil sample is put on the top sieve, and the whole assembly is fitted on a sieve shaking machine. The amount of shaking depends upon the shape and the number of particles. At least 10 minutes of shaking is desirable for soils with small particles. The portion of the soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the total weight of soil sample taken and from these results, percentage passing through each sieve is calculated. Table 3·11 shows the specimen observation and calculation sheet.

It is advisable to wash the soil portion passing through 4·75 mm sieve over 75 micron sieve so that silt and clay particles sticking to the sand particles may be dislodged. Two grams of sodium hexametaphosphate is added per litre of water used.

TABLE 3·1
SIEVES DESIGNATION AND THEIR SIZES

IS Sieves IS : 460–1962		*BS Sieves BS : 410–1962*		*ASTM Sieves ASTM E 11–1961*	
Designation	*Aperture (mm)*	*Designation*	*Aperture (mm)*	*Designation*	*Aperture (mm)*
50 mm	50·0	2-in.	50·80	2-in.	50·80
40 mm	40·0	1½-in.	38·10	1½-in.	38·10
20 mm	20·0	3/4-in.	19·05	3/4-in.	19·00
10 mm	10·0	3/8-in.	9·52	3/8-in.	9·51
*5·60 mm	5·60	—	—	3½	5·66
4·75 mm	4·75	3/16-in.	4·76	4	4·76
*4·00 mm	4·00	—	—	5	4·00
*2·80 mm	2·80	6	2·80	7	2·83
2·36 mm	2·36	7	2·40	8	2·38
*2·00 mm	2·00	8	2·00	10	2·00
*1·40 mm	1·40	12	1·40	14	1·41
1·18 mm	1·18	14	2·00	16	1·19
*1·00 mm	1·00	16	1·00	18	1·00
710-micron	0·710	22	0·710	25	0·707
600-micron	0·600	25	0·600	30	0·595
*500-micron	0·500	30	0·500	35	0·500
425-micron	0·425	36	0·420	40	0·420
*355-micron	0·355	44	0·355	45	0·354
300-micron	0·300	52	0·300	50	0·297
250-micron	0·250	60	0·250	60	0·250
212-micron	0·212	72	0·210	70	0·210
*180-micron	0·180	85	0·180	80	0·177
150-micron	0·150	100	0·150	100	0·149
*125-micron	0·125	120	0·125	120	0·125
*90-micron	0·090	170	0·090	170	0·088
75-micron	0·075	200	0·075	200	0·074
*63-micron	0·063	240	0·063	230	0·063
*45-micron	0·045	350	0·045	325	0·044

*Sieves marked with *have been proposed as an International (ISO) Standard. It is recommended to include, if possible, these sieves in all sieve analysis data or reports.

Washing should be continued until the water passing through 75 micron sieve is substantially clean. The fraction retained on the 75 micron sieve is dried in the oven. The dried portion is then ressieved through 2 mm, 1 mm, 600, 425, 300, 212, 150 and 75 micron IS sieves. The portion passing 75 micron sieve (while washing) is also dried separately and its weight determined to get % finer than 75 micron size. If the portion passing 75 micron size is substantial, wet analysis is done for further sub division of particle size distribution. [See Experiment 8].

SEDIMENTATION ANALYSIS : THEORY

In the wet mechanical analysis, or sedimentation analysis, the soil fraction, finer than 75 micron size is kept in suspension in a liquid (usually, water) medium. The analysis is based on Stokes' law, according to which the velocity at which grains settle out of suspension, all other factors being equal, is dependent upon the shape, weight and size of the grains. However, in the usual analysis, it is assumed that the soil particles are spherical and have the same specific gravity (the average specific gravity). With this assumption, the coarser particles settle more quickly than the finer ones. If v is the terminal velocity of sinking of a spherical particle, it is given by

$$v=\frac{2}{9}\,r^2\,\frac{\gamma_s-\gamma_w}{\eta} \qquad (3\cdot5)$$

or

$$v=\frac{1}{18}\,D^2\,\frac{\gamma_s-\gamma_w}{\eta} \qquad (3.5\,a)$$

where r=radius of the spherical particle (cm)

D=diameter of the spherical particle (cm)

v=terminal velocity (cm/sec)

γ_s=density (unit wt.) of particles (g/cm^3)

γ_w=density of water/liquid (g/cm^3)

η=viscosity of water/liquid (g-sec/cm^2)

$=\dfrac{\mu}{g}$

μ=viscosity in absolute units of dyne-sec/cm^2 (or poise)

g=acceleration due to gravity (cm/sec^2)

If water is used as the medium for suspension, γ_w is equal to 1 g/cm^3. Similarly, in C.G.S. units, $\gamma_s=G\gamma_w=G$. Substituting these in Eq. 3·5*a*, and expressing the diameter of the particle in *millimetre*, we get

$$v=\frac{1}{18}\left(\frac{D}{10}\right)^2\frac{G-1}{\eta}=\frac{G-1}{1800\eta}\,D^2 \qquad (3\cdot6)$$

$$D=\sqrt{\frac{1800\eta v}{G-1}}\ \text{mm} \qquad (3{\cdot}7)$$

If a particle of diameter D mm falls through a height H_e cm in t minutes,

$$v=\frac{H_e}{60t}\ \text{cm/sec}$$

Substituting this in Eq. 3·7, we get

$$D=\sqrt{\frac{1800\eta}{G-1}\cdot\frac{H_e}{60t}}$$

or

$$D=\sqrt{\frac{30\eta}{G-1}}\cdot\sqrt{\frac{H_e}{t}} \qquad (3{\cdot}8)$$

or

$$D=10^{-5}\,M\sqrt{\frac{H_e}{t}} \qquad (3{\cdot}9)$$

where $M=10^{5}\sqrt{\frac{30\eta}{G-1}}$ is a constant factor for given values of η and G. However, η depends upon the temperature (see Table 3·2), and hence factor M varies with the temperature which changes during the total time of testing. Table 3·2 gives the values of the factor M for various values of G and temperature. Also Fig. 3·4 gives the curves for factor M.

At 20°C, the viscosity μ of distilled water is approximately 0·01 poise.

Hence $\eta=\frac{0{\cdot}01}{980}$ g-sec/cm² ($\approx 10^{-5}$ g-sec/cm²)

Taking an average value of $G=2{\cdot}68$, we get from Eq. 3·6,

$$v=\frac{(2{\cdot}68-1)\,980}{1800\times0{\cdot}01}\times D^2=91{\cdot}5\,D^2 \qquad \ldots(3{\cdot}10)$$

Eq. 3·10 is an approximate version of Stokes' law, and can be easily remembered for rough determinations. Based on this, the time of settlement of particles of various diameters, through a height of 10 cm are as under

Diameter (mm)	*Time*
0·06	32 s
0·02	4 m 40 s
0·01	12 m 36 s
0·006	51 m 48 s
0·004	1 h 56 m 24 s
0 002	7 h 46 m 12 s
0·001	31 h 6 m

TABLE 3·2
VALUES OF FACTOR *M*
(After calculations by the Author)

Temp, °C	μ (Poise)	Factor *M*					
		$G=2{\cdot}50$	$G=2{\cdot}60$	$G=2\ 65$	$G=2\ 70$	$G=2{\cdot}75$	$G=2{\cdot}80$
15	0·01145	1528	1479	1458	1435	1414	1305
16	0 01116	1508	1460	1438	1417	1396	1377
17	0·01088	1490	1442	1420	1399	1379	1360
18	0 01060	1470	1423	1402	1381	1361	1342
19	0·01034	1452	1406	1384	1364	1344	1325
20	0·01009	1434	1389	1367	1347	1328	13 9
21	0·00984	1417	1372	1351	1331	1311	1294
22	0·00961	1400	1355	1335	1315	1296	1278
23	0.00938	1383	1339	1318	1291	1280	1262
24	0·00916	1367	1323	1305	1284	1265	1248
25	0·00896	1351	1308	1288	1269	1251	1233
26	0 00875	1335	1293	1273	1254	1236	1219
27	0 00855	1321	1279	1259	1241	1224	1206
28	0·00836	1305	1264	1244	1226	1208	1191
29	0·00818	1291	1250	1231	1213	1195	1178
30	0 00800	1277	1236	1217	1199	1182	1165
31	0 00783	1264	1224	1205	1187	1170	1154
32	0 00767	1251	1211	1193	1175	1158	1142
33	0·00751	1238	1199	1180	1163	1146	1130
34	0 00736	1225	1186	1168	1151	1134	1118
35	0·00721	1212	1174	1156	1139	1120	1107
36	0 00706	1199	1161	1144	1127	1110	1095
37	0 00692	1188	1150	1133	1116	1100	1084
38	0 00679	1176	1139	1122	1105	1089	1074
39	0 00666	1165	1128	1110	1094	1079	1064
40	0 00654	1155	1118	1101	1084	1069	1055

***Note*: For intermediate values, linear interpolation may be done.**

The sedimentation analysis is done either with the help of a hydrometer or a pipette. In both the methods, a suitable amount of

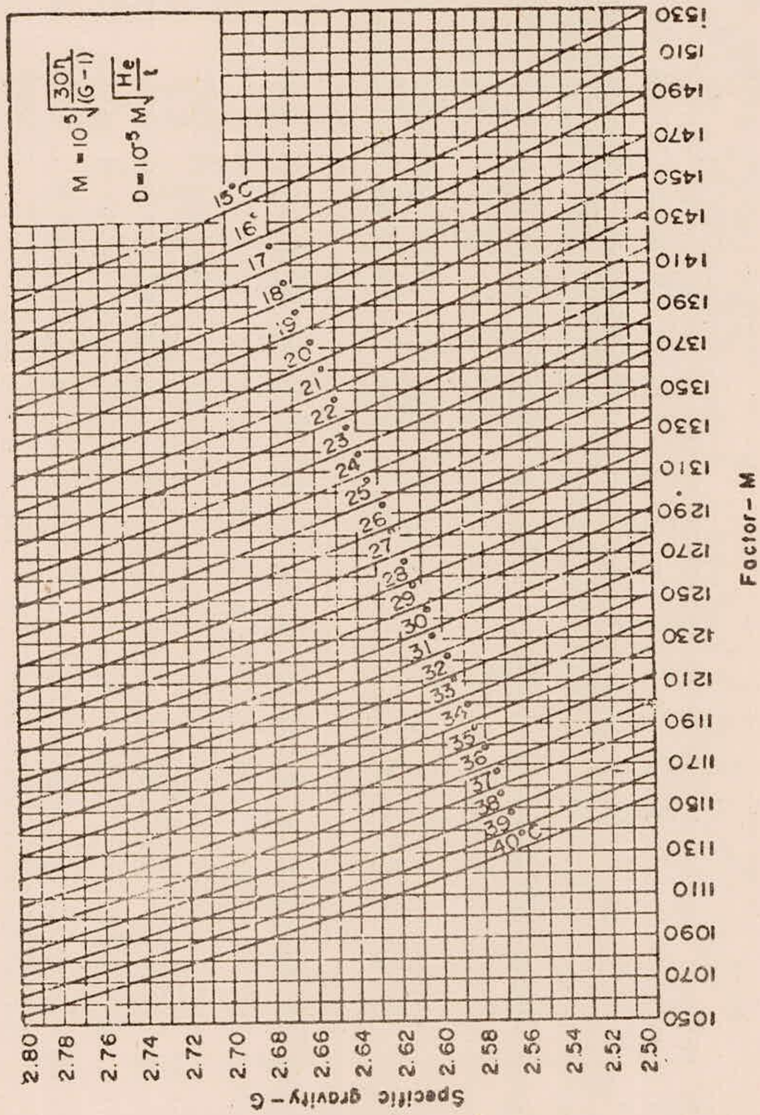


FIG. 3·4

Values of factor *M* (After calculations by the Author)

oven-dried soil sample, finer than 75-micron size, is mixed with a given volume V of distilled water. The mixture is shaken thoroughly and the test is started by keeping the jar, containing soil-water mixture, vertical. At the commencement of sedimentation test, soil particles are assumed to be uniformly distributed throughout the suspension. After any time interval t, if a sample of soil suspension is taken from a height H_e (measured from the top level of suspension), only those particles will remain in the suspension which have not settled during this time interval. The diameter of those particles, which are finer than those which have already settled, can be found from Eq. 3·9. The greater the time interval t allowed for suspension to settle, the finer are the particle sizes retained at this depth H_e. Hence sampling at different time intervals, at this sampling depth H_e, would give the content of particles of different sizes.

If, at any time interval t, W_D is the weight, per ml, of all particles smaller than the diameter D (determined from Eq. 3·9) still in suspension at the depth H_e, the percentage finer than D is given by

$$N=\frac{W_D}{W_d/V}\times 100 \tag{3·11}$$

where N = percentage finer than the diameter D

W_d = total dry weight of all particles put in the suspension

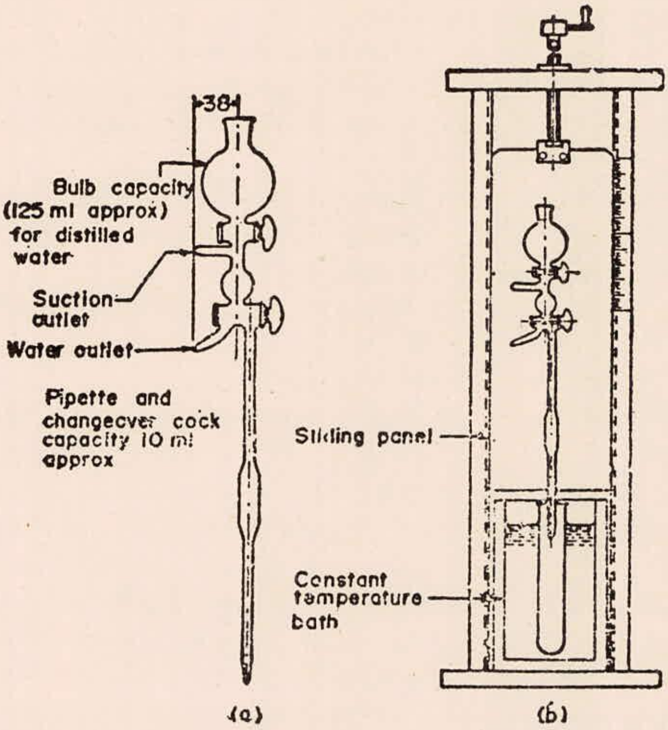
V = volume of suspension.

Thus, with the help of Eqs. 3·9 and 3·11, we can get various diameters D and the percentage of particles finer ($N\%$) than this diameter.

Limitations of sedimentation analysis. The analysis is based on the assumptions that (*i*) soil particles are spherical, (*ii*) particles settle independent of other particles and the neighbouring particles do not have any effect on its velocity of settlement, and (*iii*) the walls of jar, in which the suspension is kept, also do not affect the settlement. In actual practice, the fine particles of soil, for which this analysis is primarily meant, are not truly spherical. The particles of fine grained soils are thin platelets which do not settle out of suspension in the same manner and at the same rate as smooth spheres. Thus, the sedimentation analysis gives the particle size in *equivalent diameter*. The upper limit of particle size for the validity of the law is about 0·2 mm (Taylor : 1948) beyond which the liquid tends to develop a turbulent motion at the boundaries of the particles. The lower limit of particle size is about 0·0002 mm. For particles smaller than 0·0002 mm equivalent diameter, Brownian movement affects their settlement, and Stokes' law no longer remains valid. Also it is assumed that the soil has an average specific gravity, the value of which is used in computing the diameter D. Actually, different particles may have different specific gravity, depending upon their mineral constituents. The settlement of the particles is influenced by the surrounding particles as the liquid is not of infinite extent. The particles falling near the wall of the jar are also affected.

PIPETTE METHOD

The pipette method is the standard sedimentation method used in the laboratory. The equipment consists of a pipette, a jar and a number of sampling bottles. Generally, a boiling tube of 500 ml capacity is used in place of a jar. Fig. 3·5 shows a pipette for extracting samples from the jar (or tube) from a desired depth (H_e). The pipette consists of (*i*) a 125 ml bulb with stopcock, for keeping distilled water, (*ii*) a three way stop cock, (*iii*) suction and waste water outlets, and (*iv*) sampling pipette of 10 ml capacity (including the capacity of the cock). The method consists in drawing off samples of soil suspension, 10 ml in volume, by means of this pipette from a depth of 10 cm (H_e) at various time intervals after the commencement of the sedimentation. The recommended time intervals are : ½, 1, 2, 4, 8, 15 and 30 minutes, and 1, 2, 4, 8, 16 and 24 hours, reckoned from the commencement of the test. The pipette should be inserted in the boiling tube about 27 seconds before the selected time interval, and the time taken for sucking the sample should not be more than 10 to 20 seconds. Each



Sampling pipette Pipette, boiling tube. etc.

FIG. 3·5

Pipette Analysis Apparatus

sample, so taken, is transferred into suitable sampling bottles and dried in an oven. The weight W_D of solids per ml of suspension is thus found by taking the dry weight and dividing it by 10.

Method of preparing soil suspension. In the sedimentation analysis, only those particles which are finer than 75 micron size are included. Hence the soil sample is washed through a 75 micron sieve. About 12 to 30 g of oven-dried sample (depending upon the type of soil) is accurately weighed and mixed with distilled water in a dish or beaker to form a smooth thin paste. To have proper dispersion of soil, a dispersing agent (deflocculating agent) is added to the soil. Some of the common dispersing agents are : sodium oxalate, sodium silicate, and sodium polyphosphate compounds, such as tetra sodium pyrophosphate, sodium hexametaphosphate (*calgon*) and sodium tripolyphosphate. IS : 2720 (Part IV)—1965 recommends the use of dispersing solution containing 33 g of the sodium-hexametaphosphate and 7 g of sodium carbonate in distilled water to make one litre of solution. 25 ml of this solution is added to the dish (containing the soil and distilled water) and the mixture is warmed gently for about 10 minutes. The contents are then transferred to the cup of a mechanical mixer, using a jet of distilled water to wash all traces of the soil out of the evaporating dish. The soil suspension is then stirred well for 15 minutes or longer in the case of highly clayey soils. The suspension is then washed through 75 micron sieve, using jet of distilled water and the suspension, which has passed through the sieve, is transferred to the 500 ml capacity boiling tube (sedimentation tube). Care should be taken that all the particles finer than 75 micron size are transferred to the tube. The tube is then filled to the 500 ml mark, by adding distilled water. The tube is then put in a constant temperature water bath [Fig. 3·5 (*b*)], where used. When the temperature in the tube has been stabilised to the temperature of the bath, the soil suspension is thoroughly shaken by inverting the tube several times, and then replaced in the bath. The stop watch is then started, and soil samples are collected at various time intervals, with the help of pipette.

Those soils, which contain organic matter and calcium compounds, are *pretreated* before the dispersing agent is mixed (as explained above), since these contents act as cementing agents and cause the particles to settle as aggregations of particles instead of as individuals. The process of removal of organic matter and calcium compounds is known as *pretreatment*. The soil is first treated with hydrogen peroxide solution to remove the organic matter by oxidation. The mixture of soil and hydrogen peroxide is kept warm at a temperature not exceeding 60°C, till no further evolution of the gas takes place. The remaining hydrogen peroxide in the solution is then decomposed by boiling the solution. To remove the calcium compound, the cooled mixture of soil is then treated with 0·2N hydrochloric acid. When the reaction is complete, the mixture is filtered. and the filtrate is washed with distilled water until it becomes free from the acid. The filtrate is then dried in the oven, to know the loss of weight due to pretreatment.

Calculations of D and N

10 ml samples are collected from the soil suspension (sedimentation tube) from a depth of 10 cm, with the help of the pipette, at various time intervals. The samples are collected into the weighing bottles (sampling bottles), and kept in the oven for drying. The weight W_D, per ml of suspension so collected is calculated as under :

$$W_D=\frac{\text{Dry wt. of sample in the weighing bottles}}{V_p} \qquad (3\cdot12)$$

where V_p=valume of the pipette

=volume of sample collected in the weighing bottle

=10 ml.

The percentage finer is calculated from the following expression on Eq. 3·11 :

$$N'=\frac{W_D-\frac{w}{V}}{W_d/V}\times 100 \qquad (3\cdot13)$$

where w=Weight of dispersing agent present in the total suspension of volume V

V=Volume of suspension=500 ml

N'=Percentage finer, based on W_d.

If 25 ml of dispersing agent solution, containing 33 g of sodium hexametaphosphate and 7 g of sodium carbonate per litre is used, we get

$$w=\frac{33+7}{1000}\times 25=1 \text{ g}.$$

The corresponding diameter D of the particle, to which the above percentage of soil is finer, is calculated from Eq. 3·9. The observations may be recorded as shown in Table 3·13.

The pipette method, though very sample, requires more time, and is not suitable for routine control tests. The apparatus is very sensitive, and very accurate weighings are required. Due to these reasons, sometimes the hydrometer method of sedimentation analysis is preferred.

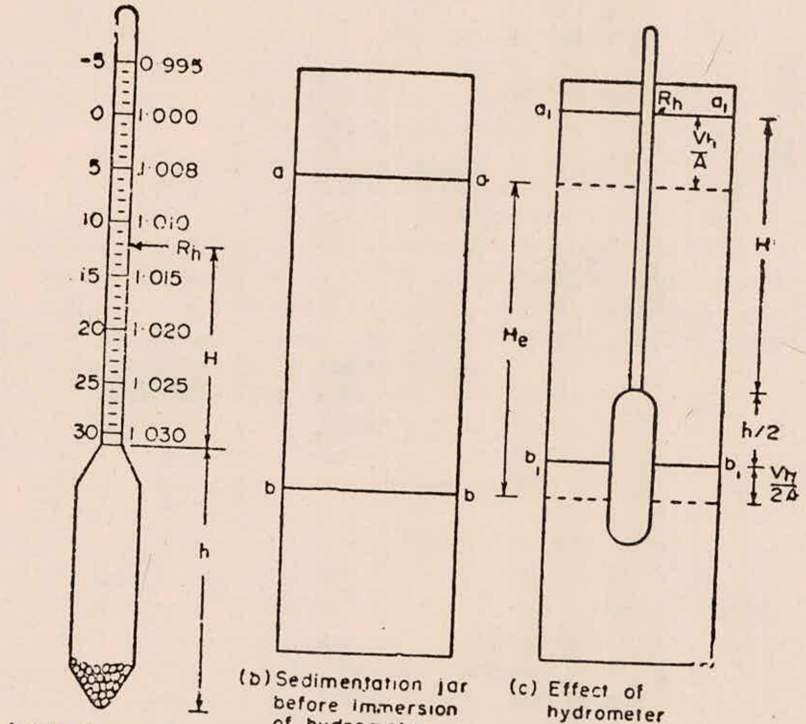
HYDROMETER METHOD

The hydrometer method of sedimentation analysis differs from the pipette analysis in the method of taking the observations—the principles of the tests being the same in both the cases. In the pipette analysis, the weight W_D per ml of suspension is found directly by collecting a 10 ml sample of soil suspension from the sampling depth H_e. However, in the hydrometer analysis, W_D is computed indirectly by reading the density of the soil suspension at a depth H_e at various time intervals. In the pipette test, the sampling depth H_e is kept constant (=10 cm) while in the hydrometer test, the sampling depth H_e (also known as the effective depth) goes on increasing as the particles settle with the increase in the time interval. It is, therefore, necessary to calibrate the hydrometer and the sedimentation jar before the start of the sedimentation test, to find a relation between H_e and the density readings of the hydrometer. If the same set of hydrometer and sedimentation jar are used for a number of tests, one calibration chart will serve the purpose of these tests.

Calibration of hydrometer

Fig. 3·6 (*a*) shows the hydrometer. The readings on the hydrometer stem give the density of the soil suspension situated at the centre of the bulb at any time. For convenience, the hydrometer readings are recorded after subtracting 1 and multiplying the remaining digits by 1000. Such a *reduced reading* is designated as R_h. For example, if the density reading at the intersection of horizontal surface of soil suspension with the stem, is 1·010, it is recorded as 10 (*i.e.* $R_h=10$). Similarly, a density reading of 0·995 is recorded as $R_h=-5$. As indicated in Fig. 3·6 (*a*) the hydrometer readings R_h (and also the density readings) increase in the downward direction towards the hydrometer bulb. Let H be the height, in cm, between any hydrometer reading R_h and the neck, and h the height of the bulb.

Fig. 3·6 (*b*) shows the jar, containing the soil suspension. When the hydrometer is immersed in the jar (Fig. 3·6 *c*), the water level *aa* rises to a_1a_1, the rise being equal to the volume V_h of the hydrometer divided by the internal area of cross-section A of the jar. Similarly the level *bb* rises to b_1b_1, where *bb* is the level, situated at a depth H_e below the top level *aa*, at which the density measurements of the soil suspension are being taken. The rise between bb and b_1b_1 will be approximately equal to $\frac{V_h}{2A}$. The level b_1b_1 is



(a) Hydrometer

(b) Sedimentation jar before immersion of hydrometer

(c) Effect of hydrometer immersion

FIG. 3·6

Hydrometer Analysis

now corresponding to the centre of the bulb, but the soil particles at b_1b_1 are of the same concentrations as they were at bb. Therefore, we have

$$H_e=\left(H+\frac{h}{2}+\frac{V_h}{2A}\right)-\frac{V_h}{A}$$

or

$$H_e=H+\frac{1}{2}\left(h-\frac{V_h}{A}\right) \tag{3·14}$$

In the above expression, there are two variables : the effective depth H_e, and the depth H which depends upon the hydrometer reading R_h. Therefore, by selecting various hydrometer readings R_h, the depth H can be measured with the help of an accurate scale, and the corresponding depths H_e can be found. The height h of the bulb is constant. Similarly V_h and A are constants. To find the volume of the hydrometer, it is weighed accurately. The weight of the hydrometer in grams gives the volume of the hydrometer in millilitres. The observations are tabulated as shown in Table 3·3.

TABLE 3·3

CALIBRATION OF HYDROMETER

1. Hydrometer No. 25
2. Volume of Hydrometer $V_h=72$ cm^3
3. Height of bulb $(h)=16\cdot6$ cm

1. Sedimentation Jar No. 5.
2. Sectional Area of Jar $A=30$ cm^2
3. Constant $\frac{1}{2}\left(h-\frac{V_h}{A}\right)=7\cdot1$ cm,

Hydrometer reading R_h	H (*cm*)	*Effective depth* H_e(*cm*)
30	1·8	8·9
25	3·6	10·7
20	5·4	12·5
15	7·3	14·4
10	9·2	16·3
5	11·1	18·2
0	13·0	20·1
–5	14·9	22·0

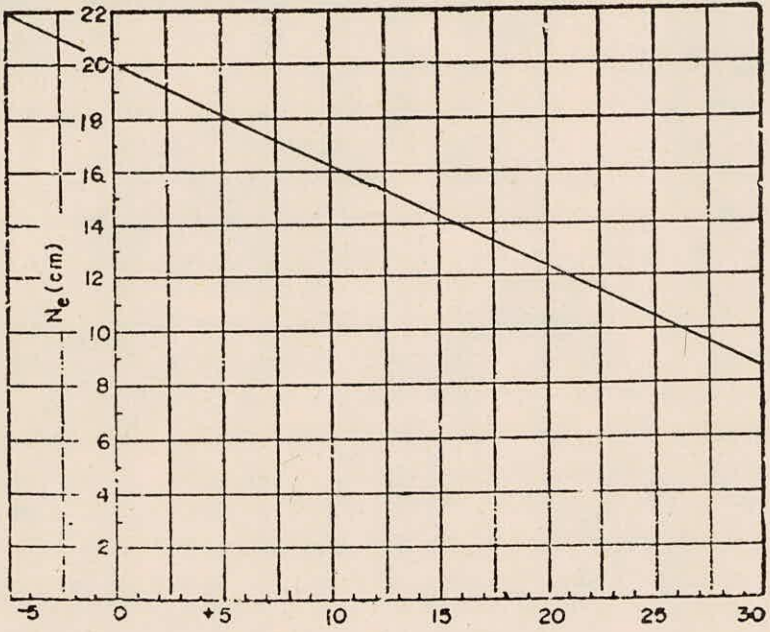


FIG. 3·7
Calibration curve for the hydrometer

Based on the observations of Table 3·3, a calibration curve (straight line) has been shown in Fig. 3·7. The curve is useful in finding the value of H_e for any value of hydrometer reading R_h.

Test procedure. The method of preparation of soil suspension is the same as indicated in the pipette test. However, the volume of suspension is 1000 ml in this case, and hence, double the quantity of dry soil and dispersing agent is taken. The sedimentation jar (cylinder) is shaken vigorously and is then kept vertical over a solid base. The stop watch is simultaneously started. The hydrometer is slowly inserted in the jar and readings are taken at ½, 1 and 2 minutes time intervals. The hydrometer is then taken out. More readings are then taken at the following time intervals: 4, 8, 15, 30 minutes and 1, 2, 4 hours etc. To take the reading, the hydrometer is inserted about 30 seconds before the given time interval, so that it is stable at the time when the reading is to be taken. Since the soil suspension is opaque, the reading is taken corresponding to the upper level of the meniscus. A suitable meniscus correction is then applied to the hydrometer readings.

Correction to the hydrometer readings. The hydrometers are generally calibrated at 27°C. If the temperature of the soil suspension is not 27°C, a *temperature correction* C_t should be applied to the observed hydrometer reading. If the test temperature is more than 27°C, the hydrometer readings will naturally be less than what they should be, and hence the temperature correction will be *positive*. Similarly, if the test temperature is lower than 27°C, the temperature correction will be negative. In addition to this, two more corrections are to be applied to the hydrometer readings: the *meniscus correction* and the *dispersing agent correction*. Since the soil suspension is opaque, the hydrometer reading is taken at the top of the meniscus. Actual reading, to be taken at the water level, will be *more* since the readings increase in the downward direction. Hence the meniscus correction C_m is always *positive*. Its magnitude can be found by immersing the hydrometer in a jar containing clear water, and finding the difference between the readings corresponding to the top and bottom of the meniscus. Similarly, the addition of dispersing agent in water increases its density, and hence the *dispersing agent correction* C_d is always *negative*. Thus, the corrected hydrometer reading R is given by

$$R = R_h' + C_m \pm C_t - C_d \qquad (3{\cdot}15)$$

where R_h' = observed hydrometer reading at the top of the meniscus

The three corrections can be combined into one correction, known as the *composite correction* $\pm C$ and Eq. 3·15 can be represented as

$$R = R_h' \pm C \tag{3·16}$$

Similarly, the hydrometer reading, corrected for meniscus correction above, is given by

$$R_h = R_h' + C_m \tag{3·17}$$

Eq. 3·17 is useful for finding the effective height H_e from the calibration chart (curve) corresponding to the observed reading R_h'.

In order to find the composite correction C, an identical cylinder with 1000 ml capacity is taken, and filled with distilled water and the same quantity of dispersing agent is used in the test cylinder. The temperature of both the cylinders should be the same. The hydrometer is immersed in this comparison cylinder containing distilled water and dispersing agent, and reading is taken at the ***top*** of the meniscus. The ***negative*** of the hydrometer reading so obtained gives the composite correction. For example, if the hydrometer reading in the comparison cylinder is $+2$, the composite correction $C = -2$. Similarly, if the reading is -1, the composite correction will be $C = +1$. The composite correction is found before the start of the test, and also at every time interval exceeding 30 minutes.

Computation of D and N. The particle size D is calculated from Eq. 3·9 :

$$D = 10^{-5} M \sqrt{\frac{H_e}{t}} \tag{3·9}$$

For various time intervals, R_h is found from Eq. 3·7 and corresponding values of H_e from Fig. 3·7. Substituting the values of H_e (cm) and t (minutes) in Eq. 3·9, the diameter D(mm) is computed. To compute the percentage of the soil finer than this diameter, the weight W_D per ml of suspension at effective depth H_e is first computed as under.

Since the hydrometer readings have been recorded by subtracting 1 from the density (ρ) readings and multiplying them by 1000, we have

$$R = (\rho - 1)\, 1000$$

or

$$\rho = 1 + \frac{R}{1000} \tag{i}$$

where ρ is the density reading actually marked on the hydrometer, and R is the hydrometer reading corrected for the composite correction.

Now let us consider 1 ml of soil suspension, at a time interval t, at the effective depth H_e. If W_D is the weight of solids in this 1 ml suspension, the weight of water in it will be

$$=1-\frac{W_D}{G}$$

$\therefore$ Total weight of 1 ml suspension$=1-\frac{W_D}{G}+W_D$

Hence density ρ of the suspension $=1-\frac{W_D}{G}+W_D$ **(*ii*)**

Equating (*i*) and (*ii*), we get

$$1+\frac{R}{1000}=1-\frac{W_D}{G}+W_D$$

or $$W_D=\frac{R}{1000}\left(\frac{G}{G-1}\right) \tag{3·18}$$

where G=specific gravity of soil solids (average)

Substituting this value of W_D in Eq. 3·11, we get

$$N'=\frac{\frac{R}{1000}\left(\frac{G}{G-1}\right)}{W_d/V}\times 100$$

Taking $V=1000$ ml, we get

$$N'=\frac{100G}{W_d(G-1)}R \tag{3·19}$$

where N'=percentage finer with respect to W_d.

Thus, for various values of R, N' can be computed. For a combined sieve and sedimentation analysis, if W is the total dry weight of soil originally taken (before sieving it over 2 mm sieve), the overall percentage finer N is given by

$$N=N'\times\frac{W'}{W} \tag{3·20}$$

where W'=cumulative weight passing 2 mm sieve (out of which the soil weighing W_d was taken for the wet analysis)

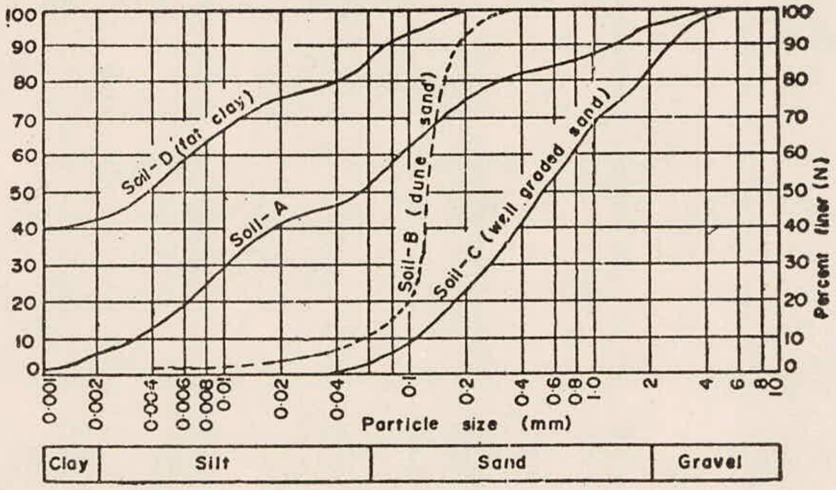
W=total dry weight of soil sample

If the soil sample does not contain particles coarser than 2 mm size, N and N' will be equal.

Table 3·12 gives the observation sheet for hydrometer analysis, [See Experiment 9].

PARTICLE SIZE DISTRIBUTION CURVE

The results of the mechanical analysis are plotted to get a particle-size distribution curve with the percentage fine N as the ordinate and the particle diameter as the abscissa, the diameter being plotted on a logarithmic scale. Fig. 3·8 shows some typical curves for various soils. A particle-size distribution curve gives us an



Diameter D (mm)

FIG. 3·8

Particle size distribution curves

idea about the ***type*** and ***gradation*** of the soil. A curve situated higher up or to the left represents a relatively fine grained soil, while a curve situated to the right represents a coarse grained soil.

A soil sample may be either *well graded* or *poorly graded* (*uniformly graded*). A soil is said to be well graded when it has good representation of particles of all sizes. On the other hand, a soil is said to be poorly graded if it has an excess of certain particles and deficiency of others, or if it has most of the particles of about the same size ; in the latter case it is known as a uniformly graded soil. Thus soil A (Fig. 3·8) is well graded while soil B is uniformly graded.

For coarse grained soil, certain particle sizes such as D_{10}, D_{30} and D_{60} are important. The D_{10} represents a size, in mm such that 10% of the particles are finer than this size. Similarly, the soil particles finer than D_{60} size are 60 per cent of the total weight of the sample. The size D_{10} is sometimes called the *effective size* or *effective diameter*. The *uniformity coefficient* Cu (or coefficient of uniformity) is a measure of particle-size range, and is given by the ratio of D_{60} and D_{10} sizes :

$$Cu=\frac{D_{60}}{D_{10}} \tag{3·21}$$

Similarly, the shape of the particle size curve is represented by the *co-efficient of the curvature* Cc, given by

$$Cc=\frac{(D_{30})^2}{D_{10}\times D_{60}} \tag{3·22}$$

For a uniformly graded soil Cu is nearly unity. For a well graded soil, Cc must be between 1 to 3 and in addition Cu must be greater than 4 for gravels and 6 for sands (USBR : 1960).

The details of particle size distribution consisting of main features of sieve analysis and sedimentation analysis have been given in the previous pages in the Appendix.

The stepwise procedures for determination of grain size distribution by sieving and by hydrometer are given as follows:

EXPERIMENT No 8

DETERMINATION OF GRAIN SIZE DISTRIBUTION BY SIEVING

Object and Scope: The object of this experiment is to determine grain size distribution of coarse grained soil by sieving. The test covers both coarse sieve analysis (for gravel fraction) as well as fine sieve analysis (for sand fraction).

Material and Equipment: (i) Balances accurate to 1 g and 0.1 g, (ii) Set of IS sieves: 100 mm, 63 mm, 10 mm, 4.75 mm, 2 mm, 1 mm, 600 micron, 425 micron, 300 micron, 212 micron, 150 micron, and 75 micron size, (iii) Thermostatically controlled oven, (iv) Two or more large metal or plastic water tight trays, (v) Sieve brushes and a wire brush, (vi) Mortar with a rubber covered pestle, (vii) Mechanical sieve shaker, and (viii) Riffler.

Test Procedure

1. Using a riffler, take a representative sample of soil received from the field and dry it in the oven.

2. Weigh the required quantity of dried soil, keep it in a tray and soak it with water. Depending on the maximum size of material present in substantial quantities in the soil the weight of soil sample taken for analysis may be as follows [IS : 2720 (Part IV) —1965].

Maximum size of material present in substantial quantities	*Weight to be taken for test*
mm	kg
63	50
20	6·5
10	1·5
4·75	0·375

3. Puddle the sample thoroughly in water and transfer the slurry to the 4·75 mm sieve which divides the gravel fraction from the sand fraction. Wash the slurry with jet of water. Collect the materials retained on 4·75 mm sieve and the material passing through it in separate containers. Keep the material retained on 4·75 mm sieve in the oven.

4. Wash the material passing through the 4·75 mm sieve through a 75-micron sieve so that silt and clay particles are separated from the sand fraction. Collect the material passing through 75 micron sieve and the material retained on it in separate containers, and keep them in the oven.

5. Sieve the dried material, retained on 4·75 mm sieve (step 3), through the following set of sieves : 63 mm, 20 mm, 10 mm and 4·75 mm by hand sieving. While sieving through each sieve, the sieve shall be agitated so that the sample rolls in irregular motion over the sieve. The material from the sieve may be rubbed, if necessary, with the rubber pestle in the motar taking care to see that individual soil particles are not broken and re-sieved to make sure that only individual particles are retained. The weight of material retained on each sieve should be recorded.

6. Sieve the dried material, retained on 75-micron sieve (step 4), through the following set of sieves : 2 mm, 1 mm, 600 micron, 425 micron, 300 micron, 212 micron, 150 micron and 75 micron size. The set of sieves should be arranged one above the other and fitted to a mechanical sieve shaker such that the 2 mm sieve is at the top and the 75 micron sieve is at the bottom. A cover should be placed on the top of the 2 mm sieve, and a receiver should be placed below the 75 micron sieve. A minimum of 10

minutes sieving should be used. The soil fraction retained on each sieve should be carefully collected in containers and the weight of each fraction determined and recorded.

Alternatively, the material retained on 75 micron sieve (step 4), may not be dried, but be washed through a nest of sieves specified in step 6, nested in order of their fineness with the finest (75 micron) at the bottom Washing should be continued until the water passing through each sieve is substantially clean. The fraction retained on each sieve should be emptied carefully without loss of material in separate container and oven-dried. The oven-dried fraction should be weighed separate and their weights should be recorded.

7. The material passing 75 micron sieve (step 4) may be used for sedimentation analysis. (See Experiments 9 or 10).

Tabulation of observations. The test observations and results are recorded as illustrated in Table 3·11.

TABLE 3·11

DATA AND OBSERVATION SHEET FOR SIEVE ANALYSIS

Sample No. 108
Wt. of dry soil sample 1000 g.

Weight Retained on 4·75 mm sieve : 167 g
Weight Passing through 75 micron sieve : 77 g

S.N.	*IS Sieve*	*Particle size D (mm)*	*Weight Retained (g)*	*% retained*	*Cumulative % Retained*	*Cumulative % finer (N)*
1	100 mm	100 mm	—	—	—	100
2.	63 mm	63 mm	—	—	—	100
3.	20 mm	20 mm	33	3·3	3·3	96·7
4.	10 mm	10 mm	49	4·9	8·2	91·8
5.	4·75 mm	4·75 mm	85	8·5	16·7	83·3
6.	2 mm	2 mm	140	14·0	30·7	69·3
7.	1 mm	1 mm	160	16·0	46·7	53·3
8.	600 micron	0·6 mm	142	14·2	60·9	39·1
9.	425 micron	0·425 mm	118	11·8	72·7	27·3
10.	300 micron	0·300 mm	82	8·2	80·9	19·1
11.	212 micron	0·212 mm	56	5·6	86·5	13·5
12.	150 micron	0·150 mm	35	3·5	90·0	10·0
13.	75 micron	0·075 mm	23	2·3	92·3	7·7

Calculations. The percentage of soil retained on each sieve is calculated on the basis of total weight of soil sample taken and from these results the per cent passing through each of the sieves is calculated, as illustrated in Table 3·11.

Note 1. Dry Sieve Analysis. If the soil sample contains little or no fines (passing 65 micron sieve), dry sieve analysis may be carried out. The gravel fraction and sand fraction are first separated by dry sieving through 4·75 mm sieve. The material retained on 4·75 mm size is further sieved through the following set of sieves : 100 mm, 63 mm, 20 mm, 10 mm and 4·75 mm sieves. The material passing 4·75 mm sieve is sieved through the following set of sieves : 2 mm, 1 mm, 600 micron, 425 micron, 300 micron, 212 micron, 150 micron, and 75 micron sizes.

Note 2. The permissible maximum weight of sample on the 200 mm diameter sieves should be as follows :

IS Sieve Designation	*Maximum weight of sample (g)*
600 micron	160
200 micron	55
75 micron	25

Note 3. If the soil contains greater amount of fines (finer than 75 micron size), the dried soil fraction passing through 4·75 mm sieve (step 6) should be soaked in water containing two grams of sodium hexametaphosphate (or one gram of sodium hydroxide and one gram of sodium carbonate) per litre of water. The soaked specimen should then be washed thoroughly over the nest of sieves specified in step 6.

EXPERIMENT 9

DETERMINATION OF GRAIN SIZE DISTRIBUTION BY HYDROMETER

Object and scope. The object of this experiment is to determine the distribution of particle size, finer than 75 micron sieve, by sedimentation analysis, using a density hydrometer, and then to plot the grain size distribution curve.

Materials and Equipment. (*i*) Density hydrometer conforming to IS : 3104-1965, (*ii*) Two glass measuring cylinder of 1000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1000 ml volume, (*iii*) Thermometer to cover the range 0 to 50°C, accurate to 0·50°C, (*iv*) Water bath or constant temperature room (optional), *(v)* Stirring apparatus, *(vi)* 75 micron sieve, *(vii)* Balance accurate to 0·01 g, *(viii)* Stop watch, *(ix)* Wash bottles containing distilled water, *(ix)* Glass rod, about 15 to 20 cm long and 4 to 5 mm in diameter, *(x)* Reagents : Hydrogen peroxide, Hydrochloric acid N solution and Sodium hexametaphosphate, *(xii)* Conical flask of 1000 ml capacity, *(xiii)* Buchner or Hirch funnel, *(xiv)* Filter flash, *(xv)* Measuring cylinder of 100 ml capacity, *(xvi)* Filter paper and blue litmus paper.

Test Procedure

(A) Calibration of hydrometer

1. *Determination of volume of the hydrometer bulb* (V_h). Pour about 800 ml of water in the 1000 ml measuring cylinder and note the reading at the water level. Immerse the hydrometer in water and note the water reading. The difference between the two readings is recorded as the volume of the hydrometer bulb plus the volume of that part of the stem which is submerged. For practical purposes, the error due to the inclusion of this stem volume may be neglected.

Alternatively, weigh the hydrometer to the nearest 0·2 g. This weight in grams is recorded as the volume of the hydrometer in ml. This includes the volume of the bulb plus the volume of the stem. For practical purposes the error due to the inclusion of the stem may be neglected.

2. In order to find the area of cross-section (A) of the measuring cylinder in which the hydrometer is to be used, measure the distance, in cm, between two graduations of the cylinder. The cross-sectional area (A) is then equal to the volume included between the two graduations divided by the distance between them.

3. Measure the distance (h) from the neck to the bottom of the bulb, and record it as the height of the bulb.

4. With the help of an accurate scale, measure the height H between the neck of the hydrometer to each of the other major calibration marks (R_h).

5. Calculate the effective depth (H_e) corresponding to each of the major calibration marks (or hydrometer readings, R_h) by the following expression :

$$H_e = H + \frac{1}{2}\left(h - \frac{V_h}{A} \right)$$

The readings may be recorded as illustrated in Table 3·3.

6. Draw a calibration curve between H_e and R_h (Fig. 3·7) which may be used for finding the effective depth (H_e) corresponding to hydrometer readings (R_h) obtained during the test.

7. ***Meniscus correction***. Insert the hydrometer in the measuring cylinder containing about 700 ml of water. Take the readings of the hydrometer at the top and bottom of the mensicus. The difference between two readings is taken as the meniscus correction (C_m) which is a constant for a hydrometer. During the actual sedimentation test, the readings should be taken at the bottom of the meniscus but since the soil suspension is opaque, readings are taken at the top of meniscus. It is clear from Fig. 3·6 (*a*) that readings decrease in the upward direction. Thus the observed hydrometer reading is always less than the true one. Hence the meniscus correction is always positive.

(B) Pre-treatment of soil

1. Weigh accurately (to 0·01 g) 50 to 100 g of oven-dried soil sample (W_d) passing the 2 mm IS sieve (50 g for clay soil and 100 g if it is a sandy soil). If the percentage of soluble salts is more than one per cent, the soil should be washed with water before further treatment, taking care to see that the soil particles are not lost.

2. Add 150 ml of hydrogen peroxide to the soil sample placed in a wide mouth conical flask and stir it gently for few minutes with a glass rod. Cover the flask with glass and leave it to stand overnight.

3. Next morning, the mixture in the conical flask is gently heated in an evaporating dish, stirring the contents periodically. Reduce the volume to about 50 ml by boiling. With very organic soils additional peroxide may be required to complete the oxidation.

4. If the soil contains insoluble calcium compounds, add about 50 ml of hydrochloric acid to the cooled mixture of soil obtained in step 3. The solution is stirred with a glass rod for a few minutes and allowed to stand for one hour or for longer periods, if necessary. The solution will have an acid reaction to litmus.

5. Filter the mixture and wash it with warm water until the filtrate shows no acid reaction to litmus. Transfer the damp soil on the filter paper and funnel to the evaporating dish using a jet of distilled water. Place the dish and its contents to the oven. Take the weight (W_d) of the oven-dried soil remaining after pre-treatment and find the loss of weight due to pre-treatment.

Note. In case of soils containing no calcium compounds or soluble salts and having a low organic content (less than 2%) the pre-treatment prescribed above may be omitted and the dispersing agent is added direct to the soil taken for analysis.

(C) Dispersion of soil

1. To the oven-dried soil in the evaporating dish (step 5 above), add 100 ml of sodium hexametaphosphate solution and warm the mixture gently for about 10 minutes. Transfer the mixture to the cup of the mechanical mixer using a jet of distilled water, and stir it well for about 15 minutes. The sodium hexametaphosphate solution is prepared by dissolving 33 g of sodium hexametaphosphate and seven grams of sodium corbonate in distilled water to make one litre of solution. This solution is unstable and should be freshly prepared approximately once in a month.

2. Transfer the soil suspension to the 75 micron IS sieve placed on a receiver and wash the soil on this sieve using jet of distilled water from a wash bottle. The amount of distilled water used during this operation may be about 500 ml.

3. Transfer the soil suspension passing the 75 micron IS sieve to the 1000 ml measuring cylinder, and add more distilled water to make the volume to exactly 1000 ml in the cylinder.

4. Collect the material retained on 75 micron sieve and put it in the oven for drying. Determine the dry weight of soil retained on 75 micron sieve.

(D) Sedimentation test with hydrometer

1. Insert a rubber bung or any other suitable cover on the top of the 1000 ml measuring cylinder containing the soil suspension (obtained in step 3 above) and shake it vigorously end over end. Stop shaking and allow it to stand. Immediately, start the stop watch, and remove the top cover from the cylinder.

2. Immerse the hydrometer gently to a depth slightly below its floating position and then allow it to float freely. Take the hydrometer readings after periods of ½, 1, 2 and 4 minutes. Take out the hydrometer, rinse it with distilled water and allow it to stand in a jar containing distilled water at the same temperature as that of the test cylinder.

3. The hydrometer is re-inserted in the suspension and readings are taken after periods of 8, 15 and 30 minutes; 1, 2 and 4 hours after shaking. The hydrometer should be removed, rinsed and placed in the distilled water after each reading. After the end of 4 hours, readings should be taken once or twice within 24 hours.

4. *Composite correction*. In order to determine the composite correction, put 100 ml of dispersing agent solution in another 1000 ml measuring cylinder and make it to 1000 ml by adding distilled water. The cylinder should be maintained at the same temperature as that of the test cylinder containing soil specimen. Insert the hydrometer in this comparison cylinder containing distilled water and the dispersing agent and take the reading corresponding to the *top* of the meniscus. The *negative* of the hydrometer reading so obtained gives the composite correction (C). The composite correction is found before the start of the test, and also at every time intervals of 30 minutes, 1 hour, 2 hours and 4 hours after the beginning of the test, and afterwards, just after each hydrometer reading is taken in test cylinder.

5. The temperature of the suspension should be observed and recorded once during the first 15 minutes and then after every subsequent reading.

Tabulation of observations. The test observations and results are recorded as illustrated in Table 3·12. The observations for the calibration of the hydrometer have been recorded in Table 3·3.

Particle size distribution curve. The results of the above table are plotted to get a particle-size distribution curve with percentage finer N as the ordinate and the particle diameter (D) on logarithmic scale of abscissa.

Calculations. (1) The loss in weight in pretreatment of the soil in percentage is calculated from the following expression :

$$P=\left(1-\frac{W_b}{W_d}\right)100$$

where

P=loss in weight in percentage

W_d=weight of dry soil sample taken from the soil passing 2 mm sieve

W_b=weight of the soil after pretreatment.

(2) The diameter of the particle in suspension at any sampling time t is calculated from Eq. 3·9 :

$$D=10^{-5}M\sqrt{\frac{H_e}{t}},$$ where factor M is taken either from Table 3·2 or from Fig. 3·4.

(3) The percentage finer N' based on the weight W_d is calculated from Eq. 3·19 :

$$N'=\frac{100\,G}{W_d(G-1)}\,R.$$

TABLE 3·12

DATA AND OBSERVATION SHEET FOR HYDROMETER ANALYSIS

1. Sample No. A—102
2. Weight of dry soil sample (W)=500 g
3. Weight of fraction passing 2 mm sieve (W')=460 g
4. Weight of dry sample taken from minus 2 mm sieve (W_d)=50 g
5. Specific gravity of soil particles of minus 75 micron : G=2·67
6. Hydrometer No. 12 ; Sedimentation jar No. 36 ; Meniscus correction : $C_m=+0·5$

Date	Time	*Elapsed time* t *(min)*	*Hydro-meter Reading* R_h'	*Temp.* °C	C	$R_h=R_h'+C_m$	*Eff. Depth* H_e *(cm)*	*Factor* M	*Particle size D (mm)*	$R=R_h'+C$	*% finer* (N') *based on* W_d	*% finer* (N) *based on whole* $N=N'\times\frac{W'}{W}$
12-4-67	08-27	½	20·25	26·5	−0·5	20·75	12·2	1254	0·061	19·75	63	58
		1	19·0	26·5	−0·5	19·50	12·7	1254	0·045	18·50	59	54·3
		2	17·5	26·5	−0·5	18·0	13·3	1254	0·033	17·0	54·4	50·0
		4	15·5	26·5	−0·5	16·0	14·0	1254	0·023	15·0	48	44·1
		8	15·5	26·5	−0·5	16·0	14·0	1254	0·0165	15·0	48	44·1
		15	11·5	27	−0·5	12·0	15·5	1252	0·0125	11·0	35	32·2
	08-57	30	9·5	27·5	−0·5	10·0	16·3	1245	0·0092	9·0	29	26·7
	09-30	63	7·25	29	0	7·75	17·1	1224	0·0062	7·25	23	21·2
	10-20	113	6·0	30	+0·5	6·5	17·6	1210	0·0017	6·5	21	19·3
	12-27	240	4·0	31·5	+1	4·5	18·3	1190	0·0033	5·0	16	14·7
	17-00	513	2·25	31·5	+2	2·75	19·0	1190	0·0023	3·25	10·4	9·6
	07-55	1408	2·25	29	0	2·75	19·0	1224	0·0015	2·25	6·5	5·8

(4) The percentage finer N based on the total weight of dry soil sample (W) is obtained from the relation :

$$N=N'\times\frac{W'}{W}$$

where W'= cumulative weight passing 2 mm sieve (out of which the soil weighing W_d was taken for the hydrometer analysis)

(5) The uniformity coefficient C_u and coefficient of curvature C_c are calculated respectively from Eqs. 3 21 and 3·22.

Note 1. If the soil sample does not contain calcium compounds or soluble salts, pretreatment should be omitted.

Note 2. Sodium hexametaphosphate has been found to be ineffective when dealing with certain highly flocculated soils. In such cases dispersion may be carried out by adding N sodium hydroxide solution at the rate of 4 ml per 10 g of soil.

Note 3. A symmetrical heating of the suspension causes convection currents which affect the sedimentation process. The suspension should, therefore be kept out of direct sunlight and away from any local source of heat. Evaporation should be retarded by keeping a cover on the measuring cylinder between the readings.

Note 4. The specific gravity G used in the above expression should be determined for the fraction of the sample passing 75 micron sieve.

APPENDIX - 2

PROCEDURE FOR FALLING HEAD TEST FOR DETERMINATION OF COEFFICIENT OF PERMEABILITY

[Reproduced with the Permission from the Book: 'Soil Mechanics and Foundations', by Dr B C Pumiya, published by M/s Standard Book House, Delhi, 1982]

DETERMINATION OF COEFFICIENT OF PERMEABILITY

The coefficient of permeability can be determined by the following methods :

(a) *Laboratory methods*

- (1) Constant head permeability test.
- (2) Falling head permeability test.

(b) *Field methods*

- (1) Pumping-out tests. **(2) Pumping-in tests.**

(c) *Indirect methods*

- (1) Computation from grain size or specific surface.
- (2) Horizontal capillarity test.
- (3) Consolidation test data.

Permeability can be determined in the laboratory by direct measurement with the help of *permeameters*, by allowing the water to flow through soil sample either under *constant head* or under *variable head*. Permeability can also be determined directly by field tests, described in chapter 8 (well hydraulics). The indirect method of computing the permeability from consolidation test data has been explained in chapter 15. Permeability can also be computed by the consideration of grain size (Hazens formula, Eq. 7·19), or from considerations of specific surface as given by Kozney's formula (Eq. 7·20) or Leudon's formula (Eq. 7·21).

CONSTANT HEAD PERMEABILITY TEST

Fig. 7·5 shows the diagrammatical representation of constant head test.

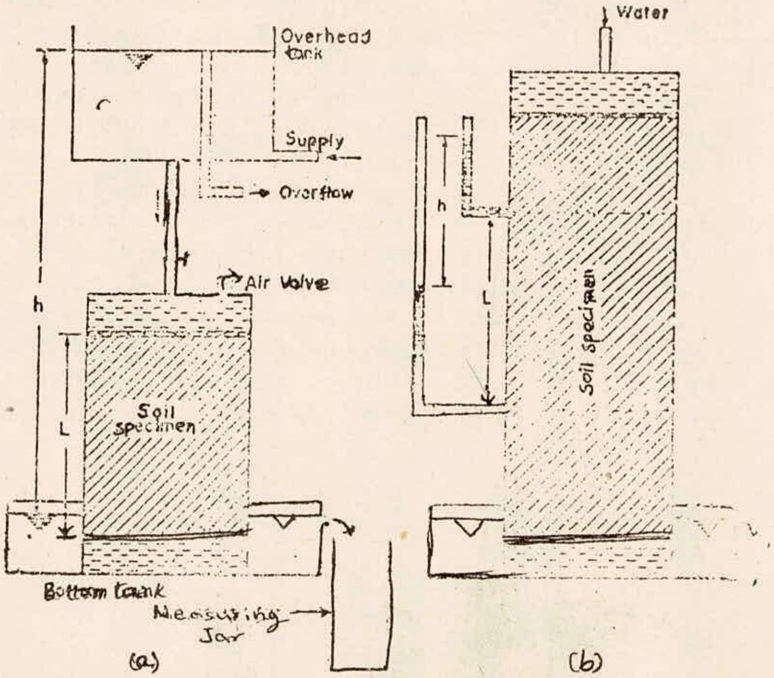


FIG. 7.5
Constant Head Test

Water flows from the overhead tank consisting of three tubes : the inlet tube, the overflow tube and the outlet tube. The constant hydraulic gradient i causing the flow is the head h (i.e. difference in the water levels of the overhead and bottom tanks) divided by the length L of the sample. If the length of the sample is large, the head lost over a length of specimen is measured by inserting piezometric tubes, as shown in Fig. 7·5 (*b*).

If Q is the total quantity of flow in a time interval t, we have from Darcy's law,

$$q=\frac{Q}{t}=k\,i\,A$$

$$k=\frac{Q}{t}\;\frac{1}{iA}=\frac{Q}{t}\;\frac{L}{h}\cdot\frac{1}{A} \tag{7·26}$$

where A=total cross-sectional area of sample.

When steady state of flow is reached, the total quantity of water Q in time t is collected in a measuring jar. The observations are recorded as shown in Table 7·2 [See Experiment 14].

FALLING HEAD PERMEABILITY TEST

The constant head permeability test is used for coarse-grained soil only where a reasonable discharge can be collected in a given time. However, the falling head test is used for relatively less permeable soils where the discharge is small. Fig 7·6 shows the diagrammatical representation of a falling head test arrangement.

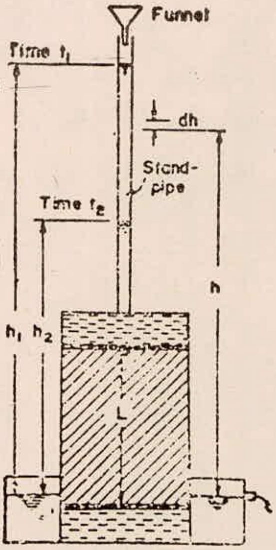


FIG. 7·6
Falling head test

A stand pipe of known cross-sectional area a is fitted over the permeameter, and water is allowed to run down. The water level in the stand pipe constantly falls as water flows. Observations are started after steady state of flow has reached. The head at any time instant t is equal to the difference in the water level in the stand pipe and the bottom tank. Let h_1 and h_2 be heads at time intervals t_1 and $t_2 (t_2 > t_1)$ respectively. Let h be the head at any intermediate time interval t, and $-dh$ be the change in the head in a small time interval dt (minus sign has been used since h decreases as t increases). Hence, from Darcy's law, the rate of flow q is given by

$$q=\frac{(-dh\,.\,a)}{dt}=kiA$$

where i=hydraulic gradient at time $t=\frac{h}{L}$

$$\therefore \qquad \frac{kh}{L}A=-\frac{dh}{dt}a$$

or

$$\frac{Ak}{aL}dt=-\frac{dh}{h}$$

Integrating between the two time limits, we get

$$\frac{Ak}{aL}\int_{t_1}^{t_2}dt=-\int_{h_1}^{h_2}\frac{dh}{h}=\int_{h_2}^{h_1}\frac{dh}{h}$$

or

$$\frac{Ak}{aL}(t_2-t_1)=\log_e\frac{h_1}{h_2}$$

Denoting $t_2-t_1=t$, we get

$$k=\frac{aL}{At}\log_e\frac{h_1}{h_2}=2{\cdot}3\ \frac{aL}{At}\log_{10}\frac{h_1}{h_2} \qquad (7{\cdot}27)$$

The laboratory observations consist of measurement of the heads h_1 and h_2 at two chosen time intervals t_1 and t_2. The observations are recorded as shown in Table 7·3.

THE JODHPUR PERMEAMETER

The *Jodhpur Permeameter* was designed and developed by Dr. Alam Singh (1958) at the Soil Engineering Laboratory of M.B.M. Engineering College. Jodhpur. The apparatus is meant for studying the permeability characteristics of all types of soil samples under different conditions of laboratory as well as in the field. Both falling head and constant head tests can be performed, on remoulded as well as undisturbed specimens. Remoulded specimens can be prepared either by static or by dynamic compaction method.

The Jodhpur permeameter (Model III) comprises of the following :

1. Permeameter mould
2. Top cap fitted with water inlet nozzle and air release valve
3. Dynamic compaction base plate
4. Perforated base plate
5. Perforated top plate
6. Static compaction flanged end-plugs, 2 Nos., 3 cm and 2·5 cm high
7. Compaction collars, 2 Nos. 3 cm and 2·5 cm high

8. Split collar
9. 2 5 kg Dynamic Ramming Tool (DRT)
10. Rod temper
11. Bottom tank
12. Constant head tank fitted with air intake tube
13. Spare brass tube and rubber stopper for vacuum saturation
14. Set of three stand pipes, fixed to the back of constant head tank
15. Core cutter
16. Dolly for core cutter
17. Centering ring for cutter
18. Wire gauge, pad of filter paper, copper, wool pad, bolts, nuts, spanner, funnel, pinch cocks and flexible tubing.

The permeameter mould which is a cylinder of internal capacity 300 ml, 50 cm^2 cross-sectional area (79 8 mm diameter) and 6 cm effective height, has two studs fixed to the side lugs which aid in assembling the mould, the top cap and the perforated base plate (or the collars and the compacting base plate as the case may be). A rubber gasket (washer) under the top cap ensures water tightness. The permeameter assembly is placed in the bottom tank having a water outlet which permits accurate control of water level for falling heads tests. The bolt head under the perforated base plate keeps the permeameter mould assembly raised a little in the bottom tank thus allowing free flow of water through the base perforations.

To test undisturbed specimen, the 0 3 litre core cutter (50 cm^2 in cross-section × 6 cm high) with dolly attached to top is pushed into the undisturbed block of soil. The soil surrounding the outside of the cutter dolly is cut, and the cutter and dolly full of undisturbed soil is removed. The soil is cut flush with top and bottom ends of the cutter, after removing the dolly. The centering ring for the cutter is placed over the perforated base plate and the core cutter with the undisturbed specimen is placed centrally over the perforated base plate with the cutting edge downwards. The top is then tightened over the cutter.

The remoulded specimen can be prepared either by static compaction, or by dynamic compaction, at any desired density. The weight of the wet soil, to compact it at a given density and water content, is first calculated. To compact it by *static compaction*, the 3 cm collar is attached to the bottom end of the 0·3 litre mould and 2·5 cm collar to the top end. The split collar is placed around the 2·5 cm flanged end plug. The mould assembly is supported over the 2 5 cm end plug with the 2·5 cm collar resting on the split collar. The calculated weight of the wet soil is put into the mould and the top plug is inserted. The entire assembly is kept in a press and the sample is compacted. After compaction, the 3 cm plug and 3 cm collar are removed and, after putting the fine mesh gauge etc., perforated base plate is fixed over it. The mould is turned upside down, the plug and the collar are removed, and the top perforated plate and top cap are fixed.

To compact the specimen dynamically, using the rod temper, the mould is fixed upside down on the dynamic compaction plate, and the collar is fixed to its other end. The wet soil of pre-calculated quantity is then compacted into the mould by means of the rod temper, in two or three layers. After compaction, the collar is removed and, after placing the fine mesh gauge, the perforated base plate is fixed. The mould assembly is then turned upside down, the compaction base plate is detached, and the top cap is fixed.

Alternatively, if permeability at Proctor's maximum dry density and at a moulding water content equal to the optimum value is required, first the maximum dry density and optimum water content is determined. (This can be done by Jodhpur Mini-compactor test, Proctor test or by compaction in permeameter mould itself). The soil is then compacted at the optimum water content in two layers in the 0·3 litre permeameter mould (mould assembly as described in the above para) with 15 blows of 2 5 kg DRT given to each layer. After the compaction, the compaction collar is removed, the excess soil is trimmed-off, and the perforated base plate is fixed, as described in the above para.

EXPERIMENT 15

DETERMINATION OF PERMEABILITY BY FILLING HEAD TEST

Object and scope. The object of the experiment is to determine the coefficient of permeability of soil in the laboratory by falling head test using Jodhpur Permeameter.

Material and equipment. Same as in Experiment 14.

Test Procedure

1. Prepare the remoulded soil specimen in the permeameter and saturate it as explained in Experiment 14.

2. Keep the permeameter mould assembly in the bottom tank and fill the bottom tank with water upto its outlet.

3. Connect the water inlet nozzle of the mould to the stand pipe filled with water. Permit water to flow for some time till steady state of flow is reached.

4. With the help of the stop watch, note the time interval required for the water level in the stand pipe to fall from some convenient initial value to some final value.

5. Repeat step (4) atleast twice and determine the time for the water level in the stand pipe to drop from the same initial head to the same final value.

6. In order to determine the inside area of cross-section of the stand pipe, collect the quantity of water contained in between two graduations of known distance apart Weigh this water accurate to 0·1 g. The weight in grams divided by the distance, in cm, between the two graduations will give the inside area of cross-section of the stand pipe.

Tabulation of observations. The test observations are tabulated as illustrated in Table 7·3.

TABLE 7·3

DATA AND OBSERVATION SHEET FOR FALLING HEAD PERMEABILITY TEST

Sample No. A/107
Moulding water content : 12%
Dry density : 1·67

Specific gravity : 2·68
Voids ratio : 0·60

1. Area of stand pipe (*a*)	(cm²)	0·785
2. Cross-sectional area of soil sample (*A*)	(cm²)	50
3. Length of the sample (*L*)	(cm)	6
4. Initial head (h_1)	(cm)	40
5. Final head (h_2)	(cm)	20
6. Time interval : (*i*) I test	(sec)	56
(*ii*) II test	(sec)	57
(*iii*) III test	(sec)	55
Average *t*	(sec)	56
7. Coefficient of permeability at test temperature	(cm/sec)	$1{\cdot}17\times10^{-3}$
8. Test temperature	(°C)	32
9. Coefficient of permeability at 27°C	(cm/sec)	$1{\cdot}05\times10^{-3}$

Calculations. The coefficient of permeability is calculated from Eq. 7·27 :

$$k=2{\cdot}3\,\frac{aL}{At}\,\log_{10}\,\frac{h_1}{h_2}$$

APPENDIX - 3

APPARATUS FOR DETERMINATION OF SOIL MOISTURE CHARACTERISTICS BY MEANS OF CERAMIC PLATES

[Reproduced with the permission from M/s Eijkelkamp Agrisearch Equipment, The Netherlands]

Eijkelkamp
Agrisearch Equipment
P.O. Box 4, 6987 ZG Giesbeek, The Netherlands
Telephone 31 (08336) 1941*
Telefax 31 (08336) 2167
Telex 35416 eykel nl

product information about:
product informatie betreffende:

08.25 Apparatus for determination of
soil moisture characteristics
by means of ceramic plates
(0.1-15 bar of suction)

Function of the ceramic pressure plate cells

In order to work effectively with this type of extraction equipment, it is important to have a thorough understanding of how the ceramic pressure plate cells function and of the physical principles involved in the extraction process. Fig. 1 shows a cross section view of a ceramic pressure plate cell mounted in a pressure vessel, with the outflow tube running through the vessel wall to the atmosphere and with a soil sample held in place on the porous ceramic surface of the cell.

Each ceramic pressure plate cell consists of a porous ceramic plate, covered on one side by a thin neoprene diaphragm, sealed to the edges of the ceramic plate. An internal screen between the plate and diaphragm provides a passage for flow of water. An outlet stem running through the plate connects this passage to an outflow tube fitting, which connects to the atmosphere outside of the extractor

To use the ceramic pressure plate cell, one or more soil samples are placed on the porous ceramic surface, held in place by retaining rings of appropriate height. The soil samples, together with the porous ceramic plate, are then saturated with water. This is usually done by allowing an excess of water to stand on the surface of the cell for several hours. When the saturation is complete, the cell can be mounted into the pressure vessel. Air pressure is used to effect extraction of moisture from the soil samples under controlled conditions.

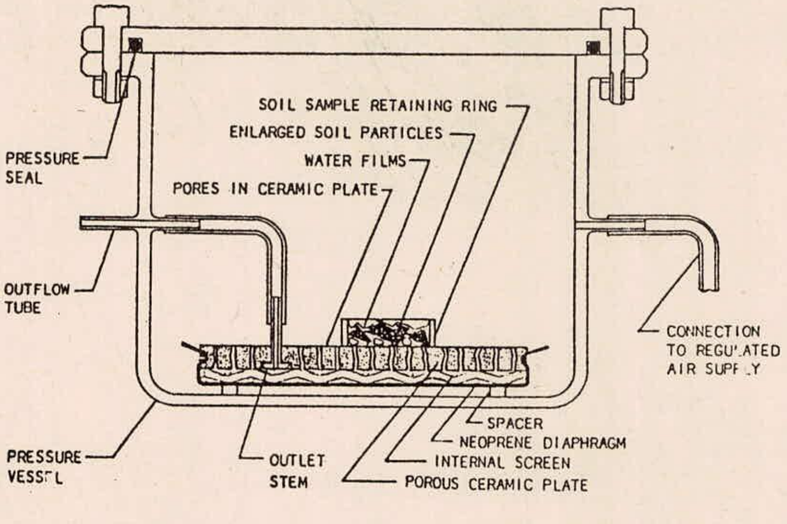


FIG. 1
CROSS SECTION VIEW OF CERAMIC PRESSURE PLATE CELL AND SOIL SAMPLE, IN EXTRACTOR

As soon as air pressure inside the chamber is raised above atmospheric pressure, the higher pressure inside the chamber forces excess water through the microscopic pores in the ceramic plate and out through the outlet stem via the passage afforded by the screen. The high pressure air, however, will not flow through the pores in the ceramic plate since the pores are filled with water and the surface tension of the water at the gas-liquid interface at each of the pores supports the pressure much the same as a flexible rubber diaphragm. To understand this action more thoroughly, refer to fig. 2, below.

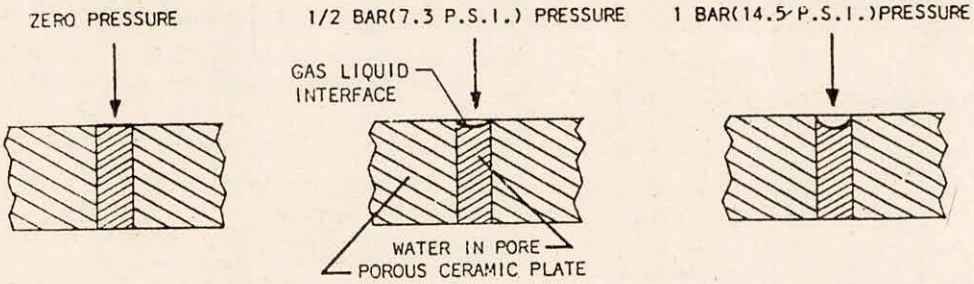


FIG. 2. CHANGES IN RADIUS OF CURVATURE OF GAS-LIQUID INTERFACE WITH PRESSURE

The maximum air pressure that any given wetted porous ceramic plate can stand before letting air pass through the pores, is determined by the diameter of the pore. The smaller the pore size, the higher the pressure shall have to be will air pass through. The pressure value that finally breaks down these water meniscuses is called the "bubbling pressure" or the "air entry value" for the porous plate. Pressure plate cells must always be used at air pressure extraction values below the "bubbling pressure" or "air entry value" for the cell.

During a run, at any set air pressure in the extractor, soil moisture will flow from around each of the soil particles and out through the ceramic plate until such time as the effective curvature of the water films throughout the soil are the same as at the pores in the plate. When this occurs, an equilibrium is reached and the flow of moisture ceases. When the air pressure in the extractor is increased, flow of soil moisture from the samples starts again and continues until a new equilibrium is reached. At equilibrium, there is an exact relationship between the air pressure in the extractor and the soil suction (and hence the moisture content) in the samples.

For example: If the air pressure in the extractor is maintained at 1/3 bar (4.8 PSI) , the soil suction in the samples at equilibrium will be 1/3 bar. If the air pressure is maintained at 1 bar (14.5 PSI), the soil suction at equilibrium will be 1 bar. Fig. 3 shows the moisture retention curves for three different soil types, that can be developed with this type of equipment. These "moisture characteristic" curves for each soil are extremely important in soils research and in the development of practical, effective irrigation practices.

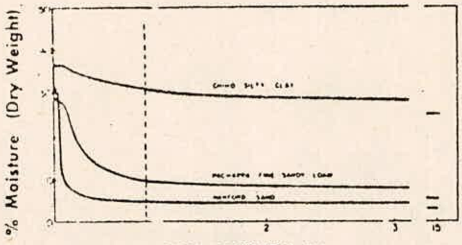


Fig.3 Moisture retention curves for three types of soils:

1 silty clay
2 fine sandy loam
3 sand

The dotted line at .85 bars of soil suction represents the limit of the tensiometer readings.

The pressure plate cell range

The 1 bar ceramic plate cells are ideal for the routine determination of the 1/10 bar and 1/3 bar percentage in the cataloging of soils as well as all other soil moisture equilibrium studies in the 0-1 bar range of soil suction. The bubbling pressure of these cells is in excess of 1 bar (14.5 PSI). These cells also have the highest permeability of any of the pressure plate cells and hence the time to reach equilibrium will be the shortest possible.

The 3 bar ceramic plate cells can also be used for determination of the 1/10 bar and 1/3 bar percentages as well as soil moisture equilibrium studies in the extended range of 0-3 bars of soil suction.
Bubbling pressure of these cells is in excess of 3 bars (43.5 PSI).

The 15 bar ceramic plate cells are not suitable for work in the 0-1 bar range of soil suction due to their small pore size.
They can, however, be used effectively in this extractor for soil moisture equilibrium studies in the 1-5 bar range of soil suction.
Bubbling pressure of these cells is in excess of 15 bars (220 PSI). For full range use, these cells must be used in the 15 bar ceramic plate extractor (08.25.01).

The various pressure plate cells are not suitable for extracting solution from soils for chemical analysis. The immense surface area within the porous ceramic plate can cause disturbance and contamination of the soil solution.

Pressure supply and control

A source of regulated gas pressure is required for all extraction work. If the extractor is to be used extensively, compressed air from a compressor is the most satisfactory source of supply. Our 08.25.12 compressor is ideally suited for use with our extractors.

Accuracy of equilibrium values will be no more accurate than the regulation of the air supply. For work in the low soil suction range and particularly for determination of the 1/10 bar and 1/3 bar percentages, it is essential to have excellent pressure regulation. Therefore our pressure control panel has independent double regulators for the 5 and 15 bar range: after the first regulator reflecting the variation in source pressure in the ratio between 1 : 12 and 1 : 25, thus after the second regulator reflecting only in the ratio of better then 1 : 100.

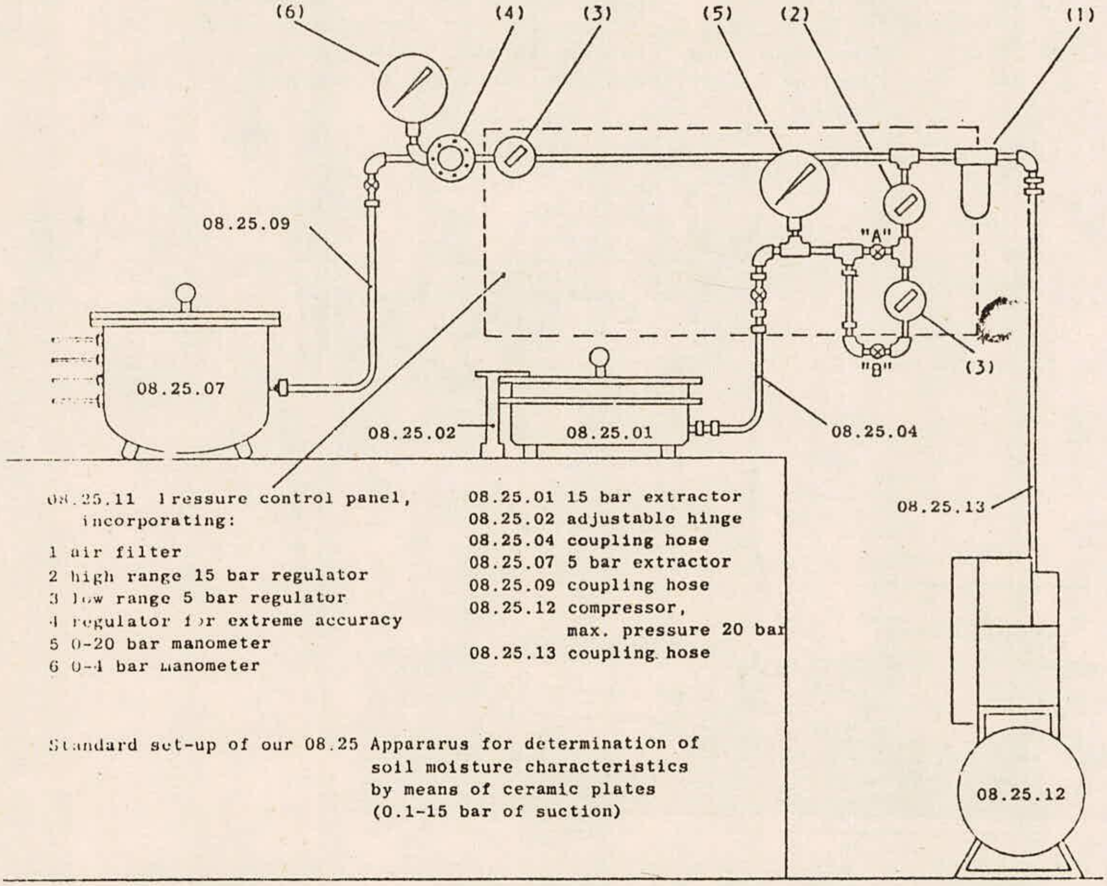
If a laboratory compressed air supply line is available, the pressure control panel can be conveniently attached to the laboratory wall adjacent to the extractor and connected directly to the supply line. Maximum input pressure to this manifold is 400 PSI (27 bar).

Sample preparation

Where moisture equilibrium studies are being run, it is desirable to keep sample heights small in order to keep the time to reach equilibrium reasonable. The time required to reach equilibrium varies as the square of the sample height. For example, a soil sample 2 cm high will require four times as long to reach equilibrium as a sample 1 cm high. Whenever possible, soil sample heights should be limited to 1 cm. Our 08.25.05 soil sample retaining rings, which will hold a 25 gram sample and are 1 cm high by 5 1/2 cm in diameter, are ideal for retaining prepared samples.

Moisture retention studies can be made with prepared soil samples or with undisturbed soil cores. Frequently, soil structure is quite an important determining factor in the value of the 1/10 bar and 1/3 bar percentages, and thought should be given to this before electing to use undisturbed soil cores or prepared samples.

Ask us for advice to equipment in reference to equipment for taking soil samples. We are specialists in this field!



08.25.11 Pressure control panel, incorporating:

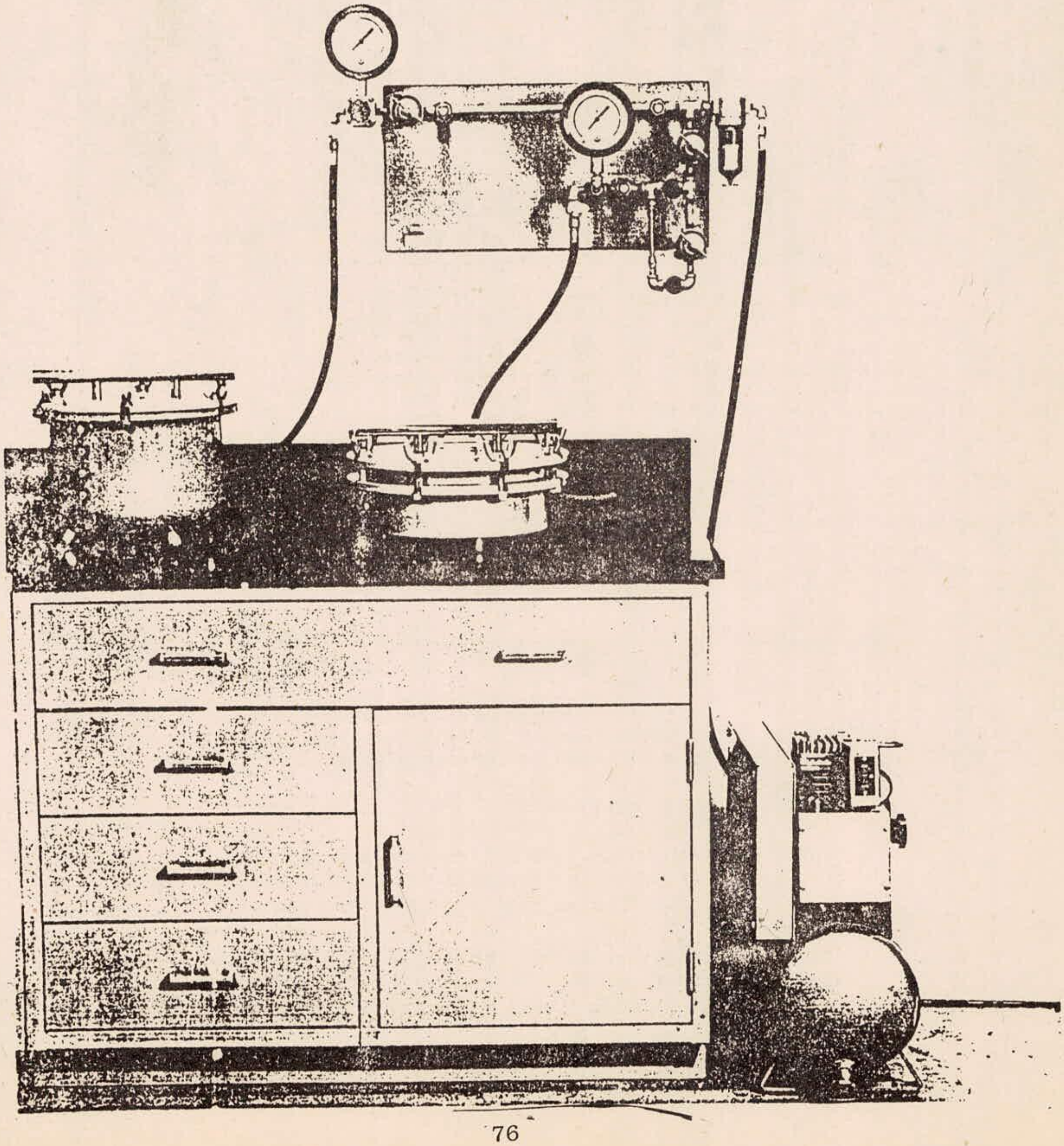
1 air filter
2 high range 15 bar regulator
3 low range 5 bar regulator
4 regulator for extreme accuracy
5 0-20 bar manometer
6 0-4 bar manometer

08.25.01	15 bar extractor
08.25.02	adjustable hinge
08.25.04	coupling hose
08.25.07	5 bar extractor
08.25.09	coupling hose
08.25.12	compressor, max. pressure 20 bar
08.25.13	coupling hose

Standard set-up of our 08.25 Appararus for determination of soil moisture characteristics by means of ceramic plates (0.1-15 bar of suction)

08.25	Apparatus for determination of soil moisture characteristics by means of ceramic plates (0.1 - 15 bar of suction). The standard set consists of:
08.25.01	15 bar extractor with 3 each 15 bar ceramic plates. Dimensions 10 x Ø 30 cm. Equipped with 3 hose connections. For taking up to 36 soil sample rings. Complete with connections.
08.25.02	Adjustable hinge for correct height adjustment of the extractor.
08.25.03	Adapter plate for hinge.
08.25.04	Coupling hose between 15 bar extractor and pressure control panel, length 1.0 metres.

08.25.05	6 Set soil sample rings (set of 12).
08.25.01.01	Spare O-ring for sealing the lid of the 15 bar extractor.
08.25.07	5 bar extractor with 4 each 1 bar ceramic plates, complete with connections.
08.25.08	4 Each 3 bar ceramic plate
08.25.05	6 Set soil sample rings (set of 12).
08.25.09	Coupling hose between 5 bar extractor and pressure control panel, length 1.0 metres.
08.25.07.01	Spare O-ring for sealing the lid of the 5 bar extractor.
08.25.11	Pressure control panel, equipped with two manometers 0 - 20 bar and 0 - 4 bar (for very accurate pressure control).
08.25.12	Compressor, max. pressure 20 bar, 220 V - 50 Hz.
08.25.13	Coupling hose between compressor and pressure control, panel, length 1.5 metres.



APPENDIX - 4

RELEVANT EXTRACTS FROM 'FINAL REPORT ON TESTING OF SOIL FOR ITS MOISTURE RETENTION CHARACTERISTICS CURVE USING PRESSURE PLATE APPARATUS' by WRDTC, University of Roorkee, Roorkee

For official use only

Final Report

on

Testing of Soil for its Moisture Retention Characteristics Curve Using Pressure Plate Apparatus

To

NATIONAL INSTITUTE OF HYDROLOGY

JAL VIGYAN BHAVAN

ROORKEE

Water Resources Development Training Centre

UNIVERSITY OF ROORKEE

ROORKEE-247 667

(U.P.) India

BACKGROUND

Dr. S.M.Seth, Scientist 'F', National Institute of Hydrology, Roorkee vide his letter No.15/222(PC)/89-NIH dated 18.12.1989 requested the Director, WRDTC, University of Roorkee to know the facilities available with the Centre to determine soil moisture retention behaviour and its testing charges. In response to this, Dr. S.K.Tripathi, WRDTC vide letter No.WR/SKT/2 dated 1.1.1990 confirmed the facilities available with the Centre for the determination of soil moisture retention and testing charge was Rs.1000/- per sample for testing against 1, 3 and 15 bar pressures. Accordingly Rs.10,000/- was sent to the WRDTC on Jan. 22, 1990 vide letter No.18/9/89-NIH dated 22.1.1990 to undertake the soil testing work. Testing of samples commenced in the second week of Jan. 1990.

Keeping in view the use of this information for soil hydrologic computer modelling the result is presented in the tabular form giving details of Bulk Density, Gravimetric moisture, Volumetric moisture and Water Retention Characteristic Equations.

INTRODUCTION

Moisture retention in soil vary with its mineral composition and organic matter content. Soils of the same place with the variable Management practices record considerable change in their physical behaviour especially with respect to their water retention. Some of such changes could be seen in the table No.1.

From the table I it could be inferred that the both Kopra and Padegaon soils collected from two different sites varied distinctly in their clay content, organic matter and thus moisture retention behaviour.

Table 1 : Showing moisture retention character of some black soils

Soil type	Location	Clay %	Organic carbon %	% by weight water retained at different pressure (bar)			References
				.1	.33	15	
Black cotton(M)	Kopra	59.2	0.33	52.7	41.4	24.4	Biswas & Mukherjee (1987)
		57.8	1.39	62.5	49.0	26.7	
Black cotton(M)	Padegaon	76.5	0.67	64.6	49.1	28.2	
		74.0	1.67	70.7	53.9	28.4	
Black cotton(M) Jabalpur	Tripuri	-	-	-	44.5	27.0	Annonymous (1982)
	Nussar	-	-	-	38.6	21.5	
	Sukha	-	-	-	32.2	15.5	

Nature of clay also plays a predominant role in soil water retention behaviour. Expanding clays retaining moisture in their lattices have much higher water retention than in non expanding clays.

METHODOLOGY

Soil samples received from National Institute of Hydrology were prepared after drying, powdering and passing through a 2 mm seive. Sampleas thus prepared were used for determining the moisture retention against 0, 0.5, 1.0, 2.0, 3.0 and 15.0 bars respectively.

Pressure plate Apparatus (Soil Moisture Equipment Co., USA) was used to test the soil moisture retention character of soil samples. Each of these samples were tested against 0.5 bar & 1.0 bar by 1 bar plate, whereas 2.0 bar and 3.0 bar with 3 bar plate as well as 15.0 bar with 15.0 bar plate and ~~samples~~ tests were replicated thrice. The apparatus was under the contineous operation i.e. from the placement of the water soaked (saturated) sample in the chamber till the end of the testing i.e. soil moisture and the pressure applied reaching to an equilibrium.

Samples taken out of the Pressure chamber were weighed on a high precision microbalance to record the moist weight of samples. These weighed samples were placed in the oven at 105°C till the weight became constant on drying. Samples taken out of the oven were placed in the desicator for cooling and dry weight was recorded by weighing it on the same microbalance. Moisture by weight was determined from the initial and dry weight of the sample.

Moisture content at 0 bar (saturation) was also determined. A core measuring 15 cm Ø and 10 cm length was filled with dried, powered and 2 mm sieved soil. It was gently packed. Core was closed from both the ends using a filter paper and wire mesh. Core sample thus prepared was placed in a trough filled with distilled water. The sample fully saturated was taken out and left for some times for the decantation of its extra water. Complete assembly with saturated soil was weighed. Assembly with wet soil was also placed in the oven for drying at 105°C till the weight became constant on drying. Dry weight of the soil was recorded and soil moisture content was estimated. Bulk Density was determined using volume and weight values of the soil mold thus formed.

Bulk density was also determined from the soil cores supplied by N.I.H. Bulk density from wet soil and dried soil was determined separately.

RESULTS

Results obtained from the testing of the samples are given in table No. 2.

Table 2 : Showing the Bulk density, Moisture Retention and Moisture Retention Equation of Sample N_1, N_2 and N_3........N_{12}

Sl. No.	Sample	Dry Bulk density (gm/cc)	Moisture (unit)	Moisture at (bars)						Soil Moisture Retention Equation	
				0	0.5	1.0	2.0	3.0	15.0		
1	2	3	4	5	6	7	8	9	10	11	
1.	N_1	-	Weight(%)	43.38	33.79	33.53	31.31	28.98	22.35	M=32.70-3.56.InX	r=-.975
		1.557*	by Vol (m/m)	.675	.526	.522	.487	.451	.347	M=.509-.055.InX	r=-.975
		1.359**		.589	.459	.455	.425	.393	.303	M=.444-.048.InX	r=-.975
		1.716***		.744	.579	.575	.537	.497	.383	M=.561-.061.InX	r=.975
2.	N_2	-	Weight(%)	29.5	19.93	18.21	15.79	10.77	9.79	M=17.346-3.216.InX	r=-.922
		1.366*	by Vol (m/m)	.403	.272	.249	.215	.147	.133	M=.237-.044.InX	r=-.922
		-		-	-	-	-	-	-	-	-
		1.64***		.484	.316	.298	.259	.176	.160	M=.284-.053.InX	r=-.922
3.	N_3	-	Weight(%)	37.93	25.24	24.32	20.0	15.60	14.46	M=22.61-3.691.InX	r=-.914
		1.532*	by Vol (m/m)	.581	.386	.372	.306	.238	.221	M=.346-0.565.InX	r=-.914
		1.155**		.438	.291	.280	.231	.180	.167	M=.261-.0426.InX	r=-.914
		1.676***		.635	.423	.407	.335	.261	.242	M=.378-.0369.InX	r=-.914
4.	N_4	-	Weight(%)	42.30	27.19	22.28	19.81	16.55	15.49	M=22.31-3.35.InX	r=-.91
		1.20*	by Vol (m/m)	.508	.326	.267	.231	.199	.186	M=.273-.040.InX	r=-.91
		1.41**		.596	.383	.314	.279	.233	.218	M=.321-.047.InX	r=-.91
		1.58***		.668	.429	.352	.312	.261	.245	M=.360-.053.InX	r=-.91
5.	N_5	-	Weight(%)	46.0	34.05	29.13	25.49	23.47	22.47	M=29.67-3.33.InX	r=-.90
		1.35*	by Vol. (m/m)	62.1	45.96	39.32	34.41	31.68	30.33	M=.40-0.0449.InX	r=-.90
		1.47**		67.22	50.05	42.82	37.47	34.50	33.03	M=.436-0.4895.InX	r=-.90
		1.67***		76.82	56.86	48.65	42.56	39.19	37.52	M=.495-0.0556.InX	r=-.90

1	2	3	4	5	6	7	8	9	10	11	12
6.	N_6	-	Weight(%)	47.36	37.62	33.71	32.27	27.17	19.90	M=34.13-5.25.InX	r=-.99
		1.32*	by Vol (m/m)	.625	.496	.445	.425	.358	.263	M=.45-.069.InX	r=-.99
		1.45**		.686	.545	.489	.468	.394	.288	M=.49-.076.InX	r=-.99
		1.47***		.696	.553	.496	.474	.399	.292	M=.50-.077.InX	r=-.99
7.	N_7	-	Weight(%)	~~56.25~~ 46.00	42.13	40.75	33.16	28.99	17.73	M=38.34-7.61.InX	r=-.99
		1.566*	by Vol (m/m)	.881	.660	.638	.519	.453	.277	M=.60-.11.InX	r=-.96
		1.63**		.916	.686	.664	.540	.473	.290	M=.625-.12.InX	r=-.96
		2.04***		1.14	.859	.831	.676	.591	.362	M=.782-.15.InX	r=-.96
8.	N_8	-	Weight(%)	45.0	31.7	27.8	25.7	24.9	23.8	M=28.42-2.16.InX	r=-.86
		1.32*	by Vol (m/m)	.594	.418	.367	.339	.329	.314	M=.375-.285.InX	r=-.86
		1.41**		.634	.446	.392	.362	.351	.336	M=.400-.0304.InX	r=-.86
		1.42***		.639	.450	.395	.365	.354	.332	M=.403-.0306.InX	r=-.86
9.	N_9	-	Weight(%)	54.5	37.8	35.9	31.2	30.4	27.6	M=35.63-3.39.InX	r=-.90
		1.18*	by Vol (m/m)	.643	.446	.423	.368	.358	.326	M=.420-.04.InX	r=-.90
		1.14**		.621	.430	.409	.356	.347	.315	M=.406-.0386.InX	r=-.90
		1.22***		.665	.461	.438	.381	.371	.338	M=.435-.0413.InX	r=-.90
10.	N_{10}	-	Weight(%)	51.06	41.36	40.01	34.96	28.00	26.91	M=37.84-4.75.InX	r=-.91
		1.18*	by Vol (m/m)	.602	.488	.472	.412	.330	.317	M=.446-.056.InX	r=-.91
		1.54**		.786	.637	.616	.538	.431	.414	M=.582-.073.InX	r=-.91

1	2	3	4	5	6	7	8	9	10	11	12
11.	N_{11}	-	Weight(%)	54.5	31.64	31.13	28.91	27.64	26.35	M=30.42-1.79.InX	r=-.95
		1.10*	by Vol (m/m)	.500	.348	.342	.318	.304	.290	M=.334-.019.InX	r=-.95
		1.15**		.626	.343	.358	.332	.318	.303	M=.349-.020.InX	r=-.95
		1.54***		.839	.487	.479	.445	.425	.405	M=.468-.027.InX	r =-.95
12.	N_{12}	-	Weight(%)	42.85	34.81	32.68	27.47	26.15	25.2	M=30.79-2.27.InX	r=-.88
		1.22*	by Vol (m/M)	.522	.424	.399	.335	.319	.307	M=.375-.0276.InX	r=-.88
		1.35**		.578	.470	.441	.371	.353	.340	M=.415-.0306.InX	r=-.88
		1.70***		.728	.591	.554	.466	.444	.428	M=.523-.0385.InX	r=-.88

* Bulk density determined from the mold prepared for estimating moisture at 0 bar (saturation point)

** Bulk density determined from the moist soil sample supplied in core

*** Bulk density determined from the mold of the dried soil sample obtained from drying of the core sample.

1 bar = 1018 cm.

M = Moisture (% or m/m)

X = Pressure applied (Bars)

I_n = Natural Log

From the table No. 2, it could be seen that the soil samples varied considerably in their moisture retention behaviour. Sample analysed could be brodly classified in the following groups.

(a) Based on the soil moisture (percentage) recorded at 0.1 bar soils tested could be devided into seven groups as given below :

Sl.No.	Range of soil moisture (%)	Sample numbers
1.	25	N_2
2.	25-30	X
3.	30-35	N_3, N_4, N_8, N_{11}, N_{12}
4.	35-40	N_5
5.	40-45	N_1, N_9
6.	45-50	N_6, N_{10}
7.	50	N_7

(b) Based on the soil moisture (percentage) recorded at 15 bar, soils tested could be divided into seven groups below :

Sl.No.	Soil Moisture range (%)	Sample numbers
1.	10	N_2
2.	10-13	N_3
3.	13-16	N_4
4.	16-19	N_7
5.	19-22	N_5, N_6
6.	22-25	N_1, N_8, N_{10}, N_{12}
7.	25	N_9, N_{11}

Minor inconsistency recorded in the two groupings could be attributed to the variation in mineralogical composition and organic matter content of the soil samples collected. Biswas and Mukherjee (1987) has reported mineral composition and organic matter affecting the soil moisture retention.

ACKNOWLEDGEMENT

Help rendered by Sri Pankaj Kumar, S.R.A., N.I.H. in supply the samples, Sri Sita Ram, S.L.T., WRDTC in testing the samples, Mr. Ram Dular in preparing the samples; Sri Sunil Kumar in typing the report(s) and Mr. Vimal Chand in drawing the figures is thankfully acknowledged.

Laboratory facilites made available by Sri Nayan Sarma, O.C., Soil Mechanics Lab of WRDTC is also thankfully acknowledged.

Thanks are also due to Dr. S.M.Seth, Scientist 'F', N.I.H., Roorkee and many visiting experts for frequent discussions during course of the testing of these samples.

Testing work could be undertaken with the financial assistance of Rs.12,000/- made available by the Director, N.I.H. Dr.Satish Chandra.

REFERENCES

Biswas, T.D. and S.K.Mukherjee (1987)
Soil Physics in Text Book of Soil Science,
Tata McGraw-Hill Publishing Company Ltd., New Delhi
pp. 117-169

Annonymous (1982)
Progress report of coordinated project for research on
Water Management (1979-81), AICWMP at CSSRI, Karnal, pp.18

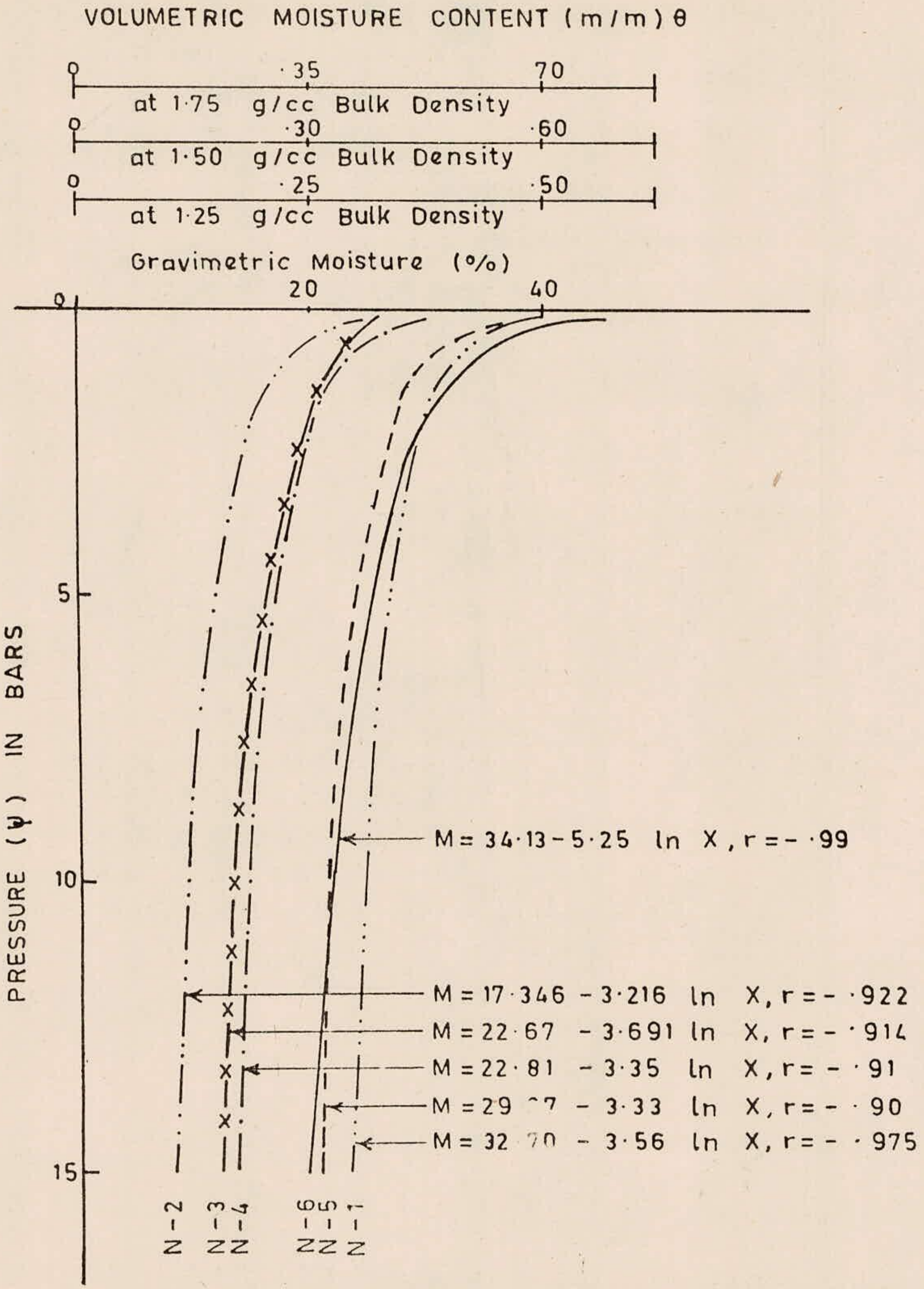


FIG. 1 - SHOWING THE MOISTURE RETENTION BEHAVIOUR OF SIX SOILS (N_1 - N_6)

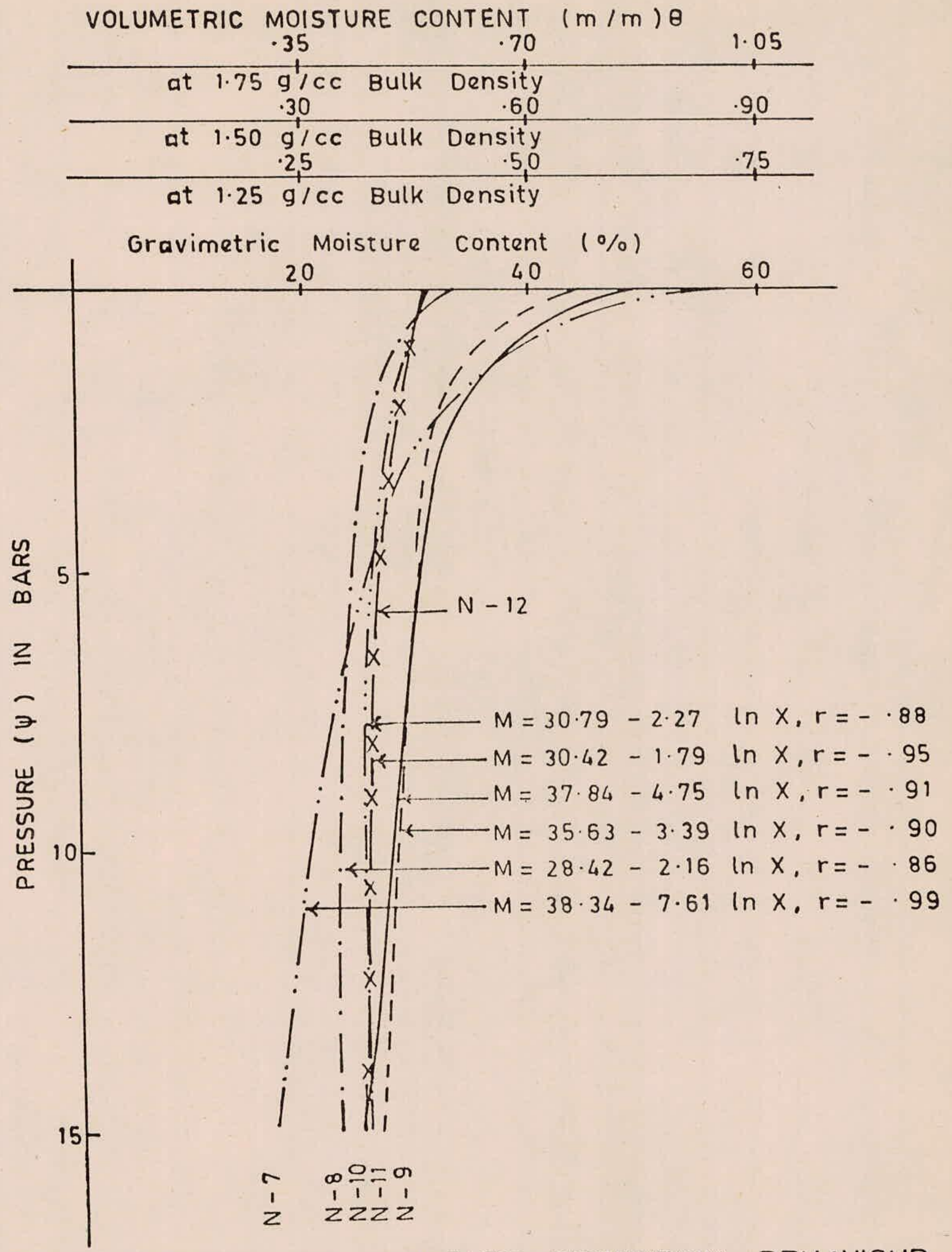


FIG. 2 - SHOWING THE MOISTURE RETENTION BEHAVIOUR OF SIX SOILS (N_7 - N_{12})

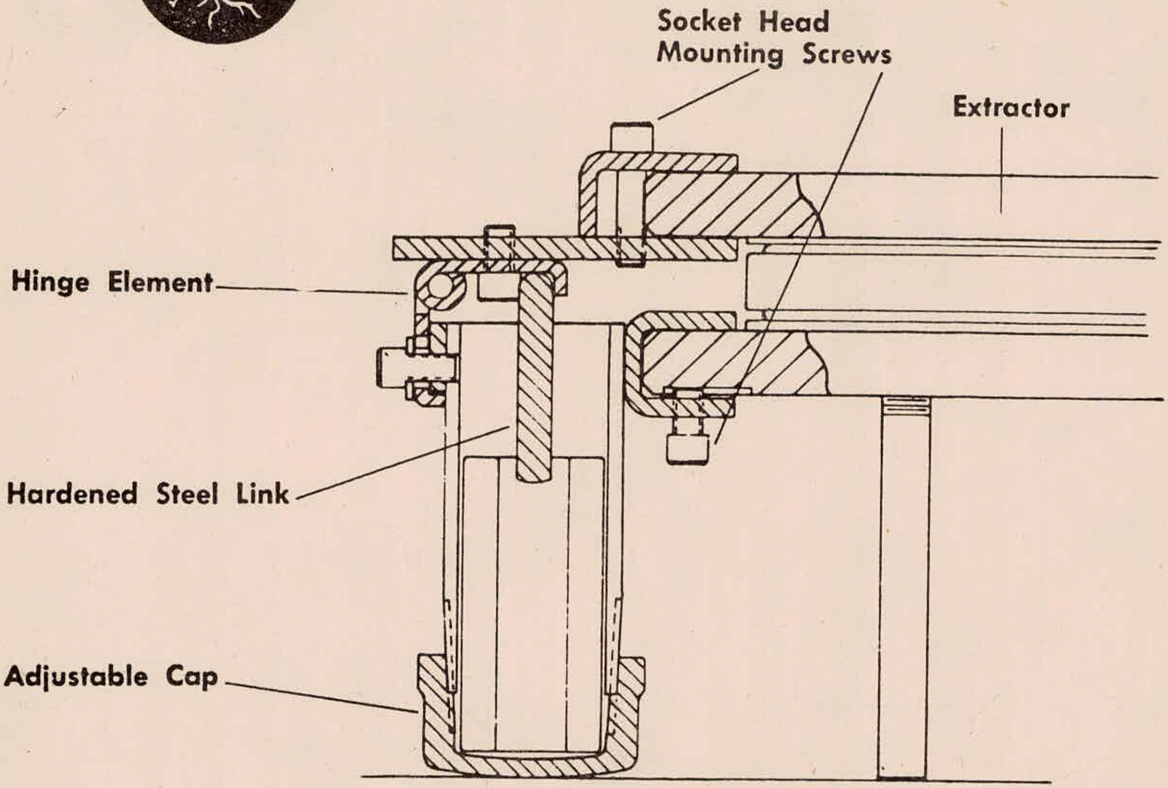
APPENDIX - 5

PRESSURE PLATE APPARATUS AND OPERATING INSTRUCTIONS

[Reproduced with the permission of M/s Soil Moisture Equipment Corporation, Santa Barbara California, U.S.A.]

INSTALLATION INSTRUCTIONS for the PM HINGE

Cat. No. 1080



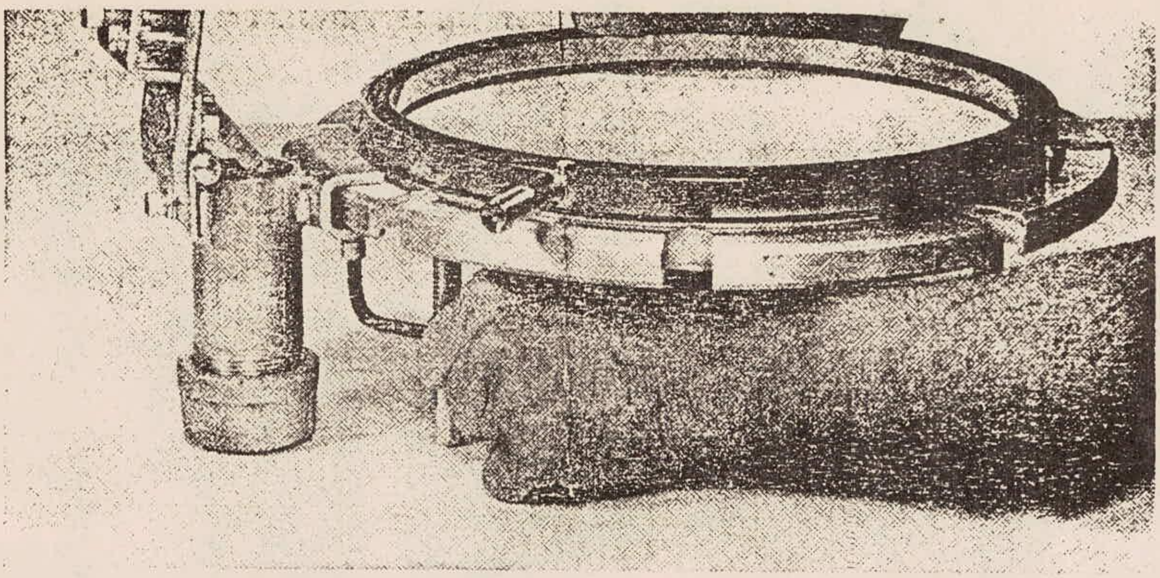
The Pressure Membrane Counterbalanced Hinge is shown in the section view above, mounted on the standard extractor. This view shows clearly the various parts of the PM Hinge and also the manner in which it is clamped to the extractor plates.

The hinge element as shown above is mounted so that it is free to move vertically through a confined distance of ⅛". This allows ample compensation for the variation in the spacing between the top and bottom plates of the extractor when they are bolted together for an extraction run.

The "adjustable cap" is screwed up or down at the time of installation to match the height of the extractor legs.

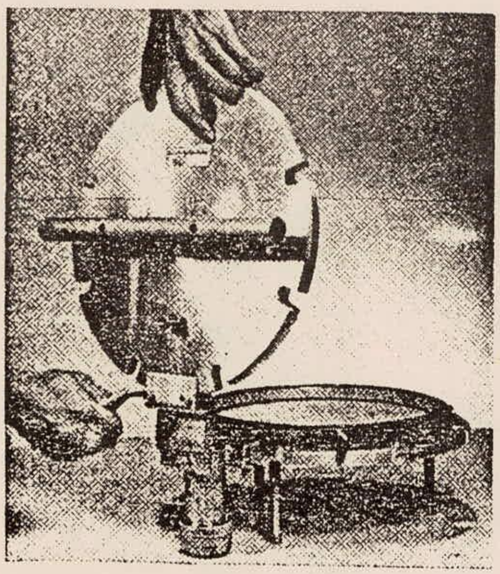
The PM Hinge is shipped completely assembled and ready to install. It should not be necessary to disassemble the hinge. If for some reason the hinge is to be disassembled, be sure to first unscrew completely the "adjustable cap" in order to relieve the spring pressure from the various parts of the assembly. A wrench is provided to fit the socket head mounting screws and should be used in mounting the hinge to the extractor.

Mounting is accomplished in two simple steps pictured and described on the reverse page.



STEP 1: The top plate of the extractor is removed. Packing tape is removed from the PM Hinge. The socket head mounting screws on the lower mounting bracket of the hinge are loosened and the bracket is slipped over the edge of the bottom extractor plate. The lower mounting bracket is centered in the section between the two bolt slots adjacent to the outlet stem of the pressure membrane cylinder, as shown in the photograph above. The mounting screws are now tightened securely, using the wrench provided. The ends of the screws enter the same groove in the bottom plate that is provided to constrain the heads of the extractor clamping bolts (see section view on reverse page).

The adjustable cap is now screwed up or down to match the leg height.



STEP 2: The top extractor plate is now held vertically and slipped into the top mounting bracket of the PM Hinge as shown to the left. The top plate is oriented so that the handle is parallel to the bench and the pressure fitting next to the hinge. The mounting bracket is centered in the section between two bolt slots. The two mounting screws are lightly tightened. The top plate can now be lowered and the PM Hinge will counteract its weight. After the top plate is lowered, its orientation with respect to the bottom plate is noted and slight adjustment in position of the top plate is made so that proper alignment is reached. The mounting screws for the top plate are now securely tightened. Both clamping screws and wrench are of heat treated steel and they will not be damaged by secure tightening.

The PM Hinge is now in operation and ready to save you valuable time. A drop of oil occasionally on the moving parts will help its action and avoid "squeaks."

OPERATING INSTRUCTIONS for the
Model 500-A
PM COMPRESSOR

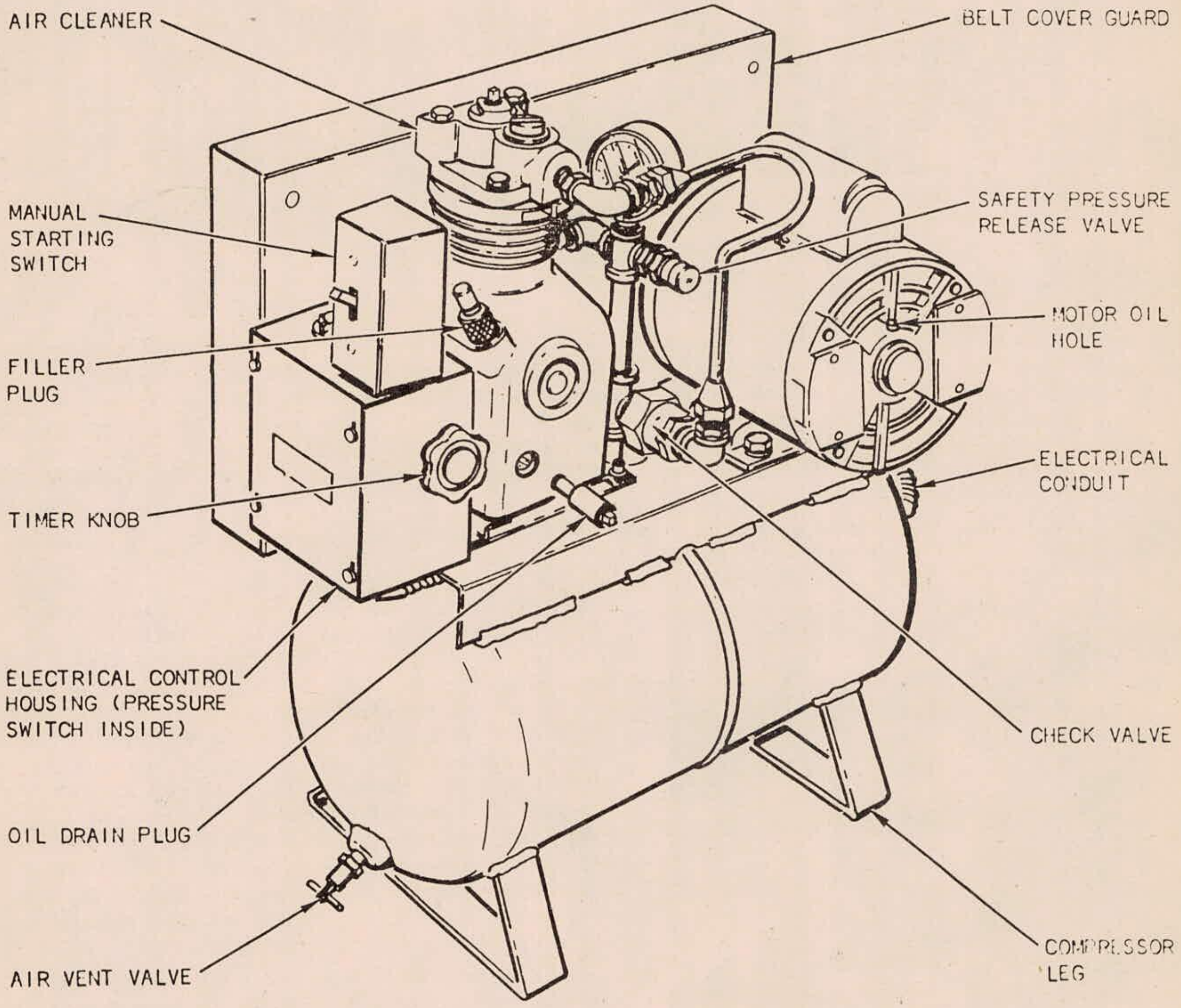
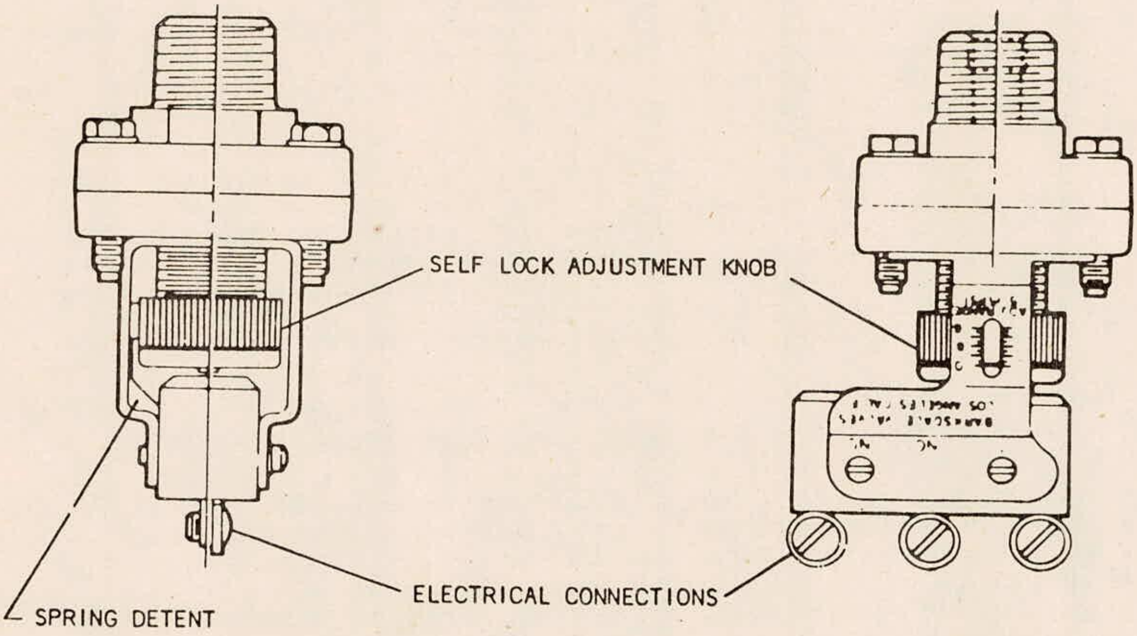


FIG. 1

NOTICE

WE HAVE INCORPORATED A NEW PRESSURE SWITCH INTO OUR MODEL 500-A & B COMPRESSOR TO PROVIDE FOR MORE PRECISE PRESSURE CONTROL AND GREATER AIR STORAGE. THE NEW PRESSURE SWITCH IS NOW SET INSIDE THE ELECTRICAL CONTROL HOUSING WITH THE TIMER AS SHOWN IN FIG. 1 OF THE OPERATING INSTRUCTIONS FOR THE PM COMPRESSOR. THE PRESSURE SWITCH IS SET AT THE FACTORY AND NORMALLY NO FURTHER ADJUSTMENT IS NECESSARY. THE SWITCH IS SET TO OPEN AT APPROXIMATELY 295 PSI AND TO CLOSE AT APPROXIMATELY 280 PSI.

IN THE EVENT IT IS DESIRED TO ADJUST THE PRESSURE SWITCH, REMOVE THE FOUR SCREWS HOLDING THE COVER ON THE TIMER CHASSIS ASSEMBLY AT THE FRONT OF THE COMPRESSOR (THE COVER HAS THE NAMEPLATE ON IT) AND REMOVE THE COVER. INSIDE, ON THE LEFT, YOU WILL SEE THE PRESSURE SWITCH, AS PICTURED BELOW. REFERRING TO THE SWITCH IN THE FIGURE BELOW, THE SELF LOCK ADJUSTMENT KNOB IS USED TO MAKE THE PRESSURE ADJUSTMENT. TO INCREASE THE PRESSURE, TURN THE SELF LOCK ADJUSTMENT KNOB WITH THE THUMB AND FOREFINGER CLOCKWISE, OR TO THE RIGHT. TO DECREASE THE PRESSURE, TURN THE SELF LOCK ADJUSTMENT KNOB WITH THE THUMB AND FOREFINGER, COUNTERCLOCKWISE, OR TO THE LEFT. WHEN TURNING THE ADJUSTMENT KNOB A SPRING DETENT SNAPS INTO THE SERRATIONS ON THE KNOB, MAKING A DEFINITE STOP OR CLICK. MOVING THE KNOB ONE SERRATION MAKES APPROXIMATELY 1.6 PSI CHANGE IN PRESSURE. AS AN EXAMPLE, IF YOU WANT TO INCREASE THE PRESSURE SETTING APPROXIMATELY 8 PSI, YOU WOULD TURN THE SELF LOCK ADJUSTMENT KNOB, 5 SERRATIONS OR CLICKS, CLOCKWISE OR TO THE RIGHT.



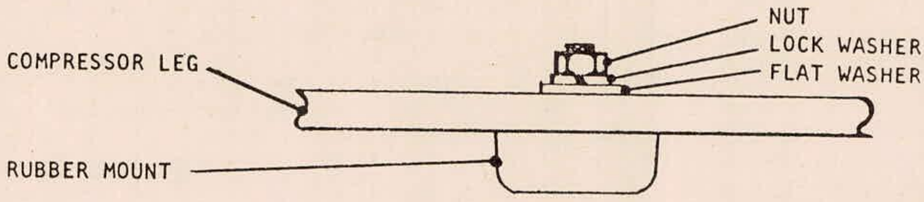
UNPACKING

THE PM COMPRESSOR, CAT. NO. 500, COMES COMPLETELY ASSEMBLED AND READY TO CONNECT TO YOUR ELECTRICAL SUPPLY.

UNPACK CAREFULLY, REMOVE ALL PACKING MATERIALS AND TAPE. BE SURE TO READ ALL INSTRUCTIONS BEFORE OPERATING UNIT.

FOUR RUBBER SHOCK MOUNTS ARE PACKED WITH UNIT. IT IS SUGGESTED THAT THESE BE MOUNTED IN THE FOUR HOLES IN THE LEGS OF THE COMPRESSOR (SEE FIG. 2). THE RUBBER MOUNTS WILL ISOLATE THE COMPRESSOR VIBRATION FROM THE FLOOR AND HELP REDUCE NOISE LEVEL TO A MINIMUM.

FIG. 2



LOCATION OF COMPRESSOR

THE COMPRESSOR SHOULD BE LOCATED IN A CLEAN ACCESSIBLE AREA FREE OF EXCESSIVE DUST AND WHERE ELECTRIC POWER IS AVAILABLE. SINCE THE NOISE LEVEL IS NOT EXCESSIVE AND SINCE IT IS COMPLETELY GUARDED, THE COMPRESSOR MAY BE LOCATED ADJACENT TO THE LABORATORY BENCH. OVERALL DIMENSIONS OF THE PM COMPRESSOR ARE 22" LONG BY 13" WIDE BY 25" HIGH. MOUNTING HOLE SPACING IN LEGS IS 7-1/2" BY 12-1/2" BETWEEN CENTERS. HOLES ARE CLEARANCE FOR 1/4" DIAMETER BOLTS. ELECTRICAL POWER REQUIREMENTS ARE FOR 1/2 HP CAPACITOR START MOTOR.

ELECTRICAL CONNECTION

THE FLEXIBLE CONDUIT EXTENDING TO THE REAR OF THE COMPRESSOR IS 3/8" SIZE AND CONTAINS THE THREE WIRES FOR ELECTRICAL CONNECTION. THE WHITE WIRE IS A GROUND WIRE AND SHOULD BE CONNECTED TO A GROUND LINE OR GROUNDED PIPE LINE. THE RED AND BLACK WIRES ARE FOR CONNECTION TO THE ELECTRICAL SUPPLY. THE FLEXIBLE CONDUIT MAY BE CONNECTED TO AN OUTLET BOX WITH STANDARD FITTINGS OR A PRONGED PLUG MAY BE ATTACHED FOR USE IN A WALL OUTLET.

THE STANDARD COMPRESSOR OPERATES ONLY ON 110 VOLT, 60 CYCLE, SINGLE PHASE CURRENT. NO ATTEMPT SHOULD BE MADE TO CHANGE THE MOTOR CONNECTIONS ON THE 1/2 HP MOTOR TO RUN THIS ON 220 VOLTS BECAUSE AN ELECTRICAL TIMER MOTOR IS ALSO USED IN THE COMPRESSOR AND THIS TIMER MOTOR WOULD BE BURNED OUT IMMEDIATELY IF THE STANDARD COMPRESSOR WERE USED ON 220 VOLTS. SPECIAL COMPRESSORS ARE AVAILABLE FOR OPERATION ON 220 VOLT, 60 CYCLE AND ALSO 220 VOLT, 50 CYCLE. THE PROPER OPERATING VOLTAGE AND CYCLE IS STAMPED ON THE NAME PLATE AT THE FRONT OF THE COMPRESSOR.

ELECTRICAL CONTROLS

THE MOTOR IS CONTROLLED BY A MANUAL STARTING SWITCH, A TIMER, AND A PRESSURE SWITCH ALL SHOWN IN FIG. 1.

THE MANUAL STARTING SWITCH IS DOUBLE POLE AND HENCE CONTROLS BOTH INCOMING ELECTRICAL LEADS. IT CONTAINS A RESETABLE HEATER ELEMENT FOR FULL OVERLOAD PROTECTION TO THE MOTOR. IF THE MOTOR IS BEING OVERLOADED AND DRAWING TOO MUCH CURRENT AT ANY TIME THIS SWITCH WILL SNAP OFF AND THE SWITCH LEVER WILL GO TO A HORIZONTAL POSITION AND STAY THERE. TO START AGAIN, LEVER IS PUSHED TO "OFF" POSITION AND

THEN SNAPPED TO "ON".

AFTER INITIAL START, THE MANUAL STARTING SWITCH IS ALWAYS LEFT IN THE "ON" POSITION. THE TIMER AND THE PRESSURE SWITCH WILL THEN CONTROL THE MOTOR IN ORDER TO MAINTAIN PROPER TANK PRESSURE.

THE TIMER CONSISTS OF AN ELECTRICAL CLOCK MOTOR THAT TURNS A CAM OPERATED, SINGLE POLE, SINGLE THROW SWITCH. THE TIMER IS SET SO THAT THE COMPRESSOR WILL RUN 5 MIN. OUT OF EACH HOUR. THIS LENGTH IS ADEQUATE FOR NORMAL USE AND IT PREVENTS DAMAGE TO THE COMPRESSOR FROM RUNNING CONTINUOUSLY IN THE EVENT OF A RUPTURE OF A PRESSURE MEMBRANE DIAPHRAGM WHILE THE EQUIPMENT IS UNATTENDED. THE TIMER KNOB AND CAM ELEMENTS MAKE ONE REVOLUTION PER HOUR. THE TIMER CAN BE OPERATED MANUALLY AT ANY TIME BY TURNING THE KNOB BY HAND IN A CLOCKWISE DIRECTION ONLY. TURNING THE KNOB BY HAND DOES NOT IN ANY WAY DAMAGE THE CLOCK DRIVE SINCE THE CLOCK MOTOR DRIVES THE KNOB AND SWITCH CAMS THROUGH A FRICTIONAL LINKAGE.

THE PRESSURE SWITCH IS SET SO THAT IT WILL BREAK THE CIRCUIT WHEN THE PRESSURE REACHES APPROXIMATELY 300 PSI AND WILL CLOSE AGAIN WHEN THE PRESSURE DROPS TO APPROXIMATELY 235 PSI. SINCE THE PRESSURE SWITCH IS CONNECTED IN SERIES WITH THE TIMER SWITCH, THE COMPRESSOR WILL NOT NECESSARILY TURN ON AS SOON AS THE PRESSURE SWITCH CLOSES, BUT WILL TURN ON WHEN THE TIMER SWITCH CLOSES ON THE FIRST CYCLE AFTER THE PRESSURE SWITCH HAS CLOSED.

ADJUSTMENTS ON THE PRESSURE SETTING OF THE PRESSURE SWITCH CAN BE MADE. TO DO SO REMOVE THE COVER AND INSERT A SCREW DRIVER INTO THE SLOTTED HEAD PROJECTING THROUGH THE SPRING YOKE, TURNING IT CLOCKWISE FOR A LOWER PRESSURE VALUE, OR COUNTERCLOCKWISE FOR A HIGHER PRESSURE VALUE. THE PRESSURE DIFFERENTIAL IS NOT ADJUSTABLE. IT IS RECOMMENDED THAT THE PRESSURE SWITCH BE LEFT AS ADJUSTED AT THE FACTORY.

AIR LINE CONNECTION.

THE 1/4" STANDARD PIPE OUTLET AT THE BACK OF THE COMPRESSOR TANK IS USED FOR CONNECTION TO THE AIR LINE. IF THE COMPRESSOR IS TO BE LOCATED NEAR THE LABORATORY BENCH, SIMPLE AND EFFECTIVE WAY OF MAKING CONNECTION TO THE PRESSURE CONTROL MANIFOLD IS BY MEANS OF A CAT. NO. 710 CONNECTING HOSE ASSEMBLY, 60" LONG WITH 1/4" STREET ELBOW AND SHUTOFF VALVE (SEE CURRENT PRICE LIST). THE 1/4" ELBOW SCREWS DIRECTLY INTO THE COMPRESSOR TANK. ONE END OF THE HOSE COUPLES DIRECTLY WITH THE SHUTOFF VALVE AND THE OTHER END OF THE HOSE COUPLES DIRECTLY TO ANY OF THE 700 SERIES MANIFOLDS. WHERE A MANIFOLD IS BEING BUILT UP, THE CAT. NO. 50/20 ADAPTER CAN BE USED. THE ADAPTER WILL SCREW DIRECTLY INTO A 1/4" PIPE THREAD AND THE CONNECTING HOSE WILL COUPLE DIRECTLY TO THE ADAPTER. USING A CONNECTING HOSE FOR THIS PURPOSE HAS THE ADVANTAGE OF ISOLATING COMPRESSOR VIBRATION FROM THE PRESSURE CONTROLS.

WHERE STANDARD 1/4" GALVANIZED PIPE IS TO BE USED FOR THE AIR LINE CONNECTION, BE SURE TO INSTALL A PIPE UNION IN THE LINE NEAR THE COMPRESSOR TO FACILITATE ANY FUTURE DISCONNECTS. USE A GOOD GRADE OF PIPE SEALING COMPOUND OR TAPE ON ALL THREADED JOINTS AND CHECK FOR AIR LEAKS AT ALL JOINTS WITH A SOAP SOLUTION AFTER COMPRESSOR HAS BEEN PUT IN OPERATION.

FILL COMPRESSOR CRANKCASE WITH OIL

THE PM COMPRESSOR IS SHIPPED LUBRICATED BUT WITH COMPRESSOR CRANKCASE DRAINED. TO FILL, REMOVE KNURLED FILLER PLUG, SEE FIG. 1. THIS PLUG SIMPLY PULLS OUT OF THE BASE CASTING. POUR IN HEAVY DUTY SAE 30 WEIGHT DETERGENT OIL UNTIL IT REACHES THE OIL LEVEL MARK ON THE INDICATOR SET IN BASE CASTING OF COMPRESSOR. A SMALL FUNNEL OR SHORT LENGTH OF TUBING WILL BE HELPFUL IN ADDING THE OIL. AFTER FILLING,

REPLACE FILLER PLUG.

TO DRAIN OIL FROM CRANKCASE, SIMPLY REMOVE PIPE PLUG FROM END OF DRAIN TUBE EXTENSION AT BASE OF COMPRESSOR HOUSING. BE SURE TO ALWAYS REPLACE PIPE PLUG SNUGLY AFTER DRAINING.

STARTING COMPRESSOR FOR FIRST TIME

AFTER ELECTRICAL CONNECTION HAS BEEN MADE, THE AIR LINE INSTALLED, AND THE COMPRESSOR CRANKCASE FILLED WITH OIL THE COMPRESSOR MAY BE TURNED ON. BEFORE TURNING MANUAL STARTING SWITCH TO "ON" BE SURE THAT THE AIR DRAIN VALVE AT THE FRONT OF THE TANK NEAR THE BASE IS CLOSED TIGHTLY, AND THAT OTHER AIR LINE VALVES ARE CLOSED.

WHEN THE MANUAL STARTING SWITCH IS TURNED "ON", THE COMPRESSOR MOTOR WILL START ONLY IF THE TIMER SWITCH HAPPENS TO BE CLOSED. TO CLOSE THE TIMER SWITCH, SIMPLY TURN THE KNOB CLOCKWISE UNTIL THE SWITCH CLOSES AND THE COMPRESSOR MOTOR STARTS. THE TIMER WILL PERMIT THE COMPRESSOR TO RUN FOR 5 MIN. DURING THIS TIME, THE TANK PRESSURE WILL BUILD UP TO APPROXIMATELY 140 PSI. AFTER AN HOUR, THE TIMER WILL TURN THE COMPRESSOR ON AGAIN AND THE TANK PRESSURE WILL RISE TO APPROXIMATELY 220 PSI. AFTER THE THIRD CYCLE THE TANK PRESSURE WILL BE UP TO APPROXIMATELY 270 PSI. A FOURTH CYCLE WILL PROBABLY BE REQUIRED FOR THE TANK PRESSURE TO REACH THE MAXIMUM VALUE REQUIRED FOR THE PRESSURE SWITCH TO OPEN. THEREAFTER, THE COMPRESSOR WILL RUN ONLY WHEN REQUIRED TO MAINTAIN TANK PRESSURE WITHIN THE OPERATING LIMITS AS DEMANDED BY THE PRESSURE SWITCH AND TIMER.

IN THE INITIAL BUILDUP OF TANK PRESSURE IT IS NOT NECESSARY TO WAIT FOR THE FULL 1 HOUR INTERVAL BETWEEN RUNS AS REGULATED BY THE TIMER. TO SPEED UP THE PROCESS YOU MAY SIMPLY TURN THE TIMER KNOB BY HAND CLOCKWISE UNTIL THE SWITCH AGAIN CLOSES. IF THIS PROCEDURE IS FOLLOWED, BE SURE TO ALLOW AT LEAST 15 MIN. INTERVALS BETWEEN RUNS TO PERMIT THE COMPRESSOR AND MOTOR TO COOL OFF SO AS TO AVOID PROBLEMS OF OVERHEATING.

AFTER AIR PRESSURE HAS BEEN BUILT UP IN THE SYSTEM, CHECK AIR LINE JOINTS FOR POSSIBLE LEAKS WITH SOAP SOLUTION AND TAKE CORRECTIVE ACTION WHERE NECESSARY TO STOP LEAKS.

IF COMPRESSOR TANK IS TO BE DRAINED OF AIR FOR ANY REASON, BE SURE TO FIRST SNAP MANUAL STARTING SWITCH TO "OFF" POSITION.

MAINTENANCE

MOTOR ADD 2 TO 3 DROPS OF OIL IN OIL HOLE AT EACH BEARING EVERY 2-3 MONTHS.

BELT DRIVE THE BELT DRIVE DOES NOT REQUIRE ANY REGULAR SERVICING AND WILL LAST INDEFINITELY.

FOR REPLACEMENT, THE COVER GUARD IS REMOVED BY UNDOING THE FOUR SCREWS AT THE CORNERS, SEE FIG. 1. LOCK WASHERS ARE PROVIDED UNDER EACH OF THESE SCREW HEADS IN ORDER TO PREVENT LOOSENING UNDER NORMAL COMPRESSOR VIBRATION.

BELT IS A 1/2" WIDE "V" BELT 41" LONG AND CARRIES THE STANDARD BELT NO. 4L-410.

COMPRESSOR LUBRICATION: USE A GOOD BRAND OF SAE 30 OIL. CHECK OIL LEVEL AT FREQUENT INTERVALS AND MAINTAIN AT OIL LEVEL MARK ON INDICATOR. DRAIN AND REFILL WITH FRESH OIL EVERY 100 HOURS OF OPERATION. SINCE THE COMPRESSOR RUNNING TIME IS A MAXIMUM OF 5 MIN. OUT OF EVERY HOUR THIS 100 HOURS CORRESPONDS TO A MINIMUM OF 2 MONTHS BETWEEN OIL CHANGES AND IT CAN BE MUCH LONGER THAN THIS DEPENDING ON THE AMOUNT OF USE.

AIR CLEANER: THE AIR CLEANER CONSISTS OF FELT PADS AND A SCREEN LOCATED AT THE TOP OF THE CYLINDER HEAD, SEE FIG. 1. TO CLEAN FELTS UNDO THE TWO SCREWS HOLDING SLOTTED COVER PLATE IN PLACE, REMOVE PLATE AND FELT PADS. FELT PADS SHOULD BE WASHED PERIODICALLY IN CLEANING SOLVENT.

TANK THE AIR TANK SHOULD BE DRAINED AT REGULAR INTERVALS TO REMOVE ACCUMULATION OF WATER CONDENSED FROM THE COMPRESSED AIR. A SIX MONTH INTERVAL IS SUGGESTED. IN DRAINING THE TANK OF AIR, FIRST SNAP THE MANUAL STARTING SWITCH TO THE "OFF" POSITION AND THEN OPEN THE AIR DRAIN VALVE AT THE FRONT OF THE TANK NEAR THE BASE. AFTER DRAINING, CLOSE VALVE TIGHTLY AND FOLLOW INSTRUCTIONS PREVIOUSLY GIVEN FOR BUILDING UP AIR PRESSURE IN TANK.

INSPECTION OF THE INSIDE OF THE TANK MAY BE MADE BY REMOVING THE 1-1/2" PIPE PLUG PROVIDED FOR THIS PURPOSE ON THE SIDE OF THE TANK. BE SURE TO DRAIN ALL AIR FROM TANK BEFORE REMOVING INSPECTION PLUG.

OPERATING INSTRUCTIONS for the

15 BAR CERAMIC PLATE EXTRACTOR

Cat. No. 1500

TABLE OF CONTENTS

UNPACKING AND ASSEMBLY OF THE EXTRACTOR

REMOVE FROM BOX

THE 15 BAR CERAMIC PLATE EXTRACTOR IS SHIPPED WITH LID ASSEMBLED TO THE PRESSURE VESSEL. THE 15 BAR CERAMIC PLATE CELLS AND TRIANGULAR SUPPORT FOR BOTTOM PRESSURE PLATE CELL ARE PACKED INSIDE THE EXTRACTOR. OUTFLOW TUBE ASSEMBLIES, PLUG BOLTS AND PLASTIC SPACERS ARE PACKED SEPARATELY OUTSIDE OF THE EXTRACTOR. AFTER LIFTING UNIT FROM PACKING CRATE, SET THE EXTRACTOR DIRECTLY ON ITS FEET.

REMOVE ALL PACKING MATERIAL AND TAPE FROM AROUND CLAMPING BOLTS AND OVER OUTLET PORTS IN THE SIDE OF THE EXTRACTOR. THE PRESSURE INLET FITTING TO THE EXTRACTOR IS CAPPED WITH A THREAD PROTECTOR WHICH MUST BE REMOVED BEFORE CONNECTING HOSE IS ATTACHED.

REMOVE LID

THE EXTRACTOR LID IS READILY REMOVED BY UNDOING THE EIGHT CLAMPING BOLTS AROUND THE PERIPHERY OF THE UNIT. THE WING NUTS ON THE CLAMPING BOLTS SHOULD NOT BE COMPLETELY REMOVED. IT IS NECESSARY ONLY TO UNDO THE WING NUTS SEVERAL TURNS. THE BOLTS CAN THEN BE SLIPPED OUT OF THE SLOTS. THE BOLTS HAVE SPECIAL RECTANGULAR HEADS WHICH FIT INTO A CONSTRAINING GROOVE IN THE BOTTOM OF THE LOWER CLAMPING RING. IN REPLACING THE CLAMPING BOLTS, ALWAYS BE SURE THAT THEIR HEADS ARE PROPERLY FITTED INTO THE CONSTRAINING GROOVE.

AFTER THE CLAMPING BOLTS ARE REMOVED, THE LID CAN BE LIFTED OFF. IF THE LID APPEARS TO "STICK", LIFT FORCIBLY AT ONE EDGE TO BREAK CONTACT BETWEEN SEALING "O" RING AND LID. IT IS IMPORTANT TO HANDLE THE LID CAREFULLY SO THAT THE SEALING AREA ON THE UNDERNEATH SIDE IS NEVER SCRATCHED OR OTHERWISE DAMAGED SINCE SUCH DAMAGE WOULD PREVENT THE UNIT FROM SEALING PROPERLY. THE "O" RING ITSELF FITS INTO A GROOVE AT THE TOP EDGE OF THE PRESSURE VESSEL WALL AND IS EASILY REMOVED AND/OR REPLACED.

REMOVE PRESSURE PLATE CELLS

THE 15 BAR CERAMIC PLATE CELLS MAY NOW BE REMOVED ALONG WITH THE TRIANGULAR SUPPORT AND ALL PACKING MATERIAL. HANDLE THE CERAMIC PLATE CELLS WITH CARE TO AVOID SHARP BLOWS WHICH MAY CAUSE CRACKING OR BREAKING.

MOUNT OUTFLOW TUBE AND PLUG BOLTS

THE METAL OUTFLOW TUBE FITTING IS SHIPPED ASSEMBLED TO THE OTHER INTERNAL CONNECTING TUBES. REMOVE THE RUBBER SLEEVE FROM THE OUTFLOW TUBE FITTING BEFORE SCREWING FITTING INTO OUTLET PORT IN VESSEL WALL. SIX OUTLET PORTS ARE PROVIDED IN THE WALL OF THE VESSEL. FOUR ARE AROUND THE TOP EDGE AND TWO OTHERS ARE SPACED DOWN THE WALL OF THE VESSEL FOR USE WHEN THE THREE PRESSURE CELLS ARE BEING RUN AT THE SAME TIME. FIVE PLUG BOLTS ARE PROVIDED FOR SEALING THE UNUSED OUTLET PORTS.

THE PRESSURE SEAL AT THE OUTLET PORT IS MADE BY A SMALL NEOPRENE RUBBER "O" RING RECESSED INTO THE HEAD OF THE OUTFLOW TUBE ASSEMBLY AND PLUG BOLT. BEFORE INITIALLY INSERTING THE OUTFLOW TUBE ASSEMBLY OR PLUG BOLT, APPLY A SMALL AMOUNT OF STOPCOCK GREASE OR VASELINE ON THE EXPOSED PORTION OF THE "O" RING TO LUBRICATE IT AS IT SLIDES AGAINST THE WALL OF THE VESSEL WHEN SCREWED INTO PLACE.

ONLY A SMALL AMOUNT OF TORQUE IS REQUIRED TO MAKE THE OUTLET PORT SEAL. A STANDARD 1/2" SIZE WRENCH WILL FIT THE OUTLET FITTINGS AND PLUG BOLTS. IN TIGHTENING

THESE FITTINGS IT IS ONLY NECESSARY TO BRING THE OUTER EDGE OF THE FITTING INTO CONTACT WITH THE FLAT "SPOT FACED" SURFACE ON THE PRESSURE VESSEL WALL. THIS PROVIDES THE PROPER COMPRESSION ON THE "O" RING TO MAKE THE SEAL. FURTHER TIGHTENING WILL ONLY SERVE TO DAMAGE THE FITTING AND SHORTEN THE LIFE OF THE "O" RING SEAL.

MOUNT PM HINGE

IF A PM HINGE, CAT. NO. 1080, IS TO BE USED IN CONJUNCTION WITH THE EXTRACTOR IT WILL BE NECESSARY TO HAVE A CAT. NO. 1081 ADAPTER PLATE. THIS PLATE FITS ON TOP OF THE EXTRACTOR LID UNDERNEATH THE TOP CLAMP OF THE PM HINGE AND PROVIDES THE PROPER SPACING TO MATCH THE CLAMP HEIGHT. INSTRUCTIONS FOR INSTALLATION OF THE PM HINGE ARE BASICALLY THE SAME AS FOR THE PRESSURE MEMBRANE EXTRACTOR WHICH ARE INCLUDED WITH THE HINGE. IT IS USUALLY DESIRABLE TO MOUNT THE PM HINGE AT THE BACK OF THE 15 BAR CERAMIC PLATE EXTRACTOR WITH PRESSURE INLET FITTING SPACED 45° TO THE RIGHT.

CLOSING AND OPENING LID WITH PM HINGE

WHEN THE PM HINGE IS USED IT IS NECESSARY TO APPLY ADDITIONAL TORQUE ON THE TWO WING NUTS ON EITHER SIDE OF THE HINGE IN ORDER TO COMPRESS THE COUNTERBALANCING SPRING IN THE HINGE WHEN THE LID IS CLOSED. THE FOLLOWING PROCEDURE SHOULD BE ADHERED TO FOR MAXIMUM EASE AND EFFICIENCY OF OPERATION. FIRST APPLY A THIN COAT OF HEAVY GREASE (SUCH AS WHEEL BEARING GREASE--OBTAINABLE AT ANY GASOLINE SERVICE STATION) ON THE UNDERSIDE OF EACH WING NUT AND TOP OF EACH WASHER. WHEN THE LID IS CLOSED INSERT FIRST TWO CLAMPING BOLT ASSEMBLIES, ONE ON EITHER SIDE OF THE HINGE AND IMMEDIATELY ADJACENT TO IT. TIGHTEN FIRST ONE WING NUT UNTIL IT IS SNUG AND THEN TIGHTEN THE OTHER ONE UNTIL SNUG. WORK BACK AND FORTH TIGHTENING FIRST ONE AND THEN THE OTHER UNTIL THE LID IS DOWN AGAINST THE TOP OF THE EXTRACTOR VESSEL. NOW INSERT THE SIX REMAINING CLAMPING BOLT ASSEMBLIES AND TIGHTEN ALL WING NUTS UNTIL THEY ARE FIRM.

WHEN THE EXTRACTOR IS BEING OPENED AFTER A RUN THE PROCESS IS JUST REVERSED. FIRST, LOOSEN AND REMOVE ALL CLAMPING BOLT ASSEMBLIES EXCEPT THE TWO ON EITHER SIDE OF THE HINGE. THEN LOOSEN ONE OF THESE REMAINING BOLTS ABOUT 1/8 TURN INITIALLY, AND THEN LOOSEN THE OTHER ABOUT 1/8 TURN. WORK BACK AND FORTH SLIGHTLY LOOSENING FIRST ONE AND THEN THE OTHER UNTIL THEY TURN EASILY (AFTER ABOUT 2-3 FULL TURNS), AND CAN BE REMOVED.

PLACEMENT OF TRIANGULAR SUPPORT

THE TRIANGULAR SUPPORT MUST BE PLACED IN THE EXTRACTOR VESSEL ON THE BOTTOM BEFORE ANY PRESSURE PLATE CELLS ARE INSTALLED. THE PURPOSE OF THE TRIANGULAR SUPPORT IS TO KEEP THE LOWER PRESSURE PLATE CELL OFF OF THE BOTTOM OF THE EXTRACTOR. THIS IS NECESSARY BECAUSE UNDER CERTAIN CIRCUMSTANCES IF IT IS NOT USED A SEAL CAN BE MADE BETWEEN THE OUTER EDGE OF THE RUBBER BACKING ON THE PRESSURE PLATE CELL AND THE FLAT BOTTOM OF THE EXTRACTOR. UNDER THESE CIRCUMSTANCES WHEN THE AIR PRESSURE IS APPLIED A LARGE PRESSURE DIFFERENTIAL WILL DEVELOP BETWEEN THE TOP AND BOTTOM OF THIS CERAMIC PLATE AND BREAK IT. BE SURE THE TRIANGULAR SUPPORT IS ALWAYS IN THE BOTTOM OF THE EXTRACTOR BEFORE THE PRESSURE PLATE CELLS ARE INSTALLED.

INSTALLING THE PRESSURE PLATE CELLS

THE FIRST PRESSURE PLATE CELL IS PLACED DIRECTLY ON THE TRIANGULAR SUPPORT AT THE BOTTOM OF THE EXTRACTOR AND CONNECTION IS MADE THROUGH THE LOWEST OUTLET PORT. THE SECOND PRESSURE PLATE CELL IS SET ON THREE PLASTIC SPACERS WHICH ARE PLACED ON THE

FIRST CERAMIC PLATE CELL NEAR THE OUTER EDGE AND LOCATED ABOUT 120° FROM EACH OTHER. CONNECTION TO THIS CELL IS MADE THROUGH THE MIDDLE OUTLET PORT. THE THIRD CELL IS MOUNTED SIMILARLY TO THE SECOND AND CONNECTION IS MADE THROUGH ONE OF THE OUTLET PORTS AT THE UPPER EDGE OF THE VESSEL WALL.

THE FLEXIBLE OUTER EDGE OF THE RUBBER DIAPHRAGM MAY BE USED TO LIFT THE PRESSURE PLATE CELLS IN AND OUT OF THE EXTRACTOR.

TUBE CONNECTIONS TO CERAMIC PLATE CELLS

THE CERAMIC PLATES IN GENERAL ARE NOT FLAT, AND HAVE A TENDENCY TO BE CONVEX. FOR THIS REASON IT IS NECESSARY TO SUPPORT THE PLATE WITH THE FINGERS DIRECTLY BEHIND THE OUTLET STEM WHEN THE RUBBER SLEEVE CONNECTION IS MADE. IN MAKING THE INTERNAL TUBE CONNECTIONS AT THE CELL AND AT THE OUTLET PORT, BE SURE THAT THE HARD NYLON TUBING RUNS THROUGH THE SLEEVE AND UP TO OR INTO THE METAL CONNECTING PARTS. THE NYLON TUBING WILL WITHSTAND THE HIGH EXTRACTION PRESSURES WITHOUT COLLAPSING WHEREAS THE RUBBER SLEEVES MAY NOT. IF THESE CONNECTIONS ARE NOT MADE IN SUCH A WAY THAT THE TUBING CANNOT COLLAPSE, AN ERRONEOUS EQUILIBRIUM READING WILL RESULT. THE ONLY OUTWARD EVIDENCE OF THIS MALFUNCTION WILL BE A RUSH OF AIR FROM THE OUTFLOW TUBE WHEN THE PRESSURE IN THE CHAMBER IS RELEASED, AS IS DONE AT THE END OF A RUN.

PRESSURE CONNECTION

THE SINGLE PRESSURE INLET TO THE EXTRACTOR IS A STANDARD 50/20 ADAPTER LOCATED PART WAY UP THE WALL OF THE VESSEL AND OPPOSITE TO THE OUTLET PORTS. A STANDARD CAT. NO. 1091 CONNECTING HOSE WILL COUPLE DIRECTLY TO THIS FITTING. THREAD SIZE OF THE PRESSURE FITTING IS 9/16-18. THE PRESSURE SEAL AT THE HOSE CONNECTION IS MADE WHEN THE ROUND "NOSE" OF THE BRASS STEM INSIDE THE HOSE NUT IS PRESSED AGAINST THE RECESSED CONICAL SURFACE OF THE 50/20 ADAPTER. THIS IS A METAL TO METAL SEAL AND IS VERY EFFECTIVE. THE SCREW THREADS ON THE FITTING AND NUT ONLY SERVE AS A MEANS OF HOLDING THE PARTS IN CONTACT. THE THREADS THEMSELVES DO NOT MAKE A SEAL. ONLY A SMALL AMOUNT OF TORQUE IS REQUIRED AND SHOULD BE USED IN CONNECTING THE HOSE.

HANDLING AND CARE OF THE 15 BAR CERAMIC PLATE CELLS AND EXTRACTOR VESSEL

CONSTRUCTION OF PRESSURE PLATE CELL

EACH PRESSURE PLATE CELL CONSISTS OF A 15 BAR CERAMIC PLATE APPROXIMATELY 10-1/4" IN DIAMETER WHICH IS SEALED ON ONE SIDE BY A THIN NEOPRENE DIAPHRAGM. AN INTERNAL SCREEN KEEPS THE DIAPHRAGM FROM CLOSE CONTACT WITH THE PLATE AND PROVIDES A PASSAGE FOR FLOW OF WATER. AN OUTLET STEM RUNNING THROUGH THE CERAMIC PLATE CONNECTS THIS PASSAGE TO THE OUTFLOW TUBE ASSEMBLY.

THE 15 BAR CERAMIC IS QUITE STRONG, HOWEVER, CARE SHOULD BE TAKEN TO AVOID SHARP BLOWS. IT IS ALSO IMPORTANT TO AVOID LARGE MECHANICAL LOADING.

CHECK OUT OF PRESSURE CELLS

BEFORE MAKING A RUN IT IS DESIRABLE TO CHECK OUT THE PRESSURE PLATE CELLS TO ACQUAINT THE OPERATOR WITH THEIR CHARACTERISTICS AND TO DETERMINE THAT THEY HAVE NOT BEEN DAMAGED IN SHIPMENT. PRIOR TO SHIPMENT EACH CELL IS TESTED FOR WATER OUTFLOW RATE AND AIR DIFFUSION RATE AND A PERMANENT RECORD IS MADE FOR EACH CELL.

IN MAKING THIS TEST THE GENERAL PROCEDURES AS GIVEN IN "MAKING A RUN FOR MOISTURE RETENTION STUDIES" [illegible], SHOULD BE FOLLOWED WITH THE EXCEPTION THAT ONLY WATER

WILL BE USED. LET AN EXCESS OF WATER STAND ON THE SURFACE OF THE CERAMIC PLATE CELLS FOR SEVERAL HOURS TO THOROUGHLY WET THE PLATE. APPROXIMATELY 150 ML OF WATER WILL BE REQUIRED TO FILL THE PORES OF EACH PLATE. NEXT MOUNT ONE OR MORE OF THE WETTED PLATES IN THE EXTRACTOR AND MAKE THE OUTFLOW CONNECTIONS. CAREFULLY ADD WATER ON TO THE SURFACE OF EACH CELL SO THAT THE SURFACE IS COMPLETELY COVERED TO THE MAXIMUM DEPTH PERMITTED BY THE OUTER EDGE OF THE NEOPRENE DIAPHRAM. CLOSE THE EXTRACTOR AND BUILD UP THE PRESSURE TO 15 BARS (220 PSI). AS THE PRESSURE BUILDS UP INSIDE THE EXTRACTOR THERE WILL BE A RUSH OF AIR FROM THE OUTFLOW TUBES. THIS IS CAUSED BY THE REDUCTION OF THE INTERNAL VOLUME OF THE CELL AS THE DIAPHRAGM AND SCREEN COLLAPSE UNDER THE PRESSURE IN THE EXTRACTOR. IF THE INTERNAL OUTFLOW TUBING CONNECTIONS ARE "TIGHT" AND THE CELL HAS NOT BEEN CRACKED OR DAMAGED, THIS AIR FLOW WILL STOP AFTER SEVERAL MINUTES AND THERE WILL BE A STEADY FLOW OF WATER. SMALL BUBBLES OF AIR WILL COME OUT IN THE FLOW OF WATER AT REASONABLY REGULAR INTERVALS. THIS IS AIR WHICH IS SLOWLY DIFFUSING THROUGH THE CERAMIC PLATE, AND IS TO BE EXPECTED. THE OUTFLOW RATE IN ML/MIN SHOULD BE MEASURED SOON AFTER FLOW STARTS, WHILE THE ENTIRE SURFACE OF THE CERAMIC IS COVERED WITH WATER.

AFTER A PERIOD OF TIME ALL OF THE WATER ON THE CERAMIC PLATE WILL HAVE BEEN CONDUCTED THROUGH AND FLOW OF WATER WILL STOP. THE SLOWLY DIFFUSING AIR WILL GRADUALLY CONDUCT SMALL AMOUNTS OF WATER SURROUNDING THE INTERNAL SCREEN TO THE OUTSIDE.

TO MEASURE THE RATE OF DIFFUSION A SHORT LENGTH OF RUBBER TUBING CAN BE CONNECTED TO THE OUTFLOW TUBE AND THE END INSERTED UNDER AN INVERTED GRADUATE WHICH HAS BEEN PREVIOUSLY FILLED WITH WATER. THE FLOW RATE OF THE AIR SHOULD BE LESS THAN 1/10 ML OF AIR AT ATMOSPHEREIC PRESSURE PER MIN WITH THE EXTRACTOR PRESSURE AT 220 PSI. IF THE FLOW RATE OF AIR IS APPRECIABLY HIGHER THAN THIS, IT INDICATES THAT THERE IS A LEAK IN THE TUBING CONNECTION OR THAT THE CELL IS CRACKED OR NOT SEALED PROPERLY.

DRYING CELL AFTER RUN

WHEN A PRESSURE CELL IS TO BE DRIED FOR STORAGE AFTER A RUN, IT IS IMPORTANT TO KEEP EVAPORATION DEPOSITS ON THE SURFACE TO A MINIMUM. THIS IS EASILY ACCOMPLISHED BY COVERING THE SURFACE OF THE CERAMIC PLATE WITH A THIN LAYER OF FINE DRY SOIL AND ALLOWING IT TO SET FOR SEVERAL DAYS UNTIL DRY. THE SOIL IS THEN REMOVED AND THE CELL IS STORED. BY THIS MEANS EVAPORATION DEPOSITS ARE FORMED ON THE SOIL PARTICLES RATHER THAN THE SURFACE OF THE CERAMIC PLATE.

REMOVAL OF EVAPORATION DEPOSITS FROM PRESSURE PLATE CELL

IF AFTER A PERIOD OF TIME THE FLOW RATE OF THE CELL DROPS DUE TO DEPOSITS, THESE CAN BE REMOVED. CALCIUM CARBONATE DEPOSITS ON THE SURFACE OF THE CERAMIC CAN BE REMOVED BY CAREFULLY SANDING THE SURFACE WITH A FINE OR MEDIUM GRADE OF GARNET OR SANDPAPER.

DEPOSITS IN THE PORES OF THE CERAMIC CAN BE REMOVED BY FLUSHING THROUGH THE PRESSURE PLATE CELL UNDER PRESSURE IN THE EXTRACTOR A 10% SOLUTION OF HYDROCHLORIC OR ACETIC ACID. THIS SHOULD BE FOLLOWED BY SIMILAR FLUSH OF CLEAR WATER.

BACTERIAL ACTION ON PRESSURE PLATE CELLS

FOR MOST SOILS AND WORK BACTERIAL ACTION IN THE PRESSURE PLATE CELL DOES NOT PRESENT A PROBLEM. HOWEVER, TO MINIMIZE THIS CONDITION, THE INTERNAL SCREEN IS OF COPPER IN ORDER TO RETARD BACTERIAL ACTION.

IN THOSE CASES WHERE BACTERIAL ACTION IS OF IMPORTANCE THE PRESSURE PLATE CELLS CAN BE FLUSHED UNDER PRESSURE PERIODICALLY WITH A SOLUTION OF COPPER SULFATE OR

MERCURIC CHLORIDE IN THE MANNER DESCRIBED FOR REMOVAL OF EVAPORATION DEPOSITS.

CARE OF EXTRACTOR VESSEL

THE EXTRACTOR VESSEL AND TOP ARE RUGGEDLY CONSTRUCTED, WELL PLATED FOR PROTECTION AND SHOULD REQUIRE LITTLE ATTENTION.

IN HANDLING THE EXTRACTOR BE SURE TO PROTECT FROM DAMAGE THOSE AREAS WHERE THE "O" RING SEAL IS MADE. KEEP SOIL PARTICLES CLEAR OF THE "O" RING AND THE SEAT IN THE WALL OF THE PRESSURE VESSEL.

THE VESSEL IS ADDITIONALLY COATED ON THE INSIDE WITH AN ASPHALT BASE PAINT, "GILA COAT", MANUFACTURED BY THE W. P. FULLER PAINT CO. IN THE EVENT RUSTING DEVELOPS IN THE VESSEL IT CAN BE RECOATED AS NECESSARY WITH THIS OR A COMPARABLE MATERIAL.

GAS PRESSURE SOURCE, PRESSURE REGULATION, LABORATORY SETUP

PRESSURE REQUIREMENTS

THE 15 BAR CERAMIC PLATE EXTRACTOR REQUIRES A SOURCE OF REGULATED GAS PRESSURE OF 220 PSI OR MORE IN ORDER TO MAKE MOISTURE EXTRACTIONS FROM SOIL SAMPLES THROUGH THE WILTING POINT (15 BARS).

EXISTING PRESSURE SUPPLY

IF THE LABORATORY ALREADY HAS A REGULATED PRESSURE SOURCE FOR PRESSURE MEMBRANE EQUIPMENT, THEN THIS SAME SUPPLY CAN BE USED FOR THE 15 BAR CERAMIC PLATE EXTRACTOR. PRESSURE CONNECTION FOR THE 15 BAR CERAMIC PLATE EXTRACTOR IS MADE TO THE SAME LINE THAT SUPPLIES AIR TO THE "EXTRACTION CHAMBER" ON THE PRESSURE MEMBRANE EXTRACTOR. APPROPRIATE SHUT OFF AND VENT VALVES SHOULD BE PROVIDED FOR THE NEW EXTRACTOR.

INITIAL SETUP

IF AN INITIAL SETUP IS BEING MADE FOR THE 15 BAR CERAMIC PLATE EXTRACTOR, THE PRESSURE SOURCE CAN BE EITHER A COMPRESSOR OR COMPRESSED GAS IN TANKS.

THE PM COMPRESSOR, CAT. NO. 500, PROVIDES A CONVENIENT, LOW COST PRESSURE SOURCE FOR ALL OF THE GAS PRESSURE EXTRACTORS AND CAN BE USED AS A PRESSURE SOURCE FOR THIS EXTRACTOR.

COMPRESSED NITROGEN OR AIR (2000 PSI) IN TANKS CAN BE USED, PARTICULARLY WHERE THE EXTRACTOR IS OPERATED ON A LIMITED BASIS. WHERE TANK GAS IS USED IT IS VERY IMPORTANT TO MAKE SURE THAT ALL PIPING IS LEAK FREE, SINCE A SMALL LEAK CAN WASTE A LARGE VOLUME OF GAS OVER A PERIOD OF A RUN.

THE INTERNAL VOLUME OF THE 15 BAR CERAMIC PLATE EXTRACTOR IS APPROXIMATELY 1/4 CU. FT. IF CONTINUOUS EXTRACTIONS ARE BEING MADE AT THE 15 BAR LEVEL AN AIR COMPRESSOR WILL BE DESIRABLE AS THE PRESSURE SOURCE.

PRESSURE REGULATION

THE TYPE OF PRESSURE REGULATOR REQUIRED WILL DEPEND ON THE TYPE OF PRESSURE SOURCE AND ON THE ACCURACY REQUIRED FOR THE STUDIES BEING CONDUCTED.

ACCURACY OF REGULATION IS DEPENDENT ON THE CONSTRUCTION OF THE REGULATOR AND ALSO ON VARIATIONS IN THE PRESSURE FROM THE SOURCE OF SUPPLY. WITH REGULATORS SUITABLE FOR USE WITH THIS EQUIPMENT ONE CAN EXPECT VARIATIONS IN THE SOURCE PRESSURE TO BE REFLECTED IN THE REGULATED PRESSURE IN THE RATIO OF ABOUT 1/12 to 1/25. IN OTHER WORDS, A

CHANGE IN THE PRESSURE FROM THE COMPRESSED AIR SOURCE OF 25 PSI WILL CHANGE THE REGULATED PRESSURE BY 1 TO 2 PSI, DEPENDING ON THE MAKE OF THE REGULATOR. IN CASES WHERE EXTREME ACCURACY IS DESIRED THIS VARIATION CAN BE ELIMINATED BY THE PROCESS OF "DOUBLE REGULATION". THIS IS DONE SIMPLY BY PUTTING TWO REGULATORS IN SERIES. THE FIRST REGULATOR IS SET AT A SOMEWHAT HIGHER PRESSURE THAN THE SECOND IN ORDER TO SUPPLY REASONABLY CONSTANT PRESSURE TO THE SECOND REGULATOR. PRESSURE FROM THE SECOND REGULATOR IN TURN WILL BE VERY CONSTANT WITH SOURCE PRESSURE VARIATIONS REDUCED IN THE RATIO OF AT LEAST 1/100.

FOR ROUTINE DETERMINATIONS OF THE 15 BAR PERCENTAGE A SETUP USING A SINGLE HIGH PRESSURE REGULATOR IS ADEQUATE. AT LOWER PRESSURES IT WILL BE DESIRABLE TO MAKE USE OF A MORE SENSITIVE REGULATOR.

TO PROVIDE GOOD REGULATION THROUGHOUT THE WHOLE RANGE FROM 0 THROUGH 15 BARS TWO REGULATORS SHOULD BE USED. THE HIGH PRESSURE REGULATOR FOR THE HIGH RANGE WITH SIMPLE VALVING SO THAT THE PRESSURE FROM THE HIGH PRESSURE REGULATOR CAN BE DIVERTED TO THE LOW PRESSURE REGULATOR FOR WORK IN THE LOW RANGE, THUS MAKING USE OF THE PRINCIPLE OF "DOUBLE REGULATION" IN THE LOW PRESSURE RANGE.

WHERE COMPRESSED GAS IN TANKS IS USED AS A PRESSURE SOURCE, THE HOKE REGULATOR CAT. NO. 510B15 SERVES WELL AS THE HIGH PRESSURE REGULATOR. THIS CAN BE COUPLED WITH THE NORGREN REGULATOR CAT. NO. 20AG-X2G WITH 0-125 LB. COMPOUND SPRING FOR USE IN THE LOW PRESSURE RANGE.

WHERE A COMPRESSOR IS USED AS THE PRESSURE SOURCE, THE NORGREN REGULATOR CAT. NO. 20AG-X2G WITH 0-250 LB. SPRING CAN BE USED FOR THE HIGH PRESSURE WORK. THIS IN TURN CAN BE COUPLED WITH THE NORGREN REGULATOR CAT. NO. 20AG-X2G WITH 0-125 LB. COMPOUND SPRING FOR THE LOW PRESSURE WORK.

AIR FILTER USE WITH COMPRESSOR

IT IS DESIRABLE TO INSTALL AN AIR FILTER, SUCH AS NORGREN CAT. NO. 30AF-N2 AHEAD OF THE REGULATORS WHERE A COMPRESSOR IS USED AS THE PRESSURE SOURCE. THE FILTER HELPS TO KEEP SMALL DIRT PARTICLES OUT OF THE REGULATORS. WHEN THE REGULATED PRESSURE TENDS TO DRIFT APPRECIABLY FROM ITS SET VALUE IT IS USUALLY DUE TO AN IMPROPERLY SEATED VALVE IN THE REGULATOR; AND THIS IS FREQUENTLY DUE TO ACCUMULATION OF DIRT ON THE VALVE SEAT. INSTRUCTIONS FOR PROPER CARE AND MAINTENANCE OF REGULATORS ARE PROVIDED WITH THE REGULATORS.

PRESSURE GAUGE

FOR ACCURATE READOUT OF THE REGULATED PRESSURE A PRECISION PRESSURE GAUGE IS REQUIRED. THE ASHCROFT LABORATORY TEST GAUGE CAT. NO. 1082A WITH 0-300 PSI RANGE IS SUITABLE FOR USE WITH THE 15 BAR CERAMIC PLATE EXTRACTOR.

SOURCE OF PRESSURE REGULATING EQUIPMENT

PRESSURE CONTROL EQUIPMENT AND MANIFOLD FITTINGS CALLED OUT CAN BE OBTAINED THROUGH LOCAL DEALERS OR IF MORE CONVENIENT THROUGH SOILMOISTURE EQUIPMENT CO.

COMPLETE MANIFOLDS ASSEMBLED AND TESTED SUITABLE FOR USE WITH THIS EQUIPMENT CAN BE OBTAINED FROM SOILMOISTURE EQUIPMENT CO. WRITE FOR FURTHER DETAILS.

MAKING A RUN FOR MOISTURE-RETENTION STUDIES

WORKING WITH THE 15 BAR CERAMIC PLATE EXTRACTOR, IS BASICALLY THE SAME AS WORKING

WITH THE PRESSURE PLATE EXTRACTOR, CAT. NO. 1200.

HANDLING OF SOIL SAMPLES

PROPER HANDLING OF THE SOIL SAMPLES IS NECESSARY FOR ACCURATE, CONSISTENT RESULTS. FOR THIS, WE RECOMMEND THAT THE USER REFER TO THE PROCEDURES AS CALLED OUT IN THE AGRICULTURE HANDBOOK NO. 60 OF THE U.S. DEPARTMENT OF AGRICULTURE, DIAGNOSIS AND IMPROVEMENT OF SALINE AND ALKALI SOILS. THIS HANDBOOK COVERS DETAILED PROCEDURES FOR THE 1/10, 1/3, AND 15 BAR PERCENTAGE DETERMINATIONS, AND ON THE DEVELOPMENT OF MOISTURE-RENTENTION CURVES.

WHERE MOISTURE EQUILIBRIUM STUDIES ARE BEING RUN IT IS DESIRABLE TO KEEP SAMPLE HEIGHTS SMALL IN ORDER TO KEEP THE TIME TO REACH EQUILIBRIUM REASONABLE. THE TIME REQUIRED TO REACH EQUILIBRIUM VARIES AS THE SQUARE OF THE SAMPLE HEIGHT.

PREPARE DUPLICATE 25 GM. SAMPLES THAT HAVE BEEN PASSED THROUGH A 2 MM ROUND-HOLE SIEVE, FOR EACH SOIL TYPE TO BE RUN. PLACE SOIL SAMPLE RETAINING RINGS, CAT. NO. 1093, ON THE CERAMIC PLATE TO RECEIVE THE GROUP OF SAMPLES. EACH CERAMIC PLATE CELL WILL ACCOMODATE 12 SAMPLES WHEN RETAINED IN THESE RINGS. IN ORDER TO AVOID PARTICLE-SIZE SEGREGATION, DUMP ALL OF THE SOIL SAMPLE FROM EACH CONTAINER INTO ONE RING. POURING OUT PART OF THE SAMPLE AND LEAVING PART IN THE CONTAINER WILL GIVE A NONREPRESENTATIVE SAMPLE. LEVEL THE SAMPLES IN THE RING, COVER WITH SQUARES OF WAXED PAPER, AND ALLOW THE SAMPLES TO STAND AT LEAST 16 HOURS WITH AN EXCESS OF WATER ON THE PLATE.

IT IS DESIRABLE TO CONNECT THE NYLON TUBE AND RUBBER SLEEVE TO THE OUTLET STEM ON THE PRESSURE PLATE CELL PRIOR TO PLACING OF THE SAMPLES.

LOADING THE EXTRACTOR

WHEN THE SAMPLES ARE READY FOR THE EXTRACTOR REMOVE THE EXCESS WATER FROM THE CERAMIC PLATES WITH A PIPETTE OR SYRINGE, MOUNT THE CELLS IN THE EXTRACTOR AND CONNECT UP THE OUTFLOW TUBES. BE SURE THE TRIANGULAR SUPPORT IS IN THE BOTTOM OF THE VESSEL.

USE THE PLASTIC SPACERS TO SEPARATE THE PRESSURE PLATE CELLS. CLOSE ALL UNUSED OUTLET PORTS WITH THE PLUG BOLTS THAT ARE PROVIDED. BE SURE "O" RING IS IN PLACE, MOUNT LID, AND SCREW DOWN CLAMPING BOLTS.

CONNECTION TO A BURETTE

IT IS DESIRABLE TO PROVIDE A MEANS FOR DETERMINING WHEN EQUILIBRIUM HAS BEEN REACHED. THIS CAN BE EASILY DONE BY CONNECTING EACH OUTFLOW TUBE TO THE TIP OF A BURETTE WITH A PIECE OF SMALL DIAMETER TUBING. GAS DIFFUSING THROUGH THE CERAMIC PLATE PASSES CONTINUOUSLY IN SMALL BUBBLES THROUGH THIS SMALL OUTFLOW TUBE, AND KEEPS THE EXTRACTED LIQUID TRANSPORTED TO THE BURETTE. THE BURETTE CAN BE READ PERIODICALLY AND THE APPROACH TO EQUILIBRIUM CAN THUS BE FOLLOWED. IF THE PRESSURE IN THE EXTRACTOR IS MAINTAINED CONSTANT, NO MEASURABLE AMOUNT OF CHANGE IN THE BURETTE READING WILL BE OBSERVED OVER A PERIOD OF MANY HOURS OR DAYS AFTER EQUILIBRIUM IS ONCE ATTAINED.

TURNING ON THE PRESSURE

BUILD UP THE PRESSURE IN THE EXTRACTOR TO THE EQUILIBRIUM VALUE SOMEWHAT SLOWLY. THIS PROCEDURE WILL PERMIT YOU TO MAKE THE MOST ACCURATE SETTING ON THE EQUILIBRIUM VALUE.

AS THE PRESSURE BUILD UP INSIDE THE EXTRACTOR THERE WILL BE A RUSH OF AIR FROM THE OUTFLOW TUBES. THIS IS CAUSED BY THE REDUCTION OF THE INTERNAL VOLUME OF THE

PRESSURE PLATE CELL AS THE DIAPHRAGM AND SCREEN COLLAPSE UNDER THE PRESSURE IN THE EXTRACTOR.

IF THE RUN IS FOR DETERMINATIONS OF THE 15 BAR PERCENTAGE, THE PRESSURE IN THE EXTRACTOR IS SET AT 15 BARS OR 220 PSI.

WHERE THE PM COMPRESSOR IS USED AS AN AIR SOURCE, IT IS POSSIBLE THAT THE COMPRESSOR TANK PRESSURE WILL BE REDUCED BELOW THE REQUIRED LEVEL IF THE EXTRACTOR PRESSURE IS SET IMMEDIATELY AT 220 PSI SINCE THE VOLUME OF THE EXTRACTOR IS LARGE COMPARED WITH THE AIR STORAGE TANK. WHEN THIS OCCURS, SIMPLY TURN THE TIMER DIAL ON THE COMPRESSOR, MANUALLY, IN THE CLOCKWISE DIRECTION UNTIL THE COMPRESSOR STARTS. A SINGLE RUN CYCLE ON THE COMPRESSOR WILL BUILD THE PRESSURE UP ABOVE THE PRESSURE VALUE REQUIRED.

REMOVAL OF SAMPLES

SAMPLES MAY BE REMOVED WHEN READINGS ON THE OUTFLOW BURETTES INDICATE FLOW HAS STOPPED AND EQUILIBRIUM ATTAINED. MOST SOILS WILL APPROACH HYDRAULIC EQUILIBRIUM WITHIN 18 TO 20 HOURS.

AT THE CLOSE OF A RUN THE EXTERNAL TUBES RUNNING FROM THE OUTFLOW TUBE ASSEMBLIES SHOULD BE REMOVED OR PINCHED OFF TO PREVENT POSSIBLE BACK FLOW OF WATER WHEN THE PRESSURE IN THE EXTRACTOR IS RELEASED.

IMMEDIATELY AFTER THE PRESSURE REGULATOR IS SHUT OFF AND THE PRESSURE EXHAUSTED FROM THE EXTRACTOR, THE CLAMPING BOLTS AND LID ARE REMOVED. SAMPLES ARE TRANSFERRED TO MOISTURE BOXES AS SOON AS POSSIBLE AFTER RELEASE OF PRESSURE IN ORDER TO AVOID CHANGES IN THE MOISTURE CONTENT.

ACTION OF GAS PRESSURE ON SOIL SAMPLES AND USES OF EXTRACTOR

AS SOON AS AIR PRESSURE INSIDE THE VESSEL IS RAISED ABOVE ATMOSPHERIC PRESSURE, THE HIGHER PRESSURE INSIDE THE VESSEL FORCES EXCESS WATER THROUGH THE MICROSCOPIC PORES IN THE 15 BAR CERAMIC PLATES. THE HIGH PRESSURE AIR, HOWEVER, WILL NOT FLOW THROUGH THE PORES SINCE THEY ARE FILLED WITH WATER AND THE SURFACE TENSION OF THE WATER AT THE GAS-LIQUID INTERFACE AT EACH OF THE PORES SUPPORTS THE PRESSURE MUCH THE SAME AS A FLEXIBLE RUBBER DIAPHRAGM. WHEN THE AIR PRESSURE IS INCREASED INSIDE THE EXTRACTOR THE RADIUS OF CURVATURE OF THIS INTERFACE DECREASES. HOWEVER, THE WATER FILMS WILL NOT BREAK AND LET AIR PASS THROUGHOUT THE WHOLE PRESSURE RANGE OF THE EXTRACTOR, FROM 0 TO 15 BARS.

AT ANY GIVEN AIR PRESSURE IN THE CHAMBER, SOIL MOISTURE WILL FLOW FROM AROUND EACH OF THE SOIL PARTICLES AND OUT THROUGH THE CERAMIC PLATE UNTIL SUCH TIME AS THE EFFECTIVE CURVATURE OF THE WATER FILMS THROUGHOUT THE SOIL ARE THE SAME AS AT THE PORES IN THE CERAMIC PLATE. WHEN THIS OCCURS, AN EQUILIBRIUM IS REACHED AND THE FLOW OF MOISTURE CEASES. WHEN THE AIR PRESSURE IN THE EXTRACTOR IS INCREASED, FLOW OF SOIL MOISTURE FROM THE SAMPLES STARTS AGAIN AND CONTINUES UNTIL A NEW EQUILIBRIUM IS REACHED. AT EQUILIBRIUM, THERE IS AN EXACT RELATIONSHIP BETWEEN THE AIR PRESSURE IN THE EXTRACTOR AND THE SOIL SUCTION (AND HENCE THE MOISTURE CONTENT) IN THE SAMPLES. FOR EXAMPLE, IF THE AIR PRESSURE IN THE EXTRACTOR IS MAINTAINED A 1 BAR OR ATMOSPHERE (15 PSI), THE SOIL SUCTION IN THE SAMPLES AT EQUILIBRIUM WILL BE AT 1 BAR. IF THE AIR PRESSURE IS MAINTAINED AT 15 BARS OR ATMOSPHERES (220 PSI) THE SOIL SUCTION AT EQUILIBRIUM WILL BE AT 15 BARS, WHICH IS THE APPROXIMATE WILTING POINT FOR ALL SOILS.

THE 15 BAR CERAMIC PLATE EXTRACTOR CAN BE USED FOR ALL TYPES OF STUDIES INVOLVING

THE MOISTURE RELATIONSHIPS IN SOILS. ALL TYPES OF SOIL SAMPLES MAY BE USED WITH THE EXCEPTION OF FINE CLAY SOILS THAT EXPERIENCE CONSIDERABLE SHRINKAGE AS MOISTURE IS REMOVED. THIS TYPE OF SOIL WILL SHRINK AWAY FROM THE CERAMIC PLATE IN 15 BAR EXTRACTIONS AND THE REDUCED FLOW AREA WILL NOT PERMIT THE SAMPLE TO REACH EQUILIBRIUM.

+ + +

FOR MOISTURE EQUILIBRIUM STUDIES THROUGHOUT THE WHOLE PLANT GROWTH RANGE FROM 0 TO 15 BARS, THE 15 BAR CERAMIC PLATE EXTRACTOR PROVIDES A NEW DIMENSION IN EASE OF HANDLING AND EFFICIENCY OF OPERATION.

+ + +

A COMPLETE STOCK OF ACCESSORIES AND REPLACEMENT PARTS FOR THE 15 BAR CERAMIC PLATE EXTRACTOR IS MAINTAINED FOR PROMPT DELIVERY. DETAILS AND PRICES ARE EITHER CARRIED IN THE CURRENT CATALOG OR MAY BE OBTAINED BY WRITING TO:

NOTICE

IT IS ADVISABLE TO ALWAYS USE THE CAT. NO. 1595, RIGHT ANGLE OUTFLOW TUBE ADAPTER, WHEN STACKING TWO OR MORE PRESSURE PLATE CELLS IN THE EXTRACTOR.

THE STEM ON THE ADAPTER IS PUSHED INTO THE HOLE IN THE RUBBER CONNECTING SLEEVE, BE SURE NYLON CONNECTING TUBE IS BUTTED UP NEXT TO THE STEM. THE RUBBER SLEEVE IS USED ONLY TO MAKE A SEAL AND CANNOT BE RELIED UPON TO SUPPORT THE HIGH EXTRACTION PRESSURES.

THE HOLE IN THE RIGHT ANGLE ADAPTER HAS AN INTERNAL "O" RING WHICH MAKES A PRESSURE SEAL WHEN IT IS SLIPPED OVER THE OUTLET STEM FROM THE CERAMIC PLATE CELL. THESE ADAPTERS ARE EXTREMELY EASY TO CONNECT AND DISCONNECT FROM THE PRESSURE PLATE CELLS, WHEN THE CELLS ARE LOADED AND UNLOADED FROM THE EXTRACTOR. THE ADAPTERS ELIMINATE ANY POSSIBLE KINKING OF THE OUTFLOW TUBE ASSEMBLY AND HENCE PREVENT ANY PINCHING OFF OF THE OUTFLOW TUBE THAT CAN RESULT IN ERRONEOUS EQUILIBRIUM VALUES AND POSSIBLE DAMAGE OR BREAKAGE, UNDER CERTAIN CONDITIONS, TO THE PRESSURE PLATE CELLS.

NOTICE

IT IS NOT ADVISABLE TO USE THE CAT. NO. 1590, 15 BAR CERAMIC PLATE CELLS, SUPPLIED WITH THIS UNIT FOR DETERMINATION OF THE 1/10 BAR AND 1/3 BAR MOISTURE PERCENTAGES OF SOILS, DUE TO THE VERY SMALL PORE SIZE OF THE 15 BAR CERAMIC THE FLOW RATE THROUGH THE CERAMIC PLATE IS VERY LOW AT PRESSURE DIFFERENTIALS ACROSS THE PLATE OF 1/10 BAR (1.5 PSI) AND 1/3 BAR (5 PSI). THIS RESULTS IN EXTREMELY LONG EQUILIBRIUM TIMES AND EQUILIBRIUM MOISTURE CONTENT VALUES WILL TEND TO BE HIGHER THAN ACTUAL. FOR THE MEASUREMENT OF THE 1/10 BAR AND 1/3 BAR MOISTURE PERCENTAGE AS WELL AS ALL OTHER WORK IN THE 0 TO 1 BAR RANGE IT IS ADVISABLE TO USE THE CAT. NO. 1290 PRESSURE PLATE CELLS. THESE PRESSURE PLATE CELLS HAVE MUCH LARGER PORE SIZE THAN THE 15 BAR CERAMIC PLATE CELLS, AND IN THE 0 TO 1 BAR RANGE EQUILIBRIUM VALUES WILL BE REACHED MUCH FASTER. THE CAT. NO. 1290 PRESSURE PLATE CELL WILL FIT INTO THE CAT. NO. 1500, 15 BAR CERAMIC PLATE EXTRACTOR, AND THE SAME OUTFLOW TUBE CONNECTORS CAN ALSO BE USED WITH THESE CELLS.

OPERATING INSTRUCTIONS for the

Cat. No. 1600

5 BAR PRESSURE PLATE EXTRACTOR

FIG.1 - VIEW SHOWING OPERATING PARTS

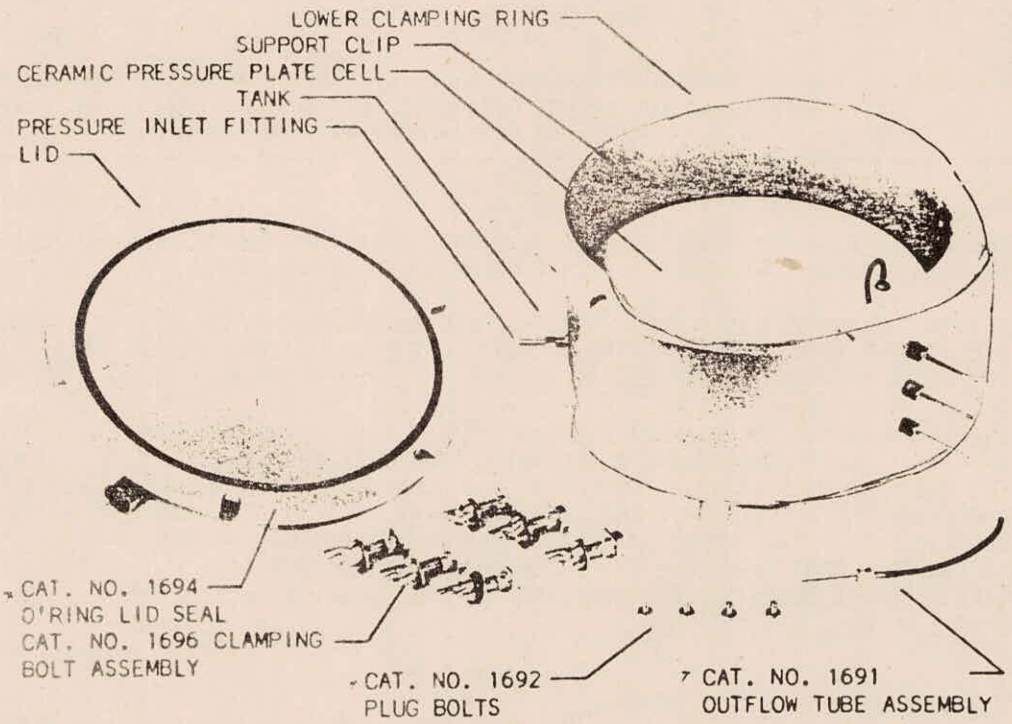


TABLE OF CONTENTS

UNPACKING AND INITIAL ASSEMBLY

THE UNIT IS SHIPPED WITH THE LID OF THE PRESSURE VESSEL CLAMPED IN PLACE ON THE TANK AND ALL FITTINGS ARE PACKED INSIDE THE VESSEL. IF PRESSURE PLATE CELLS HAVE BEEN ORDERED WITH THE UNIT, THEY MAY ALSO BE PACKED INSIDE THE VESSEL. PRESSURE PLATE CELLS ARE NOT SUPPLIED AS A STANDARD PART OF THE UNIT AND MUST BE ORDERED SEPARATELY. REMOVE THE UNIT FROM ITS PACKING BOX, MAKING SURE TO REMOVE ALL OTHER PACKING MATERIAL AND TAPE.

TO TAKE OFF THE EXTRACTOR LID, FIRST LOOSEN THE SIX WING NUTS A FEW TURNS COUNTERCLOCKWISE, UNTIL BOLTS CAN BE SLIPPED OUT OF THE SLOTS. THE BOLTS HAVE SPECIAL RECTANGULAR HEADS WHICH FIT INTO A CONSTRAINING GROOVE IN THE BOTTOM OF THE LOWER CLAMPING RING. WHEN REPLACING THE CLAMPING BOLTS, ALWAYS MAKE SURE THE RECTANGULAR HEADS ARE PROPERLY SEATED IN THE CONSTRAINING GROOVE. REMOVE THE EXTRACTOR LID BY LIFTING STRAIGHT UP. IF THE EXTRACTOR LID APPEARS TO "STICK" YOU CAN BREAK THE SEAL BY INSERTING A BLUNT INSTRUMENT SUCH AS A SCREWDRIVER, COIN, ETC., IN THE GROOVE BETWEEN THE LID AND LOWER CLAMPING FLANGE AND LIGHTLY PRY AT ANY ONE POINT. THIS WILL BREAK THE SEAL AND ALLOW YOU TO REMOVE THE LID EASILY. AFTER LIFTING OFF THE LID, YOU WILL NOTE THE "O" RING SEATED IN A GROOVE IN THE LID. THIS "O" RING MAKES A PRESSURE SEAL ON THE TOP OF THE LOWER CLAMPING FLANGE. CARE MUST BE EXCERCISED IN HANDLING THE LID AND TANK SO THAT THESE TWO SURFACES ARE NEVER SCRATCHED OR DAMAGED, OR THE UNIT WILL NOT SEAL PROPERLY. WHEN LID IS REMOVED FROM THE VESSEL, LAY THE LID WITH THE HANDLE DOWN AND "O" RING FACING UP; THIS WILL HELP PREVENT THE "O" RING FROM GETTING DAMAGED OR COLLECTING DIRT OR OTHER CONTAMINANTS.

THE CONTENTS OF THE VESSEL MAY NOW BE REMOVED. REMOVE ALL PACKING AND CHECK TO BE SURE ALL PARTS ARE ACCOUNTED FOR. CONTENTS WILL INCLUDE 3 PLUG BOLTS WITH "O" RINGS, 4 OUTFLOW TUBES WITH "O" RING AND RUBBER TUBE ATTACHED, 12 STAINLESS STEEL SUPPORT CLIPS, AND, WHEN ORDERED SEPARATELY, CERAMIC PRESSURE PLATE CELLS. WHEN REMOVING OR HANDLING THE CERAMIC PRESSURE PLATE CELLS, CARE MUST BE EXCERCISED TO AVOID SHARP BLOWS OR ROUGH TREATMENT WHICH MAY CAUSE CRACKING OR BREAKING.

THE EXTRACTOR SHOULD NOW BE ASSEMBLED TO ACQUAINT THE USER WITH THE VARIOUS PARTS AND FEATURES THAT WILL BE INVOLVED IN MAKING A RUN FOR SOIL MOISTURE EXTRACTION WORK. FIG. 1 ON FRONT PAGE SHOWS A VIEW DETAILING ESSENTIAL OPERATING PARTS.

THE OUTFLOW TUBE FITTINGS AND PLUG BOLTS ARE INSTALLED FIRST. (SEE FIG. 1) REMOVE THE 6 IN. LENGTH OF RUBBER TUBING FROM THE OUTFLOW TUBE FITTING BEFORE SCREWING THE FITTING INTO THE OUTLET PORT IN THE SIDE OF THE TANK. A MAXIMUM OF FOUR OUTFLOW TUBE FITTINGS CAN BE SCREWED INTO THE FOUR PORTS. THREE PLUG BOLTS ARE PROVIDED FOR SEALING ANY UNUSED PORTS. THE PRESSURE SEAL AT THE OUTLET PORTS ARE MADE BY A NEOPRENE "O" RING RECESSED INTO THE HEAD OF THE OUTFLOW TUBE FITTING AND PLUG BOLT. BEFORE INITIALLY INSTALLING THE OUTFLOW TUBE FITTINGS OR PLUG BOLTS, APPLY A SMALL AMOUNT OF STOPCOCK GREASE OR VASELINE ON THE EXPOSED PORTION OF THE "O" RING TO LUBRICATE IT AS IT SLIDES AGAINST THE WALL OF THE VESSEL WHEN SCREWED INTO PLACE. ONLY A SMALL AMOUNT OF TORQUE IS REQUIRED TO MAKE THE OUTLET PORT SEAL. A STANDARD 1/2 IN. WRENCH OR SMALL CRESCENT WRENCH CAN BE USED TO TIGHTEN THE FITTINGS. IN TIGHTENING THESE FITTINGS IT IS ONLY NECESSARY TO BRING THE OUTER EDGE OF THE FITTING INTO CONTACT WITH THE FLAT SURFACE OF THE OUTLET PORT ON THE PRESSURE VESSEL WALL. THIS PROVIDES THE PROPER COMPRESSION ON THE "O" RING TO MAKE THE SEAL. FURTHER TIGHTENING WILL ONLY SERVE TO DAMAGE THE FITTING AND SHORTEN THE LIFE OF THE "O" RING SEAL.

NOW THE CERAMIC PRESSURE PLATE CELLS MAY BE MOUNTED IN THE TANK. THE EXTRACTOR IS DESIGNED TO ACCEPT A MAXIMUM OF 4 CERAMIC PRESSURE PLATE CELLS, ONE STACKED ABOVE ANOTHER. FIRST INSTALL ONE STAINLESS STEEL SUPPORT CLIP, FOR THE FIRST CERAMIC PRESSURE PLATE CELL, INTO EACH OF THE THREE RACKS PROVIDED. THIS IS DONE BY FACING THE BROAD, FLAT SURFACE OF THE CLIP UP, AND PLACING THE TOP PRONG OF THE CLIP INTO THE SECOND NOTCH FROM THE BOTTOM OF THE RACK. THE BOTTOM PRONG IS THEN SNAPPED INTO THE BOTTOM NOTCH OF THE RACK. PINCHING THE CLIP WITH THE FINGERS WHILE INSERTING WILL FACILITATE INSTALLATION. THE VERTICAL RACKS ARE NUMBERED TO MAKE IT EASY TO KEEP THE THREE CLIPS ON THE SAME PLANE.

NEXT THE 6 IN. LENGTH OF RUBBER TUBE IS ATTACHED TO THE OUTFLOW STEM OF THE FIRST CERAMIC PRESSURE PLATE CELL. IT IS ADVISABLE TO SUPPORT THE CELL WITH THE FINGERS DIRECTLY BEHIND THE OUTLET STEM WHEN PUSHING THE RUBBER TUBE OVER THE OUTLET STEM. THE CERAMIC PRESSURE PLATE CELL, WITH TUBE ATTACHED, IS NOW SET ON THE THREE CLIPS WITH TUBE UP. THE FREE END OF THE RUBBER TUBE CAN NOW BE PUSHED OVER THE END OF THE OUTFLOW TUBE THAT PROJECTS INTO THE TANK. THE REMAINING CELLS, WHEN USED, ARE MOUNTED IN THE SAME WAY ABOVE THE 1ST CELL.

WHEN MOUNTING MORE THAN ONE CELL, SPACING OF THE CELLS MUST BE WATCHED. THE NOTCHES ON THE RACKS ARE SPACED 1/2 IN. APART CENTER TO CENTER. THE OUTLET PORTS ARE SPACED 1-1/2 IN. APART CENTER TO CENTER. THEREFORE, THE SPACING SHOULD BE THREE (3) NOTCHES APART, FROM TOP OF CLIP TO TOP OF CLIP.

IN THE EVENT ALL FOUR CELLS ARE NOT USED, THE REMAINING PORTS IN THE SIDE OF THE TANK ARE PLUGGED WITH THE PLUG BOLTS PROVIDED. THE LID CAN NOW BE CENTERED ON THE TANK AND CLAMPED IN PLACE WITH THE SIX CLAMPING BOLT ASSEMBLIES, MAKING SURE THAT THE RECTANGULAR HEADS OF THE BOLTS ARE PROPERLY SEATED IN THE CONSTRAINING GROOVE ON THE BOTTOM SIDE OF THE LOWER CLAMPING RING.

FUNCTION OF THE CERAMIC PRESSURE PLATE CELLS

IN ORDER TO WORK EFFECTIVELY WITH THIS TYPE OF EXTRACTION EQUIPMENT IT IS IMPORTANT TO HAVE A THOROUGH UNDERSTANDING OF HOW THE CERAMIC PRESSURE PLATE CELLS FUNCTION, AND OF THE PHYSICAL PRINCIPLES INVOLVED IN THE EXTRACTION PROCESS. FIG. 2, PAGE 3, SHOWS DIAGRAMMATICALLY A CROSS SECTION VIEW OF A CERAMIC PRESSURE PLATE CELL MOUNTED IN A PRESSURE VESSEL WITH OUTFLOW TUBE RUNNING THROUGH THE VESSEL WALL TO THE ATMOSPHERE AND WITH A SOIL SAMPLE HELD IN PLACE ON THE POROUS CERAMIC SURFACE OF THE CELL.

EACH CERAMIC PRESSURE PLATE CELL CONSISTS OF A POROUS CERAMIC PLATE, COVERED ON ONE SIDE BY A THIN NEOPRENE DIAPHRAGM, SEALED TO THE EDGES OF THE CERAMIC PLATE. AN INTERNAL SCREEN BETWEEN THE PLATE AND DIAPHRAGM PROVIDES A PASSAGE FOR FLOW OF WATER. AN OUTLET STEM RUNNING THROUGH THE PLATE CONNECTS THIS PASSAGE TO AN OUTFLOW TUBE FITTING, WHICH CONNECTS TO THE ATMOSPHERE OUTSIDE OF THE EXTRACTOR.

TO USE THE CERAMIC PRESSURE PLATE CELL, ONE OR MORE SOIL SAMPLES ARE PLACED ON THE POROUS CERAMIC SURFACE, HELD IN PLACE BY RETAINING RINGS OF APPROPRIATE HEIGHT. THE SOIL SAMPLES TOGETHER WITH THE POROUS CERAMIC PLATE ARE THEN SATURATED WITH WATER. THIS IS USUALLY DONE BY ALLOWING AN EXCESS OF WATER TO STAND ON THE SURFACE OF THE CELL FOR SEVERAL HOURS. AFTER THE POROUS CERAMIC PLATE IN THE PRESSURE PLATE CELL, AND THE SOIL SAMPLE ARE COMPLETELY SATURATED WITH WATER, THE CELL CAN BE MOUNTED IN THE PRESSURE VESSEL AND AIR PRESSURE USED TO EFFECT EXTRACTION OF MOISTURE FROM THE SOIL SAMPLES UNDER CONTROLLED CONDITIONS.

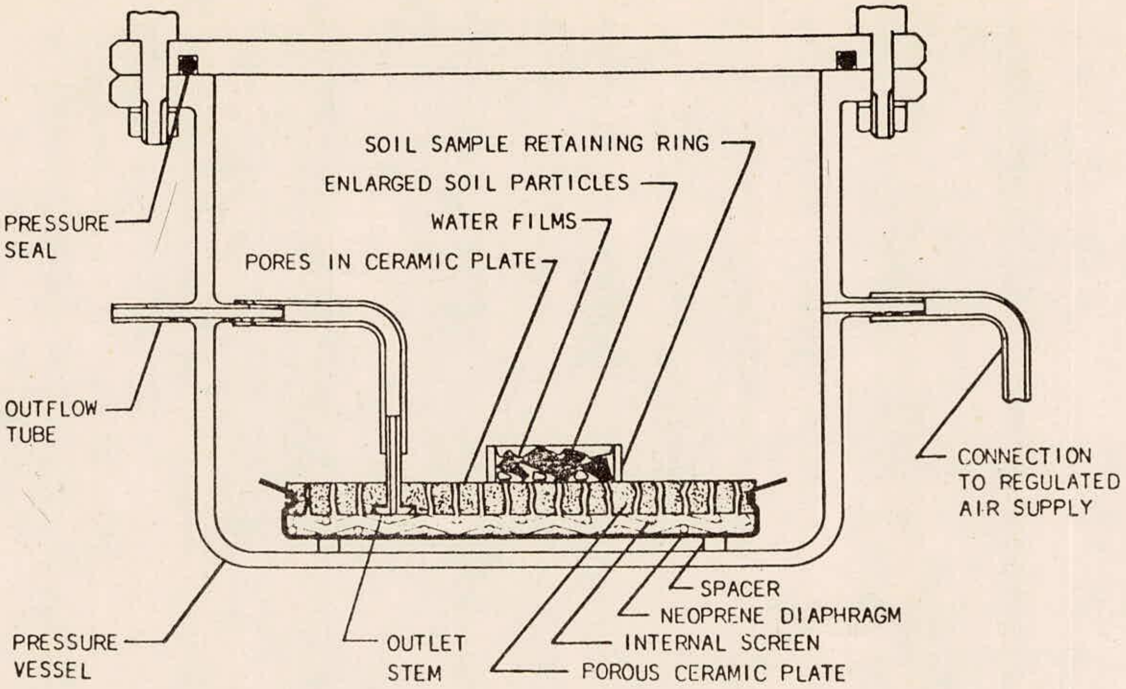


FIG. 2
CROSS SECTION VIEW OF CERAMIC PRESSURE PLATE CELL AND SOIL SAMPLE, IN EXTRACTOR

AS SOON AS AIR PRESSURE INSIDE THE CHAMBER IS RAISED ABOVE ATMOSPHERIC PRESSURE, THE HIGHER PRESSURE INSIDE THE CHAMBER FORCES EXCESS WATER THROUGH THE MICROSCOPIC PORES IN THE CERAMIC PLATE AND OUT THROUGH THE OUTLET STEM VIA THE PASSAGE AFFORDED BY THE SCREEN. THE HIGH PRESSURE AIR, HOWEVER, WILL NOT FLOW THROUGH THE PORES IN THE CERAMIC PLATE SINCE THE PORES ARE FILLED WITH WATER AND THE SURFACE TENSION OF THE WATER AT THE GAS-LIQUID INTERFACE AT EACH OF THE PORES SUPPORTS THE PRESSURE MUCH THE SAME AS A FLEXIBLE RUBBER DIAPHRAGM. TO UNDERSTAND THIS ACTION MORE THOROUGHLY, REFER TO FIG. 3, BELOW.

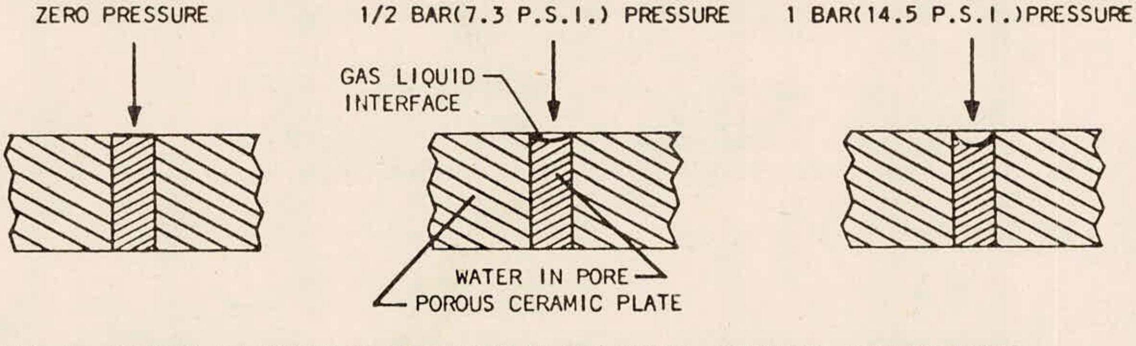


FIG. 3 CHANGES IN RADIUS OF CURVATURE OF GAS-LIQUID INTERFACE WITH PRESSURE

THE MAXIMUM AIR PRESSURE THAT ANY GIVEN WETTED POROUS CERAMIC PLATE CAN STAND, BEFORE LETTING AIR PASS THROUGH THE PORES, IS DETERMINED BY THE DIAMETER OF THE PORE. THE SMALLER THE PORE SIZE, THE HIGHER THE AIR PRESSURE WILL HAVE TO BE TO PASS THROUGH. THE PRESSURE VALUE THAT FINALLY BREAKS DOWN THESE WATER MENISCUSES IS CALLED THE "BUBBLING PRESSURE" OR THE "AIR ENTRY VALUE" FOR THE POROUS PLATE. PRESSURE PLATE CELLS MUST ALWAYS BE USED AT AIR PRESSURE EXTRACTION VALUES BELOW THE "BUBBLING PRESSURE" OR "AIR ENTRY VALUE" FOR THE CELL.

DURING A RUN, AT ANY SET AIR PRESSURE IN THE EXTRACTOR, SOIL MOISTURE WILL FLOW FROM AROUND EACH OF THE SOIL PARTICLES AND OUT THROUGH THE CERAMIC PLATE UNTIL SUCH TIME AS THE EFFECTIVE CURVATURE OF THE WATER FILMS THROUGHOUT THE SOIL ARE THE SAME AS AT THE PORES IN THE PLATE. WHEN THIS OCCURS, AN EQUILIBRIUM IS REACHED AND THE FLOW OF MOISTURE CEASES. WHEN THE AIR PRESSURE IN THE EXTRACTOR IS INCREASED, FLOW OF SOIL MOISTURE FROM THE SAMPLES STARTS AGAIN AND CONTINUES UNTIL A NEW EQUILIBRIUM IS REACHED. AT EQUILIBRIUM, THERE IS AN EXACT RELATIONSHIP BETWEEN THE AIR PRESSURE IN THE EXTRACTOR AND THE SOIL SUCTION (AND HENCE THE MOISTURE CONTENT) IN THE SAMPLES.

FOR EXAMPLE, IF THE AIR PRESSURE IN THE EXTRACTOR IS MAINTAINED AT 1/3 BAR (4.8 PSI), THE SOIL SUCTION IN THE SAMPLES AT EQUILIBRIUM WILL BE 1/3 BAR.* IF THE AIR PRESSURE IS MAINTAINED AT 1 BAR (14.5 PSI), THE SOIL SUCTION AT EQUILIBRIUM WILL BE 1 BAR. FIG. 4, BELOW, SHOWS THE MOISTURE RETENTION CURVES FOR THREE DIFFERENT SOIL TYPES THAT CAN BE DEVELOPED WITH THIS TYPE OF EQUIPMENT. THESE "MOISTURE CHARACTERISTIC" CURVES FOR EACH SOIL ARE EXTREMELY IMPORTANT IN SOILS RESEARCH AND IN THE DEVELOPMENT OF PRACTICAL, EFFECTIVE IRRIGATION PRACTICES.

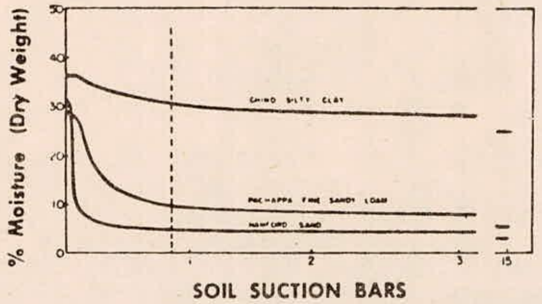


FIG. 4

Moisture Retention Curves are shown for three types of soils. The dotted line at .85 bars of soil suction represent the limit of tensiometer readings.

APPLICATION OF EXTRACTOR AND OPERATING DETAILS

THE CAT. NO. 1600, 5 BAR PRESSURE PLATE EXTRACTOR VESSEL PROVIDES A STURDY, POSITIVE SEALING, PRESSURE VESSEL TO ACCEPT THE VARIOUS PRESSURE PLATE CELLS NOW AVAILABLE FOR WORK IN THE RANGE OF 0-5 BARS OF SOIL SUCTION, THE PRIMARY GROWTH RANGE. THE VESSEL IS CONSTRUCTED OF STEEL AND HAS A WORKING PRESSURE OF 75 PSI (5 BARS). ALL STEEL PARTS ARE PLATED FOR CORROSION RESISTANCE AND

---

*NOTE: THE "BAR" HAS BECOME A STANDARD UNIT FOR THE EXPRESSION OF SOIL SUCTION. BY DEFINITION, A BAR IS A UNIT OF PRESSURE EQUAL TO 10^6 DYNE/CM^2. THIS IS EQUIVALENT TO .987 ATMOSPHERES OR 14.5 PSI.

THE INSIDE SURFACE OF THE VESSEL IS COATED WITH NEOPRENE FOR FURTHER RESISTANCE TO CORROSION. THE EXTRACTOR WILL ACCEPT THE CAT. NO. 1290, 1 BAR CERAMIC PLATE CELLS; THE CAT. NO. 1690, 3 BAR CERAMIC PLATE CELLS; AND THE CAT. NO. 1590, 15 BAR CERAMIC PLATE CELLS.

THE CAT. NO. 1290, 1 BAR CERAMIC PLATE CELLS ARE IDEAL FOR THE ROUTINE DETERMINATION OF THE 1/10 BAR AND 1/3 BAR PERCENTAGE IN THE CATALOGING OF SOILS AS WELL AS ALL OTHER SOIL MOISTURE EQUILIBRIUM STUDIES IN THE 0-1 BAR RANGE OF SOIL SUCTION. THE BUBBLING PRESSURE OF THESE CELLS IS IN EXCESS OF 1 BAR (14.5 PSI) AND IS USUALLY BETWEEN 18 AND 25 PSI. THESE CELLS ALSO HAVE THE HIGHEST PERMEABILITY OF ANY OF THE PRESSURE PLATE CELLS AND HENCE THE TIME TO REACH EQUILIBRIUM WILL BE THE SHORTEST POSSIBLE.

THE CAT. NO. 1690, 3 BAR CERAMIC PLATE CELLS CAN ALSO BE USED FOR DETERMINATION OF THE 1/10 BAR AND 1/3 BAR PERCENTAGES AS WELL AS SOIL MOISTURE EQUILIBRIUM STUDIES IN THE EXTENDED RANGE OF 0-3 BARS OF SOIL SUCTION. BUBBLING PRESSURE OF THESE CELLS IS IN EXCESS OF 3 BARS (43.5 PSI) AND IS USUALLY BETWEEN 55 AND 65 PSI.

THE CAT. NO. 1590, 15 BAR CERAMIC PLATE CELLS ARE NOT SUITABLE FOR WORK IN THE 0-1 BAR RANGE OF SOIL SUCTION DUE TO THEIR SMALL PORE SIZE AND RELATIVELY HIGH PERMEABILITY. THEY CAN, HOWEVER, BE USED EFFECTIVELY IN THIS EXTRACTOR FOR SOIL MOISTURE EQUILIBRIUM STUDIES IN THE 1-5 BAR RANGE OF SOIL SUCTION. BUBBLING PRESSURE OF THESE CELLS IS IN EXCESS OF 15 BARS (220 PSI). FOR FULL RANGE USE, THESE CELLS MUST BE USED IN THE CAT. NO. 1500 15 BAR CERAMIC PLATE EXTRACTOR.

THE VARIOUS PRESSURE PLATE CELLS ARE NOT SUITABLE FOR EXTRACTING SOLUTION FROM SOILS FOR CHEMICAL ANALYSIS. THE IMMENSE SURFACE AREA WITHIN THE POROUS CERAMIC PLATE CAN CAUSE DISTURBANCE AND CONTAMINATION OF THE SOIL SOLUTION. FOR EXTRACTION OF THE SOIL SOLUTION FOR CHEMICAL ANALYSIS, THE CAT. NO. 1000 PRESSURE MEMBRANE EXTRACTOR MUST BE USED.

PRESSURE SUPPLY AND CONTROL

A SOURCE OF REGULATED GAS PRESSURE IS REQUIRED FOR ALL EXTRACTION WORK. COMPRESSED AIR FROM A COMPRESSOR OR COMPRESSED AIR OR NITROGEN IN HIGH PRESSURE TANKS CAN BE USED. IF THE EXTRACTOR IS TO BE USED EXTENSIVELY, COMPRESSED AIR FROM A COMPRESSOR IS THE MOST SATISFACTORY SOURCE OF SUPPLY. OUR CAT. NO. 500 PM COMPRESSOR IS IDEALLY SUITED FOR USE WITH THIS EXTRACTOR, AS WELL AS FOR ALL OF OUR EXTRACTORS, AND IS AVAILABLE IN A VARIETY OF VOLTAGES AND CYCLES TO MEET ANY APPLICATION.

ACCURACY OF EQUILIBRIUM VALUES WILL BE NO MORE ACCURATE THAN THE REGULATION OF THE AIR SUPPLY. FOR WORK IN THE LOW SOIL SUCTION RANGE AND PARTICULARLY FOR DETERMINATION OF THE 1/10 BAR AND 1/3 BAR PERCENTAGES, IT IS ESSENTIAL TO HAVE EXCELLENT PRESSURE REGULATION. WE RECOMMEND THAT OUR CAT. NO. 700-3 MANIFOLD BE USED AS A PRESSURE CONTROL FOR THIS EXTRACTOR. THE CAT. NO. 700-3 MANIFOLD MAKES USE OF A LOW PRESSURE REGULATOR IN SERIES WITH A "NULLMATIC" TYPE REGULATOR TO PROVIDE DOUBLE REGULATED PRESSURE REGULATED TO WITHIN 1/100 PSI THROUGHOUT THE RANGE FROM 0-60 PSI. CAT. NO. 1293 CONNECTING HOSE IS USED TO CONNECT THE EXTRACTOR TO THE MANIFOLD.

FIG. 5 SHOWS A DIAGRAMMATIC VIEW OF THE LABORATORY SETUP FOR THE CAT. NO. 1600 EXTRACTOR PROVIDED WITH REGULATED AIR PRESSURE FROM THE CAT. NO. 700-3 MANIFOLD

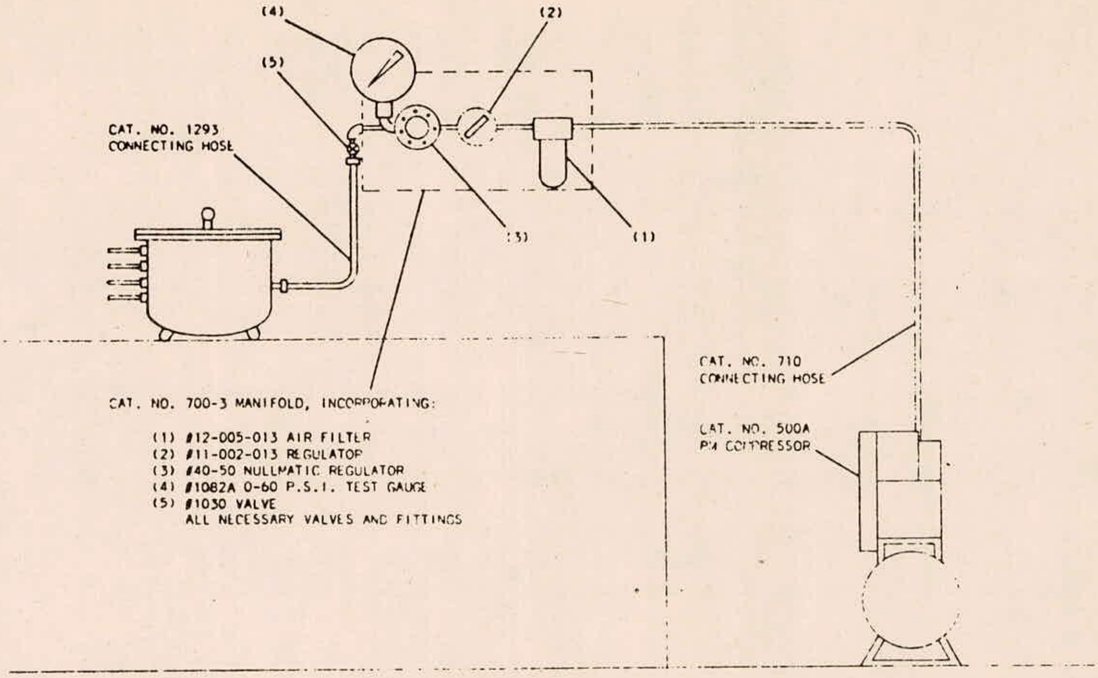


FIG. 5
LABORATORY SETUP FOR CAT. NO. 1600 5 BAR PRESSURE PLATE EXTRACTOR WITH THE CAT. NO. 500 PM COMPRESSOR AS PRESSURE SOURCE

AND WITH THE CAT. NO. 500 PM COMPRESSOR AS A PRESSURE SOURCE. THE CAT. NO. 700-3 MANIFOLD IS FREQUENTLY INCORPORATED IN COMBINATION MANIFOLDS SUCH AS THE CAT. NO. 700-13, 700-23 OR 700-123, WHERE SEVERAL DIFFERENT TYPES OF EXTRACTORS ARE BEING RUN INDEPENDENTLY FROM THE SAME PRESSURE SOURCE.

IF A LABORATORY COMPRESSED AIR SUPPLY LINE IS AVAILABLE, THE CAT. NO. 700-3 MANIFOLD CAN BE CONVENIENTLY ATTACHED TO THE LABORATORY WALL ADJACENT TO THE EXTRACTOR AND CONNECTED DIRECTLY TO THE SUPPLY LINE. MAXIMUM INPUT PRESSURE TO THIS MANIFOLD IS 400 PSI.

THE CAT. NO. 700-3 MANIFOLD IS NOT SUITABLE FOR OPERATION FROM COMPRESSED TANK GAS SINCE IT "BLEEDS" A SMALL AMOUNT OF AIR CONTINUOUSLY FROM THE AIR SOURCE IN THE PROCESS OF REGULATION. THIS AMOUNT OF AIR IS READILY REPLACED BY A COMPRESSOR BUT IT WOULD DRAIN A TANK OF COMPRESSED GAS IN A MATTER OF HOURS.

THE CAT. NO. 1600 EXTRACTOR CAN ALSO BE OPERATED FROM COMPRESSED AIR OR NITROGEN IN TANKS. OUR CAT. NO. 750-3 MANIFOLD IS DESIGNED FOR USE WITH WATER PUMPED NITROGEN IN TANKS (APPROX. 2000 PSI) AND IS APPLICABLE WHERE THE EXTRACTOR IS USED ON A LIMITED BASIS AND IN REMOTE LOCATIONS. THIS MANIFOLD HAS A PRESSURE RANGE FROM 0-125 PSI WITH AN ACCURACY OF REGULATION OF APPROXIMATELY .2 PSI.

FIG. 6 SHOWS THIS LABORATORY SETUP. THE 750-3 MANIFOLD MAY ALSO BE INCORPORATED IN COMBINATION MANIFOLDS SUCH AS THE CAT. NO. 750-13, 750-23 OR 750-123, WHERE SEVERAL DIFFERENT TYPES OF EXTRACTORS ARE BEING RUN INDEPENDENTLY FROM THE SAME PRESSURE SOURCE. THE 750 SERIES MANIFOLD ALL INCORPORATE A CAT. NO. 510B15 REGULATOR WHICH IS DESIGNED TO MOUNT DIRECTLY ON TANKS OF WATER PUMPED NITROGEN WITH A TANK FITTING DESIGNATED AS CGA NO. 580, WHICH IS STANDARD.

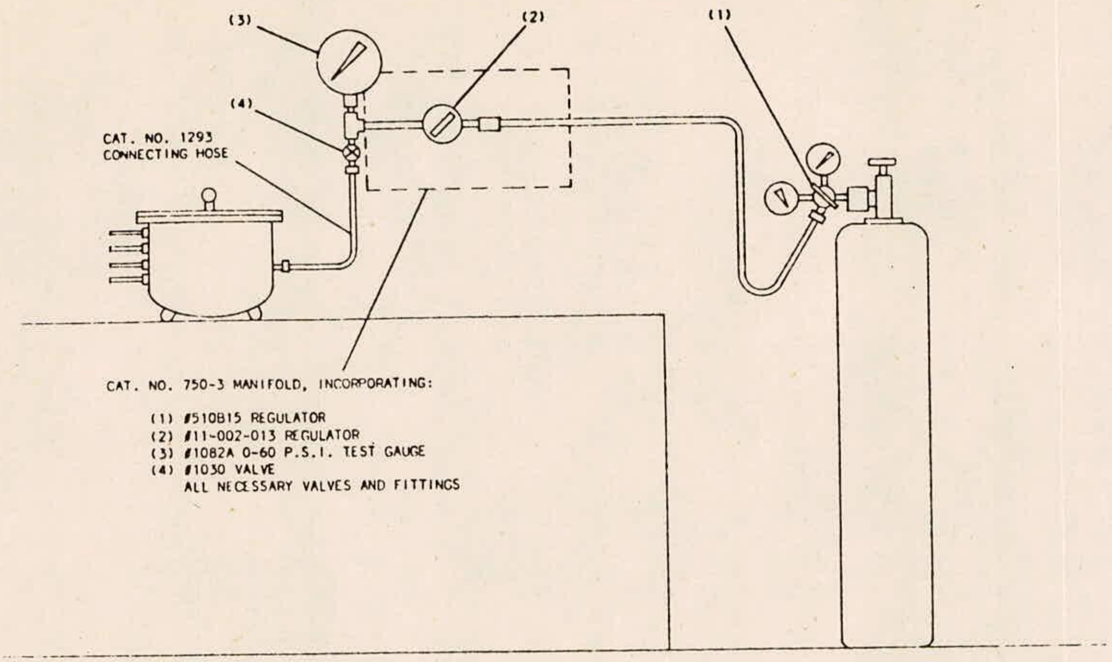


FIG. 6
LABORATORY SETUP FOR CAT. NO. 1600 5 BAR PRESSURE PLATE EXTRACTOR WITH A TANK OF NITROGEN AS A PRESSURE SOURCE

IF A PRESSURE CONTROL SETUP IS TO BE BUILT UP BY THE LABORATORY TECHNICIANS, CARE SHOULD BE EXCERCISED IN THE SELECTION OF PROPER COMPONENTS. PROPER PRESSURE REGULATORS, TEST GAUGES, VALVES AND MISCELLANEOUS ADAPTERS ARE AVAILABLE AT SOILMOISTURE EQUIPMENT CORP. AND THE CURRENT PRICE LIST SHOULD BE CONSULTED. IN GENERAL, THE TYPE OF PRESSURE REGULATOR REQUIRED WILL DEPEND ON THE TYPE OF PRESSURE SOURCE AND ON THE ACCURACY REQUIRED FOR THE STUDIES BEING CONDUCTED. ACCURACY OF REGULATION IS DEPENDENT ON THE CONSTRUCTION OF THE REGULATOR AND ALSO ON VARIATIONS IN THE PRESSURE FROM THE SOURCE OF SUPPLY.

WITH REGULATORS SUITABLE FOR USE WITH THIS EXTRACTOR, ONE CAN EXPECT VARIATION IN THE SOURCE PRESSURE TO BE REFLECTED IN THE REGULATED PRESSURE IN THE RATIO OF ABOUT 1/12 TO 1/25. IN OTHER WORDS, A CHANGE IN THE PRESSURE FROM THE COMPRESSED AIR SOURCE OF 25 PSI WILL CHANGE THE REGULATED PRESSURE BY 1 TO 2 PSI, DEPENDING ON THE MAKE OF REGULATOR. WHERE GREATER ACCURACY IS DESIRED, THIS VARIATION CAN BE ELIMINATED BY THE PROCESS OF "DOUBLE REGULATION". THIS IS DONE SIMPLY BY PUTTING TWO REGULATORS IN SERIES. THE FIRST REGULATOR IS SET AT A SOMEWHAT HIGHER PRESSURE THAN THE SECOND IN ORDER TO SUPPLY REASONABLY CONSTANT PRESSURE TO THE SECOND REGULATOR. PRESSURE FROM THE SECOND REGULATOR IN TURN WILL BE VERY CONSTANT WITH SOURCE PRESSURE VARIATIONS REDUCED IN THE RATIO OF 1/100.

WHERE EXTREME ACCURACY OF REGULATION IS REQUIRED, NULLMATIC REGULATORS WHICH BLEED A SMALL AMOUNT OF AIR CONTINUOUSLY ARE NECESSARY. BECAUSE OF THIS FEATURE, HOWEVER, THEY ARE NOT SUITABLE FOR USE WITH TANK GAS AND MUST BE USED WHERE A COMPRESSOR IS AVAILABLE AS A SOURCE OF PRESSURE.

MAKING A RUN FOR MOISTURE-RETENTION STUDIES

PROPER HANDLING OF SOIL SAMPLES IS NECESSARY FOR ACCURATE, CONSISTENT RESULTS. FOR THIS, WE RECOMMEND THAT THE USER REFER TO THE PROCEDURES AS CALLED OUT IN THE AGRICULTURE HANDBOOK NO. 60* OF THE U. S. DEPARTMENT OF AGRICULTURE. THIS HANDBOOK COVERS DETAILED PROCEDURES FOR PROPER SAMPLING METHODS, TOGETHER WITH COMPLETE INFORMATION ON THE 1/10 AND 1/3 ATM. PERCENTAGE DETERMINATIONS, AND ON THE DEVELOPMENT OF MOISTURE RETENTION CURVES. IT IS IN MANY OTHER RESPECTS A VERY VALUABLE RESEARCH REFERENCE BOOK FOR THE SOIL'S WORKER.

WHERE MOISTURE EQUILIBRIUM STUDIES ARE BEING RUN, IT IS DESIRABLE TO KEEP SAMPLE HEIGHTS SMALL IN ORDER TO KEEP THE TIME TO REACH EQUILIBRIUM REASONABLE. THE TIME REQUIRED TO REACH EQUILIBRIUM VARIES AS THE SQUARE OF THE SAMPLE HEIGHT. FOR EXAMPLE, A SOIL SAMPLE 2 CM HIGH WILL REQUIRE FOUR TIMES AS LONG TO REACH EQUILIBRIUM AS A SAMPLE 1 CM HIGH. WHENEVER POSSIBLE, SOIL SAMPLE HEIGHTS SHOULD BE LIMITED TO 1 CM. OUR CAT. NO. 1093 SOIL SAMPLE RETAINING RINGS, WHICH WILL HOLD A 25 GRAM SAMPLE AND ARE 1 CM HIGH BY 5-1/2 CM IN DIAMETER, ARE IDEAL FOR RETAINING PREPARED SAMPLES.

MOISTURE RETENTION STUDIES CAN BE MADE WITH PREPARED SOIL SAMPLES OR WITH UNDISTURBED SOIL CORES. FREQUENTLY, SOIL STRUCTURE IS QUITE AN IMPORTANT DETERMINING FACTOR IN THE VALUE OF THE 1/10 BAR AND 1/3 BAR PERCENTAGES, AND THOUGHT SHOULD BE GIVEN TO THIS BEFORE ELECTING TO USE UNDISTURBED SOIL CORES OR PREPARED SAMPLES.

FOR WORK WITH UNDISTURBED SOIL CORES, OUR CAT. NO. 200 SOIL CORE SAMPLER IS A SIMPLE, EFFECTIVE SAMPLER. THE SOIL CORES ARE RETAINED IN 2-1/4" O.D. BRASS CYLINDERS OF SEVERAL POSSIBLE LENGTHS. THE CORES OBTAINED CAN ALSO BE USED DIRECTLY IN THE CAT. NO. 210 SOIL RETAINER ASSEMBLY FOR DEVELOPMENT OF MOISTURE RETENTION CURVES. THE CAT. NO. 210 SOIL RETAINER ASSEMBLY CONSISTS OF A 1/4" THICK 1 BAR POROUS CERAMIC PLATE, A 2-1/4" O.D. BY 3 CM LONG BRASS CYLINDER AND A PLASTIC COVER PLATE, ALL HELD TOGETHER WITH A RUBBER BAND. THE ASSEMBLY WILL ACCEPT EITHER UNDISTURBED SOIL CORES OR PREPARED SAMPLES. A SLURRY OF FINE SANDY LOAM CAN BE USED TO ESTABLISH GOOD HYDRAULIC CONDUCTIVITY BETWEEN THE CERAMIC PLATE OF THE RETAINER AND THE CELL SURFACE WHEN MOUNTED FOR A RUN. THE ASSEMBLY CAN BE REMOVED FROM THE EXTRACTOR PERIODICALLY AT VARIOUS EQUILIBRIUM VALUES FOR WEIGHING, WITHOUT DISTURBANCE TO THE SOIL SAMPLE. AGRICULTURE HANDBOOK NO. 60 SHOULD BE CONSULTED FOR FURTHER INFORMATION ON THIS METHOD.

WHERE PREPARED SOIL SAMPLES ARE TO BE USED, THE PROCEDURE FOR DETERMINATION OF THE 1/3 BAR PERCENTAGE IS AS FOLLOWS.

PREPARE DUPLICATE 25 GM. SAMPLES THAT HAVE BEEN PASSED THROUGH A 2 MM ROUND-HOLE SIEVE, FOR EACH SOIL TYPE TO BE RUN. PLACE SOIL SAMPLE RETAINING RINGS, CAT. NO. 1093, ON THE CERAMIC PLATE TO RECEIVE THE GROUP OF SAMPLES. EACH CERAMIC PLATE CELL WILL ACCOMMODATE 12 SAMPLES WHEN RETAINED IN THESE RINGS. IN ORDER TO AVOID PARTICLE-SIZE SEGREGATION, DUMP ALL OF THE SOIL SAMPLE FROM EACH CONTAINER INTO ONE RING. POURING OUT PART OF THE SAMPLE AND LEAVING PART IN THE CONTAINER WILL GIVE A NONREPRESENTATIVE SAMPLE. LEVEL THE SAMPLES IN THE RING, COVER WITH SQUARES OF WAXED PAPER, AND ALLOW THE SAMPLES TO STAND AT LEAST 16 HOURS WITH AN EXCESS OF WATER ON THE PLATE. WHEN THE SAMPLES ARE READY FOR THE EXTRACTOR, REMOVE THE EXCESS WATER FROM THE CERAMIC PLATES WITH A PIPETTE

---

*NOTE: CAN BE OBTAINED FROM SUPERINTENDENT OF DOCUMENTS, U. S. GOVERNMENT PRINTING OFFICE, WASHINGTON 25, D. C. -- PRICE $2.00; OR SOILMOISTURE EQUIPMENT CORP.

OR SYRINGE, MOUNT THE CELLS IN THE EXTRACTOR AND CONNECT UP THE OUTFLOW TUBES, AND CLOSE LID OF EXTRACTOR.

IT IS DESIRABLE TO PROVIDE A MEANS FOR DETERMINING WHEN EQUILIBRIUM HAS BEEN REACHED. THIS CAN BE EASILY DONE BY CONNECTING EACH OUTFLOW TUBE TO THE TIP OF A BURETTE WITH A PIECE OF SMALL DIAMETER TUBING. GAS DIFFUSING THROUGH THE CERAMIC PLATE PASSES CONTINUOUSLY IN SMALL BUBBLES THROUGH THIS SMALL OUTFLOW TUBE, AND KEEPS THE EXTRACTED LIQUID TRANSPORTED TO THE BURETTE. THE BURETTE CAN BE READ PERIODICALLY AND THE APPROACH TO EQUILIBRIUM CAN THUS BE FOLLOWED. IF THE PRESSURE IN THE EXTRACTOR IS MAINTAINED CONSTANT, NO MEASURABLE AMOUNT OF CHANGE IN THE BURETTE READING WILL BE OBSERVED OVER A PERIOD OF MANY HOURS OR DAYS AFTER EQUILIBRIUM IS ONCE ATTAINED.

PRESSURE IS NOW BUILT UP IN THE EXTRACTOR TO 1/3 BAR, WHICH IS 4.83 PSI.

WHEN SETTING THE PRESSURE ON THE 700-3 MANIFOLD FOR A RUN, THE CAT. NO. 1030 VALVE IS FIRST CLOSED. THE 40-50 NULLMATIC REGULATOR IS THEN OPENED SEVERAL TURNS (TURN KNOB CLOCKWISE) TO ALLOW FOR FREE FLOW OF AIR. THE 11-002-013 REGULATOR IS THEN CAREFULLY OPENED (TURN HANDLE CLOCKWISE) UNTIL THE PRESSURE, AS INDICATED BY THE TEST GAUGE, IS 3 TO 5 PSI ABOVE THE EQUILIBRIUM PRESSURE DESIRED. THIS REGULATOR IS LEFT AT THIS SETTING AND THE NULLMATIC REGULATOR IS CLOSED (TURN KNOB COUNTERCLOCKWISE). WHEN THE NULLMATIC REGULATOR IS CLOSED, ALL OF THE AIR IN THE SYSTEM BEYOND THE REGULATOR IS DRAINED FROM THE SYSTEM BECAUSE THIS IS A "RELIEVING TYPE" REGULATOR. NOW THE NO. 1030 VALVE IS OPENED AND THE NULLMATIC REGULATOR IS CAREFULLY OPENED UNTIL THE PRESSURE BUILDS UP IN THE PRESSURE PLATE EXTRACTOR TO THE EQUILIBRIUM PRESSURE DESIRED, AS INDICATED ON THE TEST GAUGE. THE REGULATORS WILL NOW MAINTAIN THIS PRESSURE. THE SAME PROCEDURE IS FOLLOWED WHEN ADJUSTING THE EQUILIBRIUM PRESSURE FROM ONE VALUE TO ANOTHER. AT THE END OF A RUN THE NULLMATIC REGULATOR IS CLOSED (TURN KNOB COUNTERCLOCKWISE). IN SO DOING, ALL OF THE AIR IN THE PRESSURE PLATE EXTRACTOR WILL DRAIN OUT THROUGH THE REGULATOR SINCE IT IS A "RELIEVING TYPE".

SETTING THE PRESSURE ON THE 750-3 MANIFOLD IS SIMILAR TO THE SYSTEM USED ON THE CAT. NO. 700-3 MANIFOLD WITH THE EXCEPTION THAT THE CAT. NO. 510B15 REGULATOR CAN BE SET IMMEDIATELY AT A PRESSURE OF 40-50 PSI AS READ ON THE SEPARATE OUTPUT PRESSURE GAUGE OF THIS REGULATOR. THIS PROVIDES THE SOURCE PRESSURE FOR THE CAT. NO. 11-002-013 REGULATOR WHICH IN TURN IS USED TO ESTABLISH THE PRESSURE TO THE EXTRACTOR.

AS SOON AS PRESSURE IS APPLIED, MOISTURE WILL START TO FLOW FROM THE OUTFLOW TUBES. SAMPLES 1 CM HIGH WILL REACH EQUILIBRIUM AND CAN BE REMOVED ANY TIME AFTER 48 HOURS FROM INITIATING THE EXTRACTION OR WHEN READINGS ON A BURETTE INDICATE THAT OUTFLOW HAS CEASED FROM ALL OF THE SAMPLES ON EACH PLATE. SOME SOILS WILL APPROACH EQUILIBRIUM IN 18 TO 20 HOURS.

AT THE END OF A RUN, BEFORE RELEASING THE AIR PRESSURE IN THE EXTRACTOR, THE ENDS OF THE OUTFLOW TUBES SHOULD BE SEALED OFF WITH A SHORT LENGTH OF RUBBER TUBING AND A PINCH CLAMP, OR OTHER MEANS, TO PREVENT BACKFLOW OF WATER TO THE SAMPLES AFTER THE PRESSURE IS RELEASED. REMOVE THE EXTRACTOR LID AND TRANSFER THE SAMPLES QUICKLY TO MOISTURE BOXES AND WEIGH. DETERMINE THE MOISTURE CONTENT BY DRYING TO CONSTANT WEIGHT AT 105 C. AND EXPRESS MOISTURE CONTENT AS PERCENT, DRY-WEIGHT BASIS.

FOR DETERMINATION OF THE 1/10 BAR PERCENTAGE, THE SAME PROCEDURE IS USED WITH THE EXCEPTION THAT THE PRESSURE APPLIED IS 1/10 BAR OR 1.45 PSI.

PRECAUTIONS

IN WORKING WITH THE EXTRACTOR, CARE SHOULD BE TAKEN TO KEEP SOIL PARTICLES AWAY FROM THE PRESSURE SEALS AND SEALING AREAS. IT IS ALSO VERY IMPORTANT TO AVOID SCRAPING OR BANGING THE METAL SURFACES ON WHICH THE PRESSURE SEALS ARE MADE. DAMAGE TO THESE SEALING SURFACES MAY RESULT IN LEAKAGE OF AIR FROM THE EXTRACTOR. THIS LEAKAGE IS CALLED "VENTILATION" AND IT CAN RESULT IN ERRONEOUS EQUILIBRIUM VALUES SINCE ANY FLOW OF AIR WILL ALSO CARRY OFF SOIL MOISTURE AND REDUCE THE EQUILIBRIUM MOISTURE CONTENT VALUE BELOW ACTUAL VALUES.

ONE SHOULD NEVER ATTEMPT TO REMOVE THE LID OF THE EXTRACTOR UNTIL ALL PRESSURE IS RELEASED. EQUAL CARE SHOULD BE TAKEN TO SEE THAT THE LID IS SECURELY FASTENED IN PLACE BEFORE AIR PRESSURE IS APPLIED.

MAINTENANCE

PRESSURE VESSEL:

THE EXTRACTOR LID AND TANK ARE RUGGEDLY CONSTRUCTED, CAREFULLY PLATED AND COATED FOR MAXIMUM CORROSION RESISTANCE. LITTLE ATTENTION SHOULD BE REQUIRED EXCEPT FOR REMOVING EXCESS MOISTURE AND SOIL PARTICLES FROM THE INTERIOR SURFACES AFTER A RUN. REPLACEMENT PRESSURE SEALING RINGS ARE AVAILABLE FOR IMMEDIATE SHIPMENT FROM OUR STOCK. THE CAT. NO. 1694 IS THE REPLACEMENT "O" RING LID SEAL. THE CAT. NO. 1693 IS THE REPLACEMENT "O" RING PORT SEAL.

CERAMIC PRESSURE PLATE CELLS:

WHEN A CERAMIC PRESSURE PLATE CELL IS TO BE DRIED FOR STORAGE AFTER A RUN, IT IS IMPORTANT TO KEEP EVAPORATION DEPOSITS ON THE SURFACE TO A MINIMUM. THIS IS EASILY ACCOMPLISHED BY COVERING THE SURFACE OF THE CERAMIC PLATE WITH A THIN LAYER OF FINE DRY SOIL AND ALLOWING IT TO SET FOR SEVERAL DAYS UNTIL DRY. THE SOIL IS THEN REMOVED AND THE CELL IS STORED. BY THIS MEANS, EVAPORATION DEPOSITS ARE FORMED ON THE SOIL PARTICLES RATHER THAN THE SURFACE OF THE CERAMIC PLATE.

IF AFTER A PERIOD OF TIME THE FLOW RATE OF THE CELL DROPS DUE TO DEPOSITS, THESE CAN BE REMOVED. CALCIUM CARBONATE DEPOSITS ON THE SURFACE OF THE CERAMIC CAN BE REMOVED BY CAREFULLY SANDING THE SURFACE WITH A FINE OR MEDIUM GRADE OF GARNET OR SANDPAPER.

DEPOSITS IN THE PORES OF THE CERAMIC CAN BE REMOVED BY FLUSHING THROUGH THE PRESSURE PLATE CELL UNDER PRESSURE IN THE EXTRACTOR A 10% SOLUTION OF HYDROCHLORIC OR ACETIC ACID. THIS SHOULD BE FOLLOWED BY SIMILAR FLUSH OF CLEAR WATER.

FOR MOST SOILS AND WORK, BACTERIAL ACTION IN THE PRESSURE PLATE CELL DOES NOT PRESENT A PROBLEM. IN THOSE CASES WHERE BACTERIAL ACTION IS OF IMPORTANCE, THE PRESSURE PLATE CELLS CAN BE FLUSHED UNDER PRESSURE PERIODICALLY WITH A SOLUTION OF COPPER SULFATE OR MERCURIC CHLORIDE IN THE MANNER DESCRIBED FOR REMOVAL OF EVAPORATION DEPOSITS.

SOILMOISTURE EQUIPMENT CORP. SANTA BARBARA, CALIFORNIA U.S.A.

INSTRUCTIONS FOR SETUP OF THE CAT. NO. 700-23 MANIFOLD

THE CAT. NO. 700-23 MANIFOLD SUPPLIED IS COMPLETELY ASSEMBLED AND TESTED AND READY FOR MOUNTING ON THE LABORATORY WALL. THE 3/4" THICK PLYWOOD BASE WHICH SUPPORTS THE VARIOUS COMPONENTS CAN BE DRILLED AT ANY CONVENIENT LOCATION FOR MOUNTING WITH WOOD SCREWS OR BOLTS IN THE LABORATORY WALL. NORMALLY, THE CAT. NO. 500-A PM COMPRESSOR IS SET ADJACENT TO THE LABORATORY BENCH AND THE PRESSURE CONTROL MANIFOLD. THE ATTACHED ENGINEERING DRAWING SHOWS A TYPICAL LABORATORY SETUP FOR THIS MANIFOLD. AS INDICATED ON THE ENGINEERING DRAWING, A CAT. NO. 710 CONNECTING HOSE COMBINATION IS USED FOR PRESSURE CONNECTION BETWEEN THE COMPRESSOR AND MANIFOLD. THIS CONNECTING HOSE COMBINATION HAS THE ELBOW FITTING WHICH SCREWS INTO THE BACK PRESSURE OUTLET ON THE COMPRESSOR TANK. THESE ARE 1/4" NPT PIPE THREADS AND A SUITABLE PIPE DOPE OR TAPE SHOULD BE USED TO MAKE A PRESSURE SEAL. A SHUT-OFF VALVE IS CONNECTED TO THIS ELBOW FITTING AND CAN BE USED FOR SHUTTING OFF THE AIR SUPPLY AT THE TANK. THE FLEXIBLE NEOPRENE HOSE THEN CONNECTS THIS SHUT-OFF VALVE WITH THE INLET FITTING ON THE MANIFOLD. THE THREAD SIZE OF THIS CONNECTING HOSE AS WELL AS THE CONNECTING HOSE USED TO CONNECT THE VARIOUS EXTRACTORS TO THE MANIFOLD IS 9/16-18. PRESSURE SEAL AT THE HOSE CONNECTION IS MADE WHEN THE ROUND "NOSE" OF THE BRASS STEM INSIDE THE HOSE NUT IS PRESSED AGAINST THE RECESSED CONICAL SURFACE OF THE PRESSURE FITTINGS. THIS IS A METAL-TO-METAL SEAL AND IS VERY EFFECTIVE. THE SCREW THREADS ON THE FITTING AND HOSE NUT ONLY SERVE AS A MEANS OF HOLDING THE PARTS IN CONTACT. THE THREADS THEMSELVES DO NOT MAKE A SEAL. ONLY A SMALL AMOUNT OF TORQUE IS REQUIRED AND SHOULD BE USED IN CONNECTING THE HOSES.

THE CAT. NO. 700-23 MANIFOLD IS A COMBINATION MANIFOLD COMBINING THE 700-2 STATION AND THE 700-3 STATION. THE 700-2 STATION IS FOR OPERATION OF THE CAT. NO. 1500 15 BAR CERAMIC PLATE EXTRACTOR. THE CAT. NO. 700-3 STATION PROVIDES VERY PRECISE LOW PRESSURE REGULATION IN THE PRESSURE RANGE FROM 0 TO 50 PSI AND IS USED FOR OPERATION OF THE CAT. NO. 1200 PRESSURE PLATE EXTRACTOR, CAT. NO. 1250 VOLUMETRIC PRESSURE PLATE EXTRACTOR, CAT. NO. 1400 AND 1450 TEMPE PRESSURE CELLS, AND THE CAT. NO. 1600 5 BAR EXTRACTOR.

THE CAT. NO. 700-2 STATION CONSISTS OF A CAT. NO. 11-002-017, 0 TO 250 PSI, PRESSURE REGULATOR; A CAT. NO. 11-002-013, 0 TO 125 PSI, PRESSURE REGULATOR; A CAT. NO. 1082-A, 0 TO 300 PSI, TEST GAUGE; AND ALL NECESSARY VALVES AND FITTINGS. IN SETTING EXTRACTION PRESSURES IN THE RANGE FROM 125 PSI TO 225 PSI, VALVE A, REFERENCE THE ATTACHED ENGINEERING DRAWING, IS OPENED, AND VALVE B IS CLOSED. ALL PRESSURE REGULATION IS THEN DONE WITH THE ONE CAT. NO. 11-002-017 REGULATOR. THE REGULATOR IS TURNED CLOCKWISE FOR HIGHER PRESSURE VALUES AND THE PRESSURE IS READ DIRECTLY ON THE TEST GAUGE. FOR LOW EXTRACTION PRESSURES IN THE RANGE FROM 0 TO 125 PSI, VALVE A IS CLOSED AND VALVE B IS OPENED. THE HIGH PRESSURE REGULATOR, CAT. NO. 11-002-017, IS SET FOR A PRESSURE VALUE IN EXCESS OF 125 PSI, AND USUALLY IN THE RANGE OF 125 TO 150 PSI. THIS HIGH PRESSURE REGULATOR THEN SUPPLIES PRESSURE TO THE 11-002-013 LOW PRESSURE REGULATOR. THIS LOW PRESSURE REGULATOR IS THEN SET FOR THE EXTRACTION PRESSURE DESIRED AND THE PRESSURE IS READ OUT ON THE TEST GAUGE.

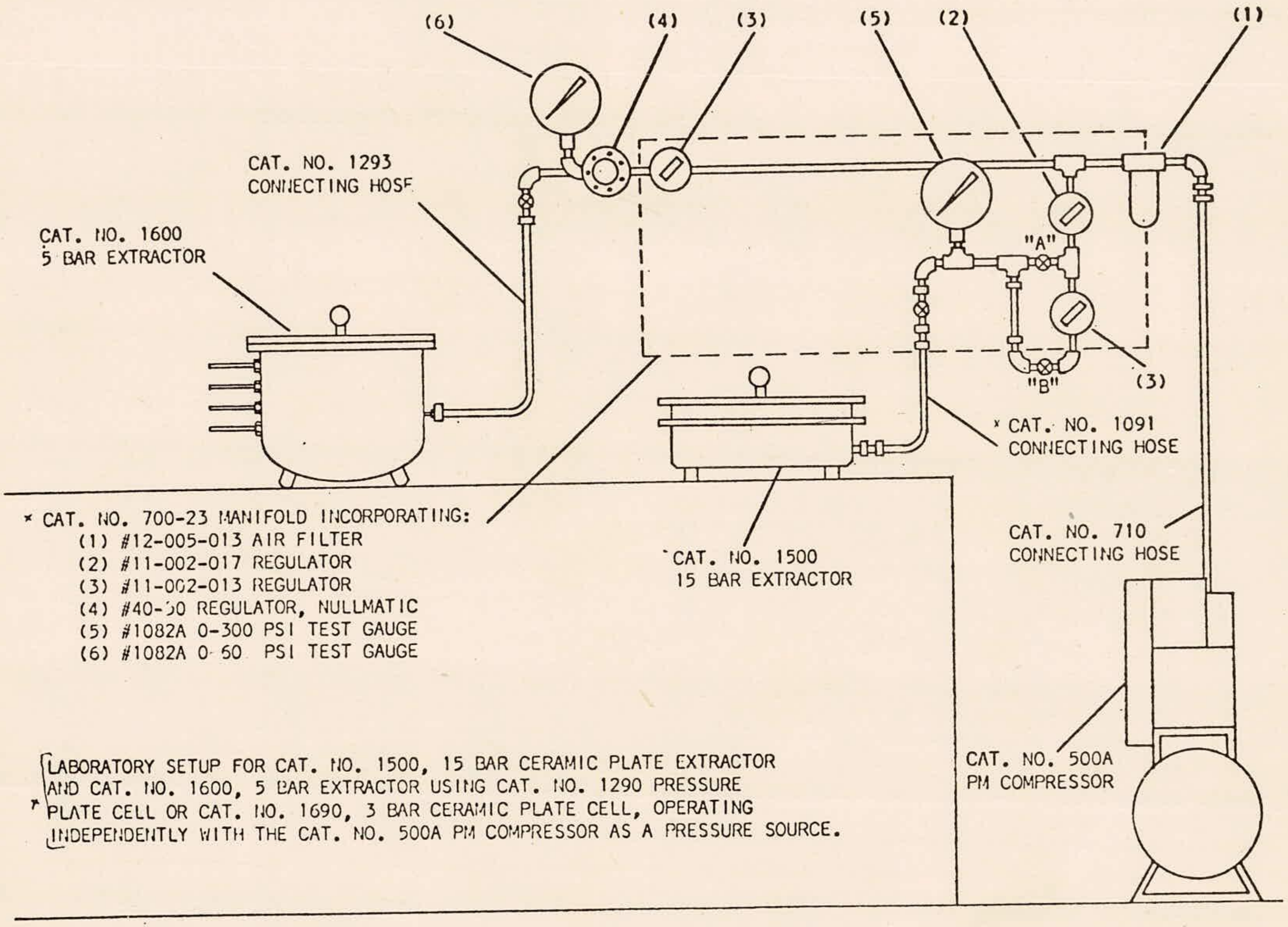
THIS SYSTEM FOR LOW PRESSURE REGULATION IS KNOWN AS "DOUBLE REGULATION" AND IS FREQUENTLY USED TO PROVIDE VERY ACCURATE CONTROL OF PRESSURE. ALL REGULATORS REFLECT IN THEIR OUTPUT PRESSURE VARIATIONS PRESENT IN THE PRESSURE FROM THE SOURCES OF SUPPLY. BY PLACING TWO REGULATORS IN SERIES, SUCH AS MENTIONED ABOVE, VARIATIONS IN THE OUTPUT PRESSURE FROM THE FIRST REGULATOR ARE CONSIDERABLE REDUCED BY THE SECOND REGULATOR SO THAT THE OUTPUT PRESSURE FROM THE SECOND REGULATOR IS VERY CONSTANT WITH SOURCE PRESSURE VARIATIONS REDUCED IN THE RATIO OF 1:100 OR MORE.

AT THE END OF A RUN WHEN IT IS DESIRED TO EXHAUST THE AIR FROM THE EXTRACTOR, IT IS ONLY NECESSARY TO CLOSE EITHER OF THE REGULATORS BEING USED BY TURNING IN A COUNTERCLOCKWISE DIRECTION. AS THIS IS DONE, THE AIR FROM THE EXTRACTOR WILL EXHAUST THROUGH THE REGULATOR. THIS IS A FEATURE OF "RELIEVING TYPE" REGULATORS AND IT ELIMINATES THE NECESSITY OF HAVING A SEPARATE EXHAUST VALVE. ON A RELIEVING TYPE REGULATOR, ANY PRESSURE ON THE OUTPUT SIDE OF THE REGULATOR WHICH IS IN EXCESS OF THE PRESSURE VALUE SET BY THE REGULATOR WILL AUTOMATICALLY EXHAUST THROUGH THE REGULATOR MECHANISM.

THE 700-3 STATION CONSISTS OF A CAT. NO. 11-002-013, 0 TO 125 PSI, PRESSURE REGULATOR; A NULLMATIC PRESSURE REGULATOR, 0 TO 60 PSI; CAT. NO. 1082-A, 0 TO 60 PSI TEST GAUGE; AND ALL NECESSARY VALVES AND FITTINGS. IN MAKING PRESSURE SETTINGS AT THIS STATION, IT IS IMPORTANT TO CAREFULLY ADJUST BOTH OF THE PRESSURE REGULATORS. THE NULLMATIC REGULATOR CONTINUOUSLY EXHAUSTS A CERTAIN AMOUNT OF AIR WHEN IT IS USED ON "DEAD END SERVICE" SUCH AS IS THE CASE WITH OUR EXTRACTORS. THE AMOUNT OF AIR EXHAUSTED IS PROPORTIONAL TO THE PRESSURE DIFFERENCE BETWEEN THE SUPPLY AIR AND THE PRESSURE SETTING OF THE DELIVERED AIR. FOR NORMAL USE AND FOR MAXIMUM CONSERVATION OF COMPRESSED AIR FROM THE TANK, THE CAT. NO. 11-002-013 REGULATOR SHOULD BE SET AT A PRESSURE 2-3 PSI HIGHER THAN THE EQUILIBRIUM PRESSURE THAT YOU WISH TO DELIVER FROM THE NULLMATIC REGULATOR. WHEN THIS PROCEDURE IS FOLLOWED, THE AMOUNT OF AIR ESCAPING FROM THE NULLMATIC REGULATOR IS IN THE ORDER OF 2/100 CU.FT. OF AIR PER MINUTE. THIS AMOUNT OF AIR IS VERY EASILY BUILT UP BY THE COMPRESSOR PUMP IN THE COURSE OF ITS PUMPING CYCLE.

WHEN SETTING THE PRESSURE FOR A RUN, THE PROCEDURE IS AS FOLLOWS, REFERENCE THE ATTACHED ENGINEERING SKETCH. THE VALVE AT THE END OF THE CONNECTING HOSE IS FIRST CLOSED. THE NULLMATIC REGULATOR IS THEN OPENED A NUMBER OF TURNS SO THAT YOU ARE SURE IT IS SET AT A PRESSURE CONSIDERABLY ABOVE THAT WHICH YOU PLAN TO USE. THEN, THE CAT. NO. 11-002-013 REGULATOR IS OPENED SO THAT THE PRESSURE CAN FLOW THROUGH THE NULLMATIC REGULATOR AND REGISTER ON THE TEST GAUGE. THE CAT. NO. 11-002-013 REGULATOR IS ADJUSTED SO THAT THE PRESSURE GAUGE READS, SAY, 3 PSI HIGHER THAN THE EQUILIBRIUM PRESSURE YOU PLAN TO USE IN THE EXTRACTOR. THE NULLMATIC REGULATOR IS NOW CLOSED UNTIL THE EXCESS AIR IS EXHAUSTED UP TO THE PRESSURE VALUE YOU DESIRE IN THE EXTRACTOR AND WHICH WILL NOW BE REGISTERED ON THE TEST GAUGE. THE VALVE TO THE PRESSURE EXTRACTOR CAN NOW BE OPENED AND THE REGULATORS WILL MAINTAIN THE PRESSURE IN THE EXTRACTOR AT THE VALUE SET.

IN ORDER TO EXHAUST THE AIR FROM AN EXTRACTOR AFTER A RUN, EITHER OF THE PRESSURE REGULATORS ARE SIMPLY CLOSED IN A COUNTERCLOCKWISE DIRECTION AND, SINCE THESE ARE BOTH RELIEVING TYPE REGULATORS, THE AIR FROM THE EXTRACTOR WILL EXHAUST THROUGH THE REGULATOR.



LABORATORY SETUP FOR CAT. NO. 1500, 15 BAR CERAMIC PLATE EXTRACTOR AND CAT. NO. 1600, 5 BAR EXTRACTOR USING CAT. NO. 1290 PRESSURE * PLATE CELL OR CAT. NO. 1690, 3 BAR CERAMIC PLATE CELL, OPERATING INDEPENDENTLY WITH THE CAT. NO. 500A PM COMPRESSOR AS A PRESSURE SOURCE.

PROJECT DIRECTOR : SATISH CHANDRA

PROJECT COORDINATOR : S M SETH

STUDY GROUP

SCIENTIST : S M SETH

LABORATORY STAFF : S P L SRIVASTAV
SANJAY MITTAL

SCIENTIFIC STAFF : RAJAN VATSA
PANKAJ GARG
T VIJAY

OFFICE STAFF : T P PANICKER
RAM KUMAR