THE WATER HOLDING CAPACITY OF SOME IRRIGATED SOILS OF OKLAHOMA

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PREFACE

The studies reported in this thesis are a part of the irrigation research conducted by the Oklahoma Agricultural Experiment Station. The facilities of the irrigation research and Soils Department laboratories were made available for this problem.

The author is grateful to James E. Garton, Assistant Professor of Agricultural Engineering for his patient assistance throughout the experiment and analysis of data.

Appreciation is expressed to Dr. Harold V. Eck, Assistant Professor, and Bob Stewart, Instructor of Soils, cooperative with the U. S. Department of Agriculture for making the laboratory facilities available and for their assistance during the study.

The author is also grateful to the farmers who made their farms available for soil sampling in order that the experiment could be conducted and to Elmer R. Daniel, Assistant Professor of Agricultural Engineering for his photographic work.

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I. INTRODUCTION

The satisfactory design of irrigation systems depends on accurate estimates of the available water holding capacities of the soils to be irrigated. The water holding capacities of soils are used to determine how much water to apply per application, time required to apply sufficient water, the frequency of application for a particular crop and the acreage that can feasibly be irrigated from a given water supply.

In some areas of extensive irrigation, tests have been conducted on soils to determine the available water holding capacities. The results are valid only for the soils tested since they are climatically different from soils of other areas.

Irrigation in Oklahoma has been on a limited basis until recent years. Little or no attention has been given to the subject of water holding capacities of the soils. In the design of irrigation systems, proper attention has not been given to water holding capacities. At present prices, an over design can be very costly, while an under-design may cause an economic loss to the farmer. Accurate estimates must be made of the water holding capacities of soils in order to properly design irrigation systems.

Several methods are available for determining moisture storage capacities of soils. The direct methods that make use of field application are more accurate but also more costly both in time and money. Israelsen (11, p. 209-211) says:

"The field capacity depends in part on the initial moisture

> distribution, the moisture-transmitting properties of the soil, its moisture-retaining properties, and the depth of water applied. It is, therefore, difficult to base a field-capacity estimate on disturbed soil samples. However, to facilitate progress toward increasing water-application efficiencies, it is essential to develop low-cost methods of estimating field capacities, wilting points, and available water capacities."

Therefore, various laboratory measurements have been used to determine the water storage capacities of soils.

II. OBJECTIVES

The principal objective of this study was to determine the water holding capacities of some Oklahoma irrigated soils. In addition, other studies were made of the soil moisture characteristics.

Specifically the objectives were:

1. Determination of water holding capacities of irrigated soils.
2. Determination of the type of moisture-tension curve.
3. Determination of the correlation between the Atterberg limits and the moisture-tension curves.
4. Determination of the correlation between the single value soil moisture characteristics.
5. Determination of the correlation between the moisture characteristics and the mechanical analysis of the soils.

III. REVIEW OF LITERATURE

Water storage capacities of soils have been studied by engineers and agronomists for many years. In the study of soil moisture, it is necessary to have in mind the relation between plants and the soil moisture with two defining points. Field capacity of soils is defined as the percent moisture on a dry weight basis that a soil can hold against the forces of gravity, while permanent wilting point is the moisture content of the soil on a dry weight basis at which point the plant wilts and will not revive (11, 4). The moisture available to plants is the range between field capacity and the wilting point.

In 1936 Richards and Gardner (30) devised a tensiometer--a device by which the tension on the moisture could be determined in the soil. Russell (32) in 1939 reported on studies of tension on soil water giving the point of field capacity and permanent wilting point as determined by field application. These studies show that field capacities occur when the tension of the soil moisture is approximately 400 cm. of water or 5.3 pounds. There is a range of tensions corresponding to wilting point varying from 8,500 to 25,000 cm. of water or from 120 to 350 pounds.

Richards and Weaver (29) made extensive studies to correlate tension and moisture content of the soil. Although they pointed out that a disturbed sample will not produce accurate results, the moisture retained by the soil when subjected to a tension of 1/3 atmosphere corresponded very closely with field capacity and produced a good estimate for most soils. Also, it was found that the tension corresponding to wilting point ranged from 10 to 20 atmospheres, or an average of

15 atmospheres. A comparison of these values with those of Russel shows they are very nearly equal. Although 15 atmospheres is considered to be the limiting force plants can exert to obtain sufficient moisture for growth, pressures as high as 60 atmospheres have been recorded for some plants (35).

Richards (26) developed an apparatus known as the pressure membrane apparatus for extracting the moisture from soil samples by air pressure. The principal part of this apparatus is a membrane permeable to water under pressure. The pressure on the soil samples is exerted by air on a rubber diaphram. Moisture is continuously extracted for a given pressure until equilibrium is reached between the pressure exerted and the tension on the water in the soil. The apparatus was devised from the principle of the pressure cooker with the added feature of removing the extracted moisture. The water permeable membrane is simply a sausage casing.

Very little or no moisture would pass through the membrane at pressures less than 2 atmospheres. Therefore, another apparatus was devised from the same idea but using a porous ceramic plate instead of a membrane. This apparatus could easily be used to determine the field capacity of soils.

During Richards' studies it was found that temperature affects the amount of moisture that can be extracted from a soil. As the temperature increases the amount of water extracted increases. Therefore, if temperature fluctuates throughout the tests, it may be difficult to determine exactly when equilibrium has been reached. For this reason, it is desirable to conduct the moisture tension tests at a constant temperature if possible.

On the basis of Richards' information concerning the correlation of moisture retained by the soil and pressure or tension, moisture-tension curves can be derived for soils by the use of the pressure membrane apparatus. From the moisture-tension characteristics of a soil, the percent of available moisture can be determined.

By making use of Israelsen's (11) relationship of volume weight and available moisture percent,

$$d = \frac{A_s P_{ac} D}{100},$$

the depth of water storage can be determined.

Based on the needs for an inexpensive and rapid determination of water holding capacities, several investigators have attempted to predict the moisture values of soils from the moisture equivalent or mechanical analysis of the soil. Although moisture equivalent is a single value moisture characteristic of soils, correlations have been made with field capacity and permanent wilting point.

In 1950, Peele and Beale (20) reported studies of the comparison of moisture equivalent and field capacity, and wilting point and moisture retained after the soil was subjected to 15 atmospheres of tension. The field capacity and wilting point were determined by field application. A correlation coefficient of 0.985 was reported for the moisture equivalent and field capacity while a near perfect correlation of 0.998 was found for the wilting point and moisture remaining after the soil was subjected to 15 atmospheres of tension. The relationships derived were:

Field capacity=2.62+0.865x moisture equivalent, and

Wilting point=0.99+0.97x moisture at 15 atmospheres.

Briggs and Shantz (4) determined from their studies the wilting coefficient (which is defined the same as wilting point) could be determined from the moisture equivalent. Their relationship was:

$$W.C. = \frac{M.E.}{1.84}.$$

Also Briggs and Shantz (4), Alway and Russel (2), Smith (33) and Middleton (17) stated that moisture equivalent could be determined from the mechanical analysis of soils. The following are the relationships reported:

Briggs & Shantz--$M.E. = 0.02Sand + 0.22Silt + 1.05Clay$,
Alway & Russel---$M.E. = 0.14Sand + 0.27Silt + 0.53Clay$,
Smith------------$M.E. = 0.023Sand + 0.25Silt + 0.61Clay$, and
Middleton--------$M.E. = 0.063Sand + 0.291Silt + 0.42Clay$.

There is considerable variation between the constants determined by each of the investigators. There is one notable characteristic that the value of clay is placed considerably higher than the other two separates in the four expressions reported.

Acquino and Komkris (1), reporting on their studies of Philippine soils, concluded the moisture content of all the soils were apparently controlled by their clay content.

IV. METHODS OF PROCEDURE

Samples and Sampling

In obtaining samples for the study, an attempt was made to take homogeneous samples of the major soil types being irrigated in Oklahoma. Samples were taken from a total of fifteen soils with eleven from the two major irrigated areas of Oklahoma--the Panhandle and Altus Irrigation District--and the remaining four from areas with planned or proposed systems. Table 5 in the appendix shows the location over the state from which the samples were taken.

Bowen (5) reported in 1939 that the largest percent of total moisture used by plants is taken from the first foot of soil depth. Since the time available for the research limited the amount of soil samples that could be tested, samples were taken from only the first foot of depth at one location in each soil type.

For the purpose of determining the depth of water storage, volume weight samples were taken by use of the Pomona soil sampler. A photograph of the sampler is shown in figure 1. The cylinders slip into the sampler in the relative position shown with the tapered cutting tip holding them in place. A longer handle is screwed onto the threads shown in the picture and the sampler is driven into the soil by raising and dropping a weight on the end of the handle. The taper end of the cutting tip is such that the soil around the sampler is forced outward leaving a smooth undisturbed sample in the cylinder. The angle-ring on the outside of the sampler gauges the depth to which the sampler is driven. The sampler is taken out, the cutting tip removed and the

Figure 1. An exploded view of the Pomona soil sampler with the parts in their relative position.

sample filled rings taken out. The short end rings are removed by slicing with a piano wire, leaving the undisturbed sample (as nearly as possible) in the long ring giving a sample with a diameter of 1.9 inches and a length of 2 inches.

It was necessary to take volume weight samples in undisturbed soil, therefore the loose plowed soil was removed to a depth of approximately 8 inches, or below plow depth, and the volume samples taken. Three volume weight samples were taken at each location. The loose plowed soil that was excavated was used in the laboratory tests.

Apparatus Used for Testing

The pressure membrane apparatus used for the moisture-tension studies had only slight modifications from the one Richards originally developed. The major difference was the connection of the compressed air lines to the apparatus.

At the beginning of the study an apparatus was used where the room temperature varied from 88 to 100°F. Due to the quantity of moisture retained by the soils being affected by temperature, a cooperative project was worked out with the Soils department whose laboratory remained at a constant 65°F.

The equipment available in the soils laboratory was arranged similar to the panel connection described by Miller (18) in 1953. Figure 2 is a photograph showing the arrangement of the pressure membrane apparatus including the panel, U-tube manometer and air compressor. The connections were such that as many as four apparatus could be used simultaneously.

For pressures less than 2 atmospheres, the pressure membrane

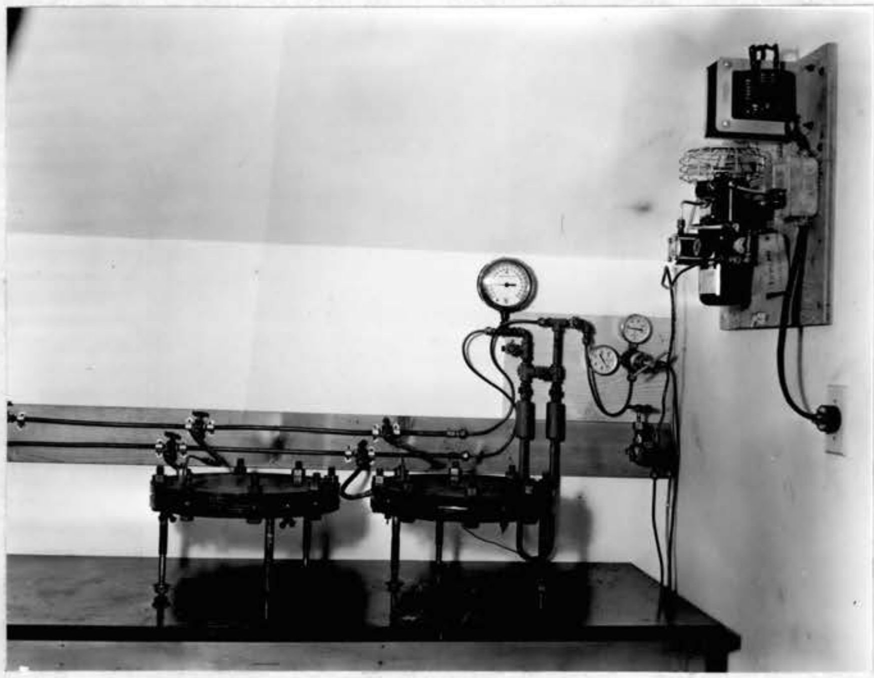

Figure 2. An overall view of the panel arrangement of the pressure membrane apparatus, air compressor, pressure regulator and U-tube manometer.

apparatus is not satisfactory.[1] Therefore, for pressures less than 2 atmospheres a porous plate apparatus was used.

The porous plate apparatus is similar to the pressure membrane apparatus except that compressed air is applied directly to the soil sample on the permeable material consisting of a porous ceramic plate. The porous plate apparatus of the soils laboratory were arranged similar to the pressure membrane apparatus. Figure 3 is a picture of the porous plate apparatus and the arrangement of the distribution panel.

Methods of Testing

The samples used in the pressure membrane tests were pulverized in a mortar with a rubber covered pestle (to prevent crushing the coarser separates) and sieved with a 20 mesh sieve. That fraction passing the 20 mesh sieve was sub-sampled by the quartering method to select the sample used in the apparatus.

A total of 15 of the 2 inch rubber rings for holding the individual samples were placed in the apparatus at one time. Three replications were made of each soil at each pressure which made it possible to use 5 different soils per run.

In order that a sample was not deliberately placed in one specific location if the location affected the moisture retained, the samples were located at random. This was done by drawing a number for each sample for the location from a cup of 15 numbers. The randomized placings removed personal bias from the experiment.

After the soils were placed in the apparatus, water was put on

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[1]The air pressure forces the moisture extracted from the soil sample through the membrane. At pressures less than 2 atmospheres, moisture can not be removed at low temperatures.

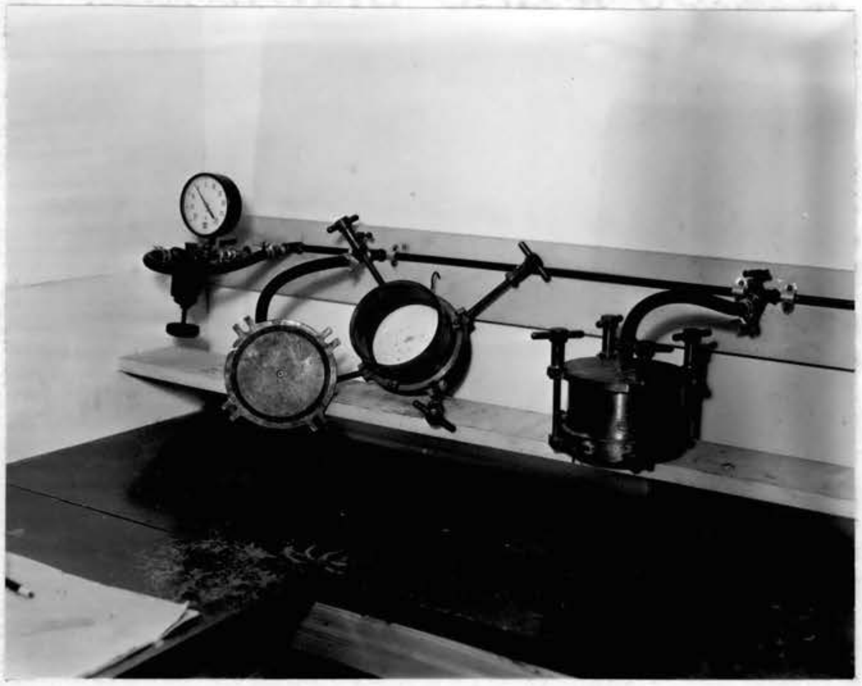

Figure 3. The panel arrangement of the porous ceramic plate apparatus and pressure regulator.

the membrane to a depth of approximately 1 cm. The soil samples were allowed to soak for a period of 12 to 16 hours at which time saturation was completed.

The excess water was removed and the top of the apparatus fastened into place with steel bolts. A torque of 20 foot-pounds was applied to the bolts with a calibrated torque wrench.

The desired air pressure was adjusted with the control valve and pressure was applied above and below the rubber diaphram. A period of 5 to 8 hours was allowed for the extraction of the excess moisture.

When the excess moisture was removed, a stop-cock on the U-tube manometer was opened to allow air to bubble through the mercury and then the stop-cock was closed. The mercury manometer allowed a 5 pound pressure differential to be applied to the diaphram, that is, 5 pounds more pressure applied to the top of the diaphram than below it. This was to allow the diaphram to be pressed against the samples for more effective moisture extraction.

When moisture ceased to be extracted from the soil, the samples were removed from the apparatus, weighed and placed in a standard soils oven at 105°C. After 24 hours the samples were removed from the oven, weighed and the moisture content calculated.

Different times were required for the samples to reach equilibrium at different pressures for the constant temperature tests. Five days were required at 15 atmospheres pressure, 4 days for 8 atmospheres and 3 days for 3 atmospheres. For the apparatus operating at higher temperatures, the time ranged from 48 to 60 hours.

The procedure for the porous plate apparatus was the same as for the pressure membrane apparatus except the time required for the samples to reach equilibrium was only 24 hours. Also, there being no diaphram in the porous plate apparatus, no manometer was necessary and the air was applied directly to the sample.

The samples for the moisture equivalent tests were prepared in the same way as for the pressure membrane tests. The centrifuge cups were filled and allowed to soak for 24 hours, at which time they were allowed to drain of excess water. The samples were duplicated with the duplicates directly opposite each other to balance the centrifuge. The centrifuge was run at 1440 rpm for 30 minutes. The samples were removed from the centrifuge and the same drying procedure was followed as in the pressure tests.

The liquid and plastic limits, real specific gravities and mechanical analyses were determined by standard methods designated by the American Society for Testing Materials (A.S.T.M.). The following is a list of the test designations:

A.S.T.M. Designation: D 423-39--Standard Method of Test for Liquid Limit of Soils

A.S.T.M. Designation: D 424-39--Standard Method of Test for Plastic Limit and Plasticity Index of Soils

A.S.T.M. Designation: D 854-45T--Tentative Method of Test for Specific Gravity of Soils

A.S.T.M. Designation: D 422-39--Standard Method of Mechanical Analysis of Soils.

From the mechanical analyses, the textural classification of the soils were determined by use of the U. S. Bureau of Soils triangular nomograph.

V. ANALYSIS OF DATA

Moisture-Tension Curves and Pressure Membrane Studies

Data taken from the pressure membrane tests at constant temperature have a more uniform basis than the data taken from tests at varying temperatures. Since the 1/3 and 0.8 atmosphere tests were made on the porous plate apparatus in the constant temperature room, the data were used from pressure membrane tests at the corresponding temperature for determining the moisture-tension curves. The data used for these curves are shown in table 3 of the appendix.

The data for the moisture tension curves did not fall in an exact straight line when plotted on log log paper. There appeared to be a definite "sag" from the straight line as can be seen in figures 4, 5 and 6 on the following pages. The "sag" is more pronounced in the lighter textured soils. A straight line is approached more than any other type of curve.

Assuming a straight line, the moisture-tension curves were determined by the method of least squares in the form

$$M = aT^b,$$

where M=moisture content in percent,

T=tension in atmospheres,

a=M intercept at T=1, and

b=the slope of the line.

The slopes of the lines were found to vary from -0.1746 to -0.2586. The slope indicates the amount of moisture which the soil makes available to the plants. The greater the slope, the greater the amount of

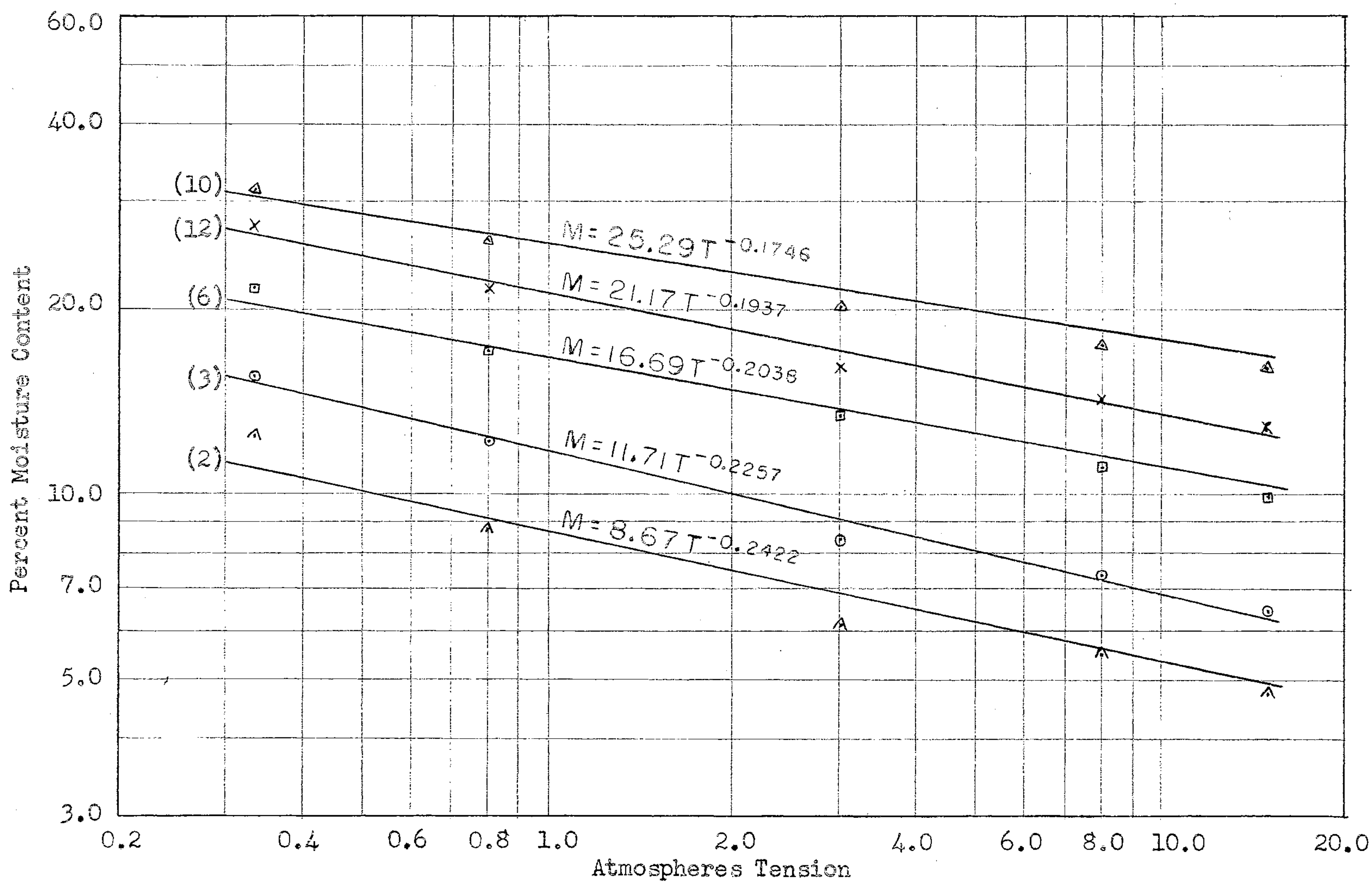

Figure 4. Moisture-tension curves for some Oklahoma irrigated soils. Numbers in parentheses refer to locations in table 5.

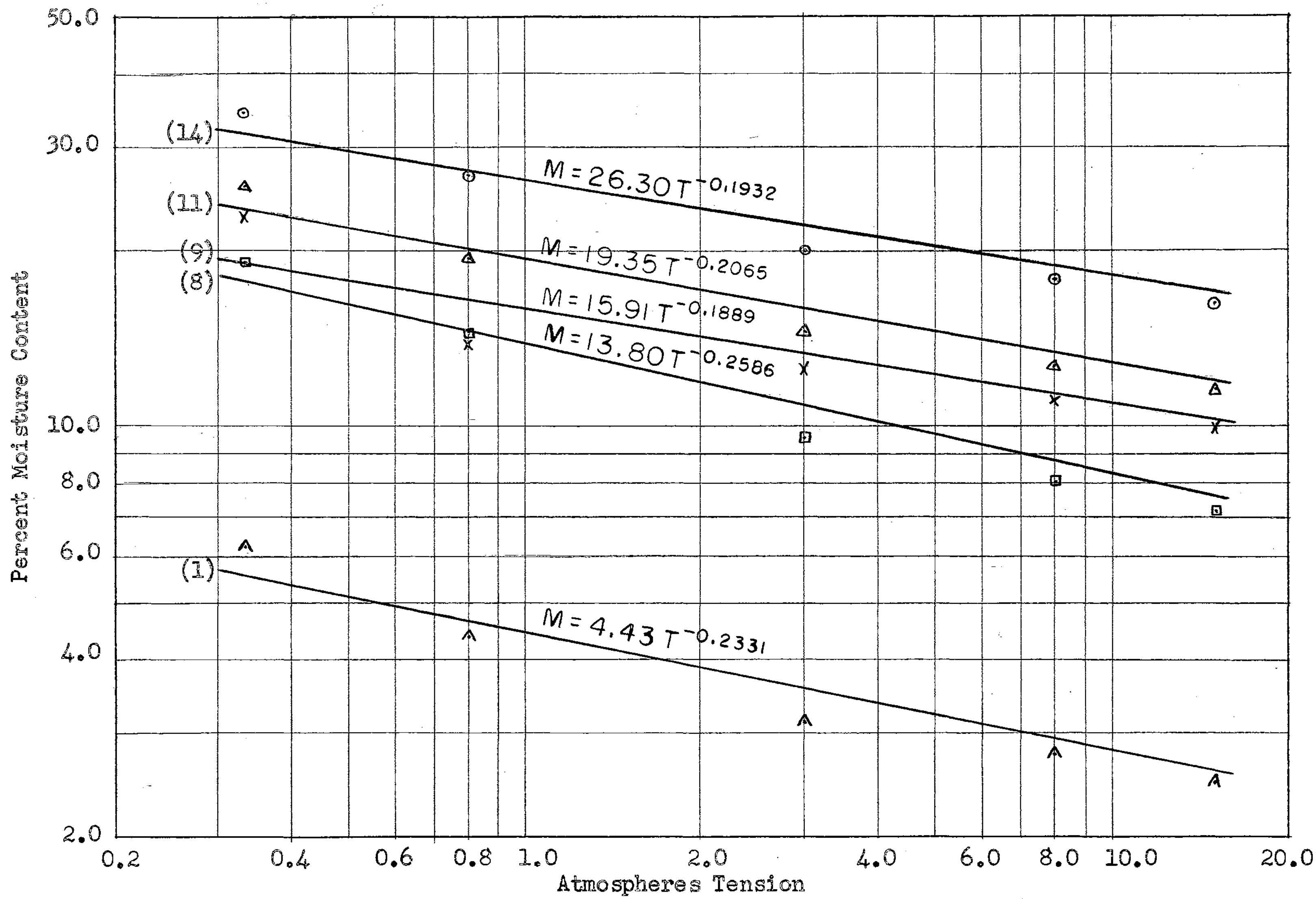

Figure 5. Moisture-tension curves for some Oklahoma irrigated soils. Numbers in parentheses refer to locations in table 5.

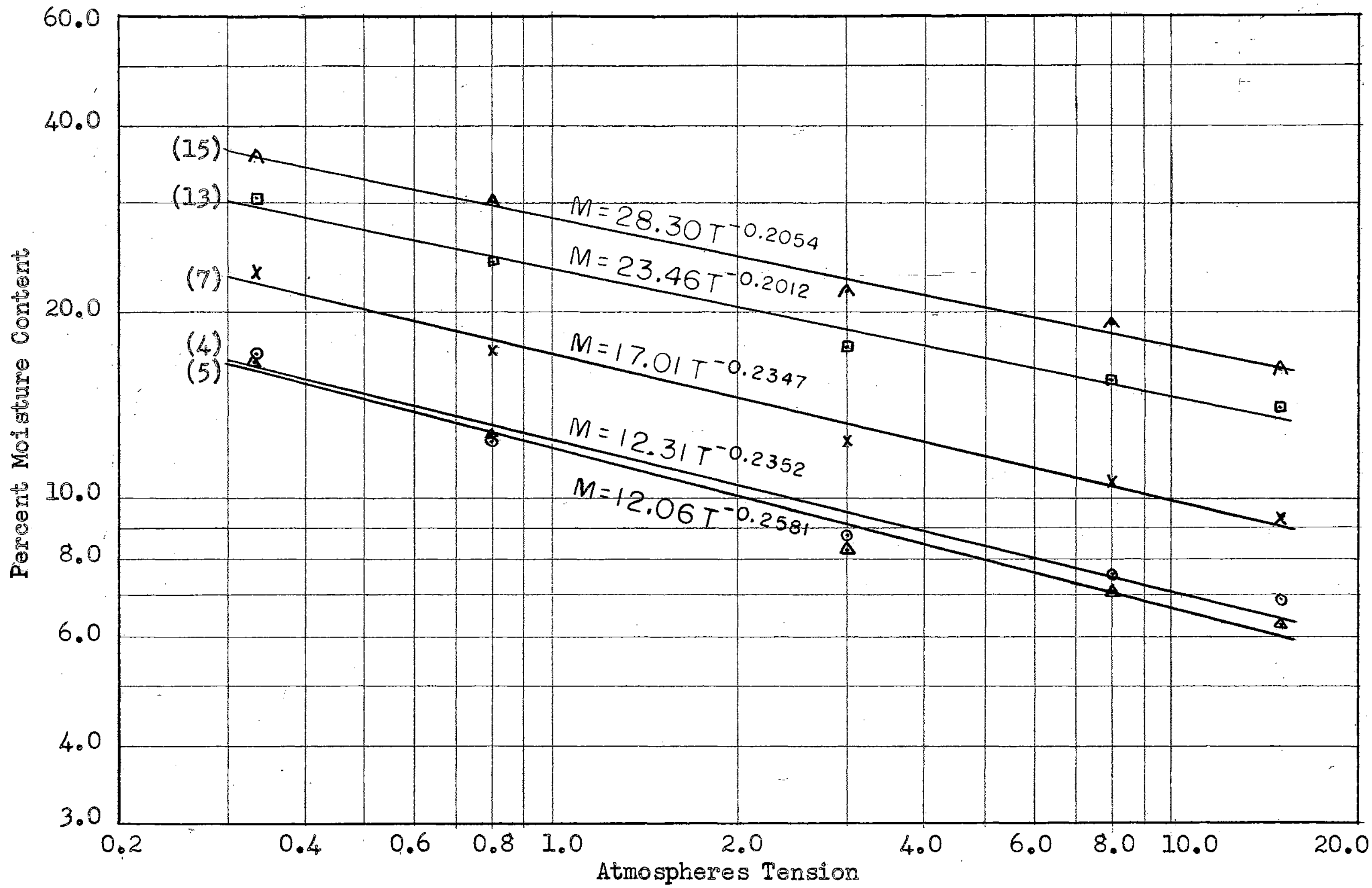

Figure 6. Moisture-tension curves for some Oklahoma irrigated soils. Numbers in parentheses refer to locations in table 5.

available moisture. The sag of the lighter texture soils curves indicate that more of the moisture is available to plants when the moisture content is near field capacity rather than an even distribution throughout the range from field capacity to wilting point.

A study was made of the effect of temperature on the moisture retained by the soil after being subjected to pressure in the apparatus. Data are extremely difficult to duplicate with the pressure membrane apparatus, one reason being due to subsampling error. A statistical analysis was made to determine if the differences between the data were caused by experimental error or by temperature. The analysis showed there was not a significant difference between the data from the constant temperature tests and data from higher temperature tests at 3 atmospheres pressure. However, for 8 and 15 atmospheres there were significant differences caused by temperature. The data for the analysis are shown in table 2 of the appendix. The tabulated data are averages of all the replications.

From the differences found in this study, the per-degree effect of temperature is very small with a differential temperature range of from 15 to 35°F, depending on the temperature when equilibrium was reached. These findings are along the same line as those of Richards and Weaver.

The temperature of the soil changes during the year with the maximum occurring during the summer months. Since water application is more critical during the summer than in the wetter cooler months, the maximum available water holding capacity is desired. On the basis of temperature effects, it appears there would be a difference in moisture content at wilting point under actual field conditions in the summer and in the spring. Therefore, the summer wilting point should be determined, and to do this the temperature of the soil should be used. By making tests at summer soil temperatures, the wilting point determination should be more nearly correct.

Available Water Holding Capacity

The available water holding capacity of the soils tested varied over a considerable range. The capacity of the soils were computed as percentage moisture on a dry weight basis and also depth basis according to the relationship $d=P_{ac}A_sD/100$ with a D of 12 inches since the samples were from the first foot of soil.

The percent available moisture ranged from 3.75% for the sand to 19.37% for the clay. The depth in inches per foot ranged from 0.73 inches to 3.21 inches for the above soils. This is a range of 2.48 inches. The various percentages and depths for all the soils tested are shown in ascending order by textures in table 1 of the appendix.

From this information it can be seen that an inaccurate design of an irrigation system may be made by not knowing the water holding capacity of the soil.

Atterberg Limits

Field operations should not be conducted when the moisture content of the soil is above the moisture content at the plastic limit. Oftentimes soils are compacted due to normal field operations when the soil is too wet. This results in such detrimental effects as decrease in infiltration rate and decrease in water holding capacity by altering the structure of the soil. From the standpoint of ill-effects it is important to know the liquid and plastic limits of irrigated soils.

The purpose of obtaining these limits was to determine if there was a possible correlation between tension and liquid and plastic limits. If such a correlation existed, the limits could be taken from the moisture-tension curve.

In order to determine if a definite relationship existed, the moisture content at the liquid and plastic limits were plotted on the moisture-tension curves. No apparent relation existed between a specific pressure and liquid or plastic limit.

A correlation test was made to determine the relation between moisture content at plastic limit and the 5 micron clay content. The correlation coefficient was very low, 0.352, which indicated there was very little relation between them.

A similar test was made with liquid limit and clay content with a coefficient of 0.870. Although the relationship is not perfect, there is a high degree of correlation between liquid limit and clay content.

Relationship Between Mechanical Analysis and Moisture Characteristics

The structure of the soil is one of the factors that determines the water holding capacity. According to Joffe[1], no structure is possible without a definite quantity of clay, from 8 to 10 per cent. Therefore, there should be some relationship between the clay content of the soil and the moisture characteristics.

Israelsen (11) related the maximum theoretical capillary rise in a tube to the radius of a tube by the expression $h_t = 0.75/r$. The relationship was derived from the expression for surface tension of the

[1]Jacob S. Joffe, Pedology, (New Brunswick, New Jersey, 1949), p. 50

water in a tube. The tension force, acting upward, is opposed by the pull of gravity, acting downward. Therefore, the radius of the tube affects the amount of water that can be held in equilibrium between surface tension and gravity. Applying the relationship to soils in which the tubes are triangular in cross-section, the relative amount of water held by the soil is greater for clay that has small tubes than for sand with large tubes which is borne out in actual tests.

The above correlations indicate there should be a definite relation between the moisture characteristics and the clay content of the soil. A statistical analysis was made to determine the correlation between various moisture characteristics, and between moisture values and clay content.

The U. S. Department of Agriculture definition of clay separates is that fraction less than 0.002 mm. in diameter. The U. S. Bureau of Soils specifies particles less than 0.005 mm. in diameter. The per cent of material with particles smaller than 2 micron diameter and per cent smaller than 5 micron were used to determine which particle size gave the better correlation. As shown in table 4, the correlation coefficient between field capacity and 2 micron particles was 0.920 and 0.953 for 5 micron clay. In order to find where the best relation occurred, analyses were made for 4 and 6 micron particles. The correlation was less at 4 micron than either the 2 or 5, but a coefficient of 0.953 was calculated for the 0.006 mm. size. A check for particles less than 0.0055 mm. showed a relation of 0.954.

Similar analyses were made between wilting point and clay content with correlation coefficients being 0.905, 0.939 and 0.938 for 2, 5 and 6 micron particles respectively. Since there was very little difference in the 0.005 and 0.0055 mm. relations with field capacity, the per cent of material with particles less than 0.005 mm. in diameter was used in determining the relationships after better correlation was found for this size with other moisture characteristics.

By plotting the data as shown in figures 7 and 8, and determining the equations by the method of least squares, the following relationships were derived between field capacity and clay content, and wilting point and clay content:

$$P_{FC} = 5.55 + 0.851 C_{\%} \text{ and}$$

$$P_{WP} = 1.20 + 0.438 C_{\%}.$$

As shown in table 4, the relation between depth of water per foot of soil and clay content is not as high as for field capacity and wilting point, but there is a good correlation, 0.920. The relationship derived from figure 9 was

$$d = 0.94 + 0.063 C_{\%}.$$

A high degree of correlation was found to exist between moisture retained at 1/3 atmosphere and moisture retained at 15 atmospheres, that is, the laboratory determined field capacity and wilting point. The coefficient of correlation was calculated as 0.988. By plotting these values in figure 10 and determining the equation by the method of least squares, the relation of wilting point with respect to field capacity was found to be

$$P_{WP} = -1.80 + 0.517 P_{FC}.$$

Correlation coefficients of other characteristics are shown in table 4, but the relationships were not derived.

The relationship was calculated between moisture equivalent and moisture retained at 15 atmospheres of pressure. The relationship was

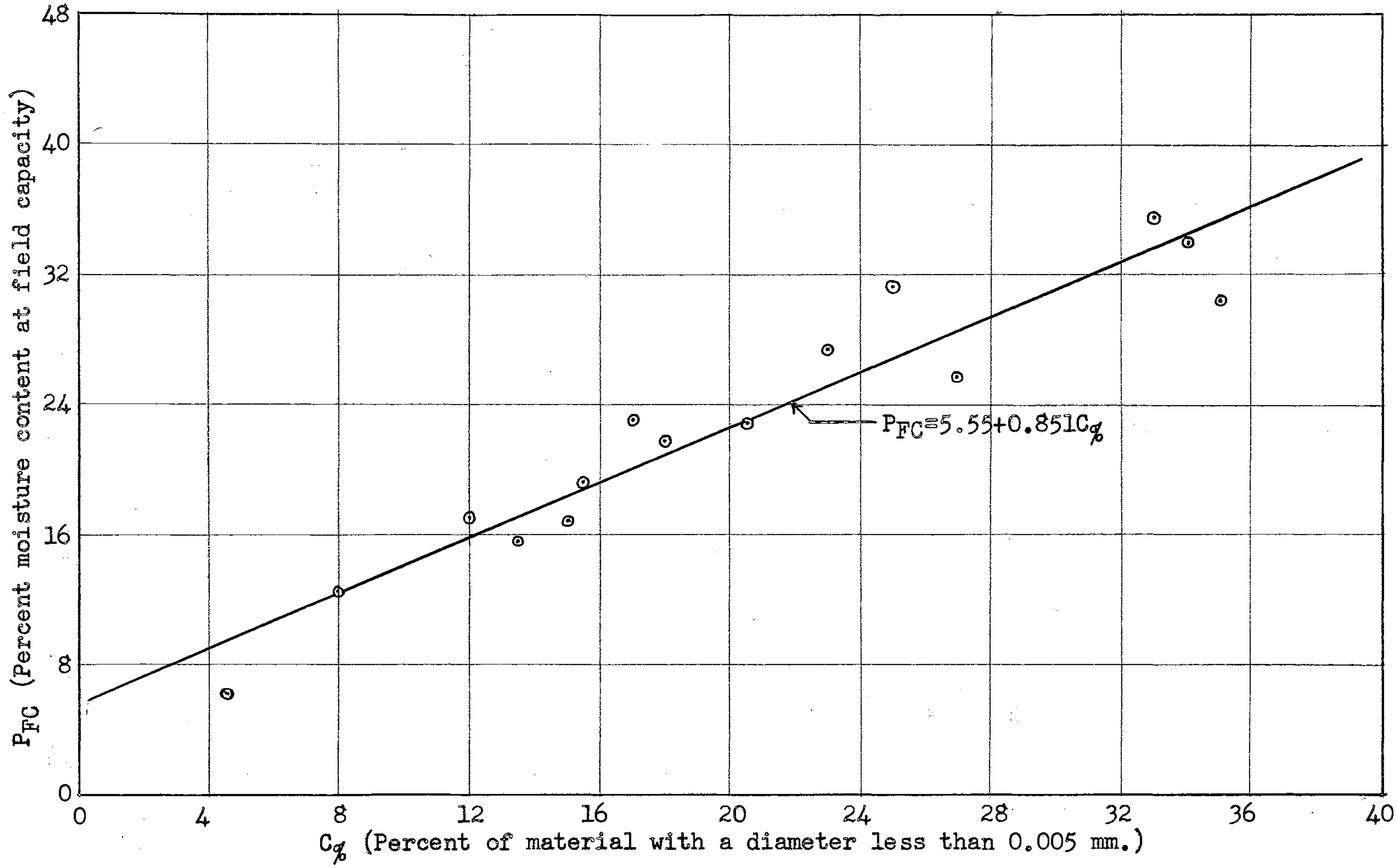

Figure 7. Relationship of field capacity and clay content of some Oklahoma irrigated soils.

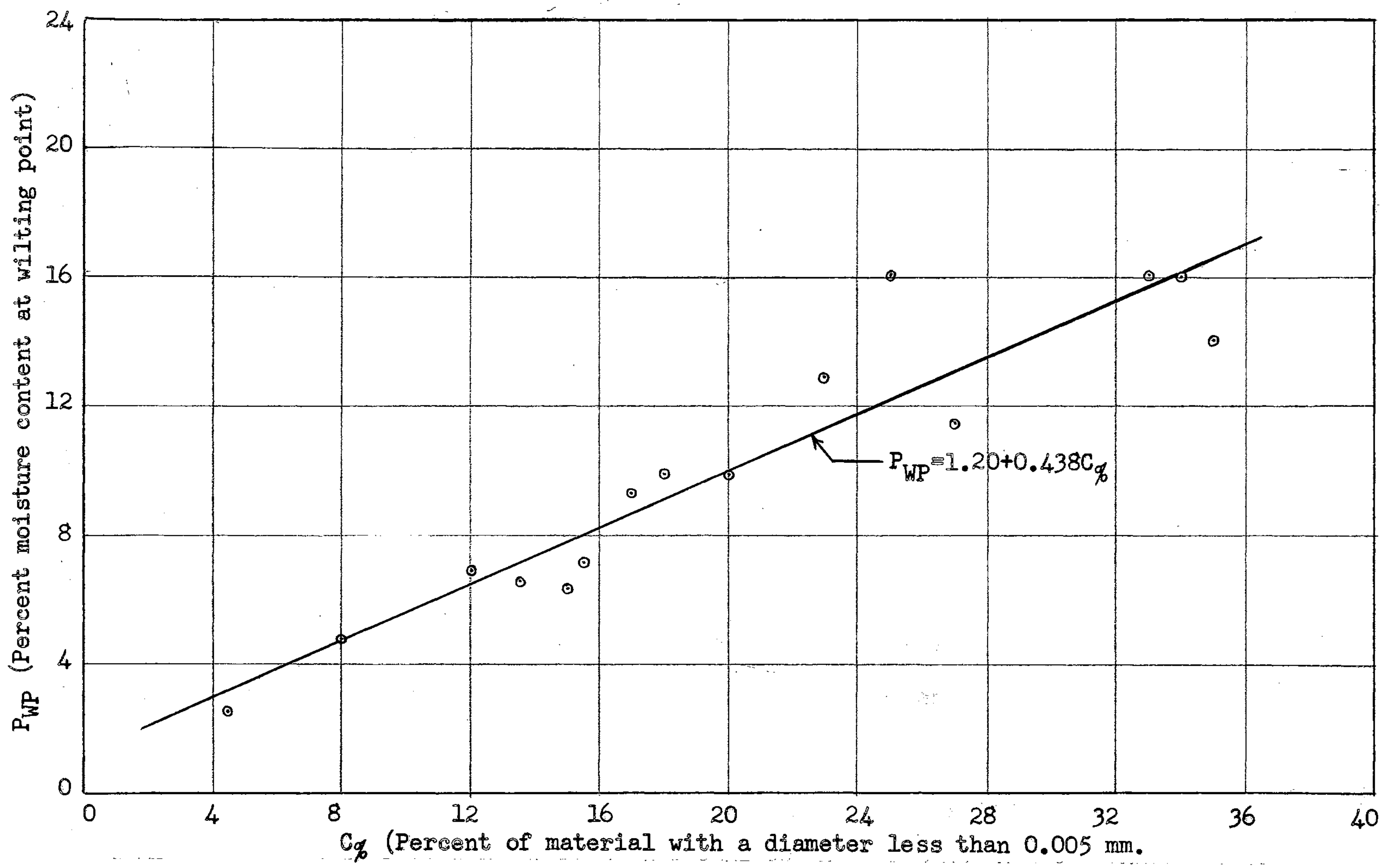

Figure 8. Relationship of wilting point and clay content of some Oklahoma irrigated soils.

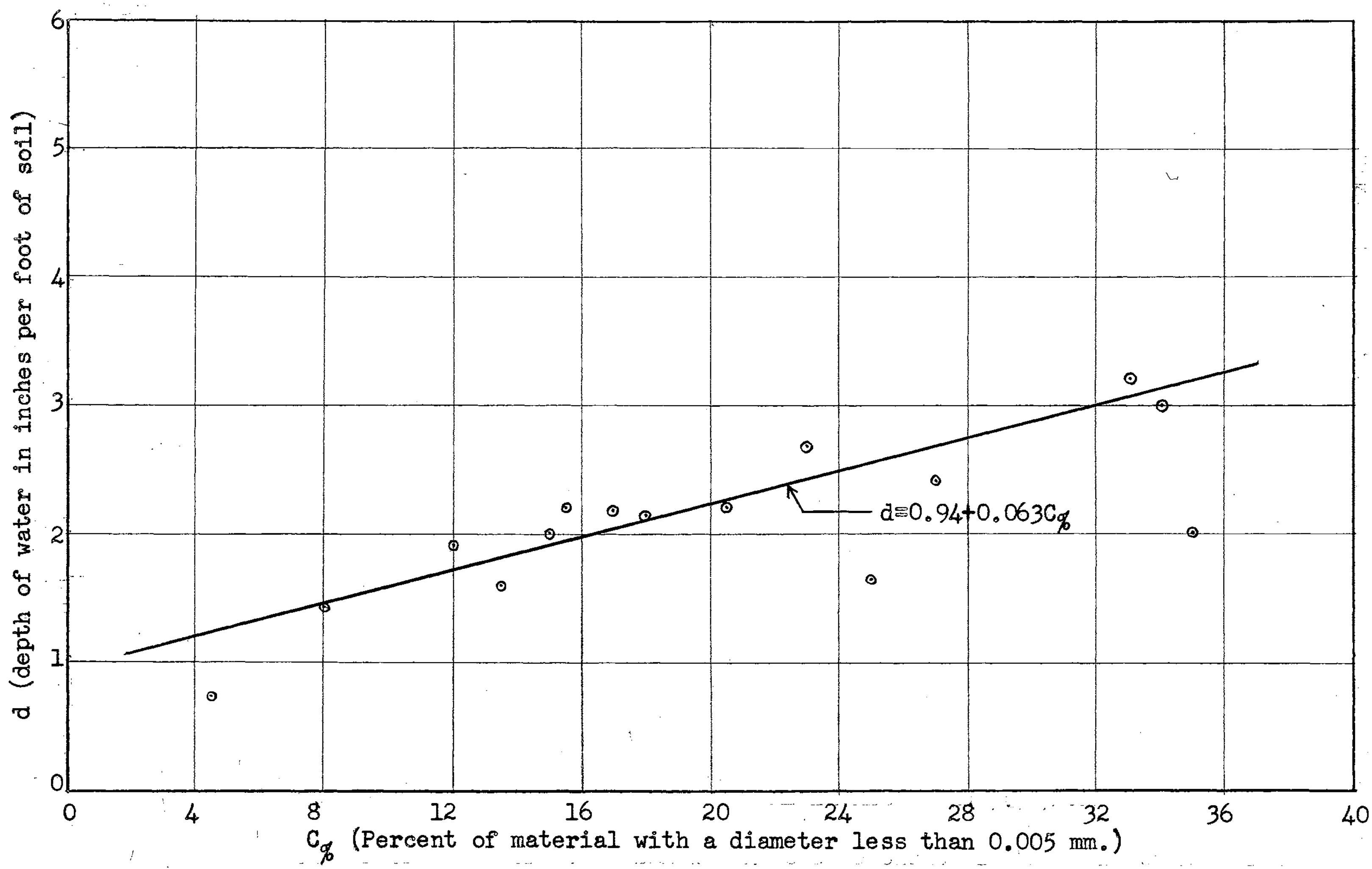

Figure 9. Relationship of depth of available water holding capacity and clay content of some Oklahoma irrigated soils.

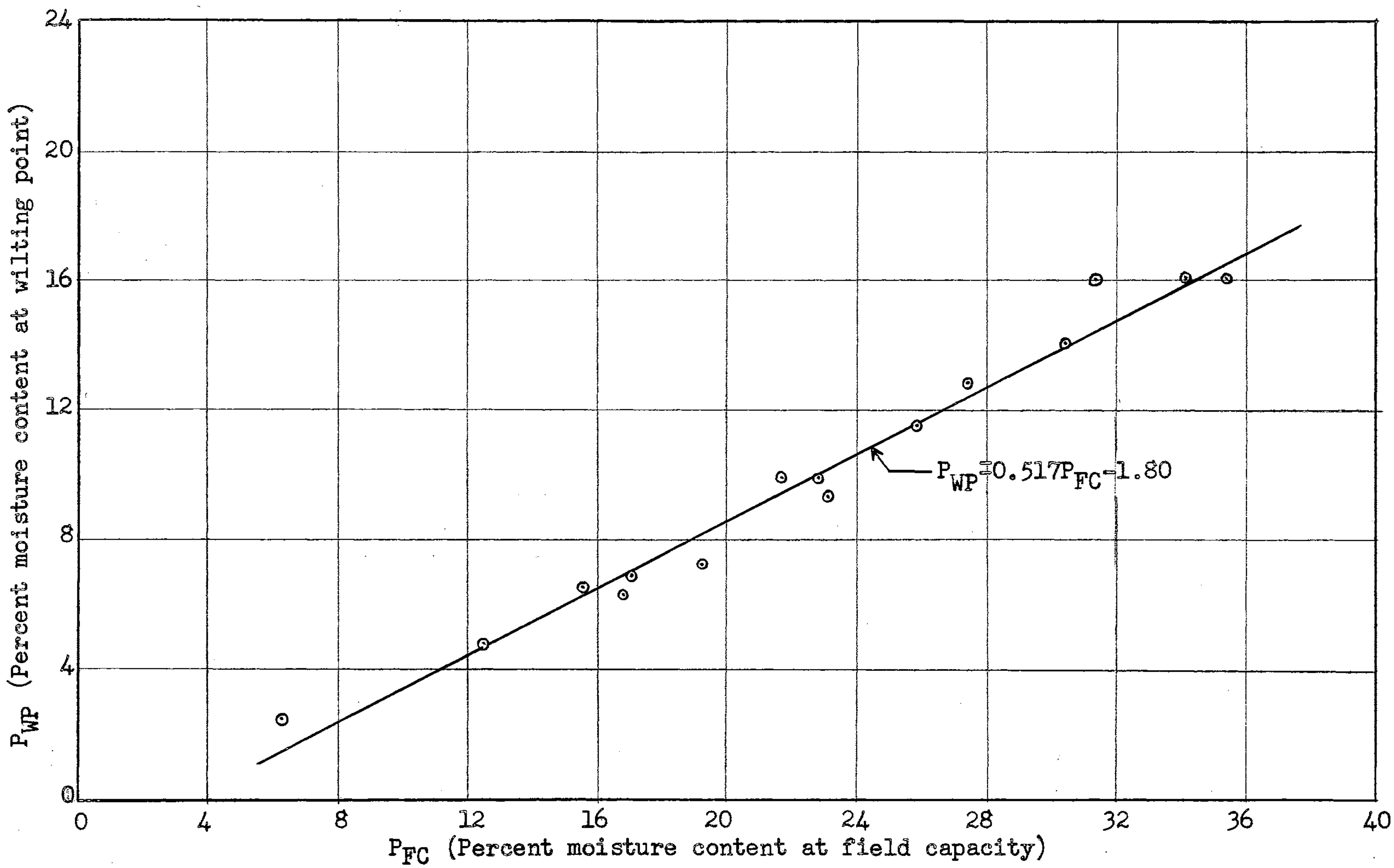

Figure 10. Relationship of wilting point and field capacity of some Oklahoma irrigated soils.

found to be

$$P_{WP} = \frac{M.\ E.}{1.965}\ .$$

This compares closely with Briggs and Shantz's relationship with a constant of 1.84, or a difference of less than 7%. By the least squares method the following expression was developed from figure 11:

$$P_{WP} = 0.666M.E. - 3.08.$$

This relation appears to hold for moisture equivalents above 10%.

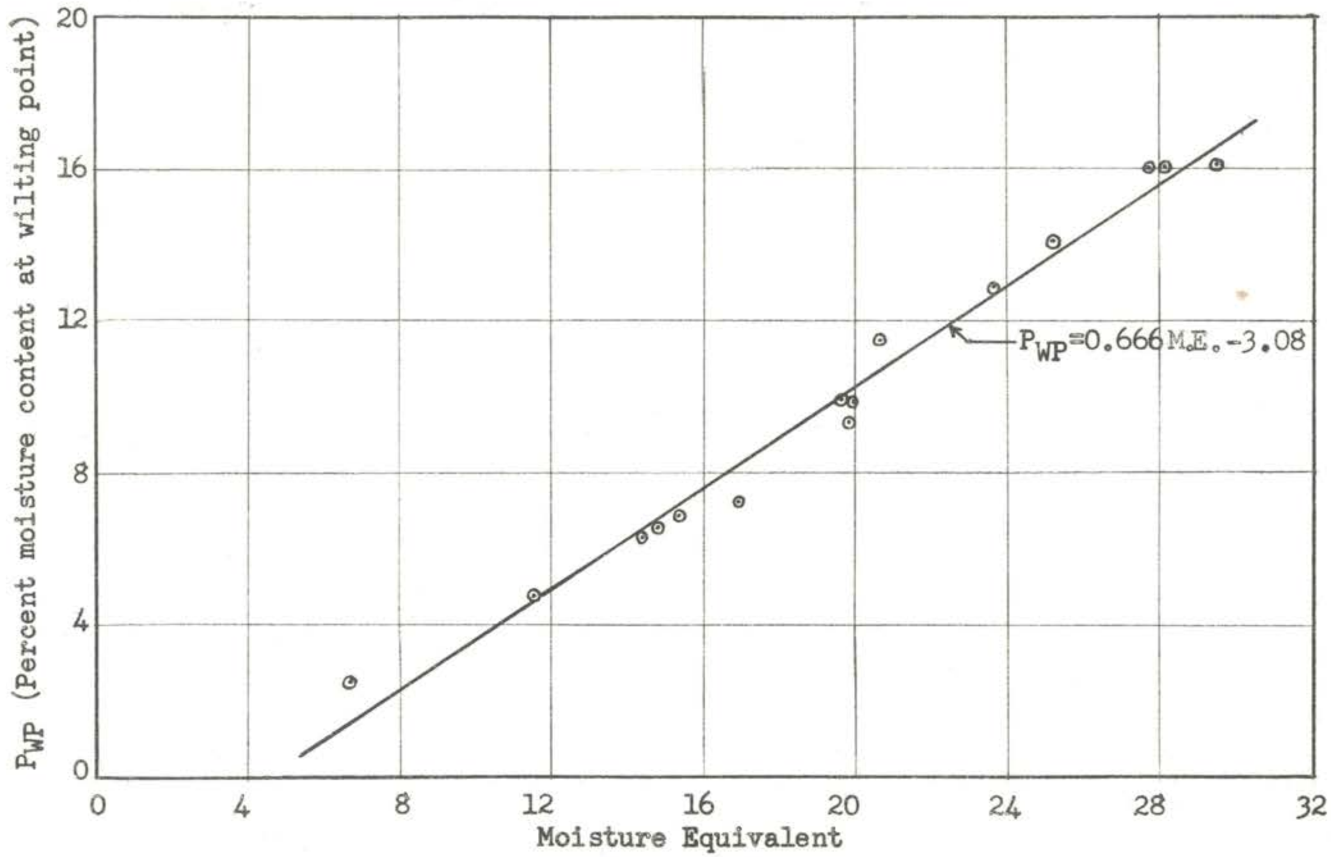

Figure 11. Relationship of wilting point and moisture equivalent of some Oklahoma irrigated soils.

VI. CONCLUSIONS

1. The water holding capacity of the irrigated soils of Oklahoma were found to vary considerably. The ranges for the fifteen soils tested according to textures as compared with values reported by Israelsen are as follows:

Texture	Test Values (Inches)	Reported Values
Sand	0.73	0.50-0.75
Sandy Loam	1.43-2.21	1.25-1.50
Sandy Clay Loam	2.21-2.64	1.25-1.75
Clay Loam	2.41-2.68	1.75-2.25
Clay	2.69-3.21	1.80-2.00

Israelsen also reported a depth of 3.17 inches for an agricultural soil in California. There are many factors that affect the water holding capacity and in order to make an efficient design of an irrigation system, the moisture storage capacity should be determined for the soil in question.

2. The temperature at which the pressure membrane apparatus is operated affects the amount of moisture retained by the soil at 8 and 15 atmospheres tension. There was no effect observed at 3 atmospheres. Using the data taken at constant temperature, moisture-tension curves were drawn and found to be approximately a straight line when plotted on logarithmic paper. The correlation between the slopes of the curves and the clay content was negligible.

3. The liquid and plastic limits were determined for the soils and plotted on the moisture-tension curves. A scatter diagram was obtained and no particular tension could be correlated with the limits. The Atterberg limits were correlated with clay content and a correlation coefficient of 0.352 was found for plastic limit and a coefficient of 0.870 for liquid limit.

4. A high degree of correlation was found to exist between: (1) field capacity and wilting point, (2) field capacity and total pore space, (3) depth of water holding capacity and field capacity, (4) depth and wilting point, (5) depth and pore space, (6) moisture equivalent and field capacity, and (7) moisture equivalent and wilting point. Of these, 1 and 7 are the most important and the relationships derived were:

$$P_{WP} = -1.80 + 0.517 P_{FC} \text{ and}$$

$$P_{WP} = 0.666 M.E. - 3.08.$$

5. Correlations were made between soil moisture characteristics and the mechanical analysis. The highest degree of correlation was found to exist between the moisture characteristics and the percent of clay less than 0.005 mm. in diameter. The following relationships were derived:

$$d = 0.94 + 0.063 C_{\%},$$

$$P_{FC} = 5.55 + 0.851 C_{\%},$$

$$P_{WP} = 1.20 + 0.438 C_{\%}.$$

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APPENDIX

Table 1. Moisture characteristics, apparent specific gravity, clay content and pore space for some Oklahoma irrigated soils.

Soil No.	Textural Classification	P_{FC} (%)	P_{WP} (%)	P_{ac} (%)	d (in)	S (%)	A_s	Clay (% < 0.005)	W_P (%)	W_L (%)	M.E.
1	Sand	6.24	2.49	3.75	0.73	39.0	1.61	4.5	-----	17.90	6.64
2	Sandy Loam	12.50	4.78	7.72	1.43	41.0	1.54	8.0	-----	21.50	11.50
3	Sandy Loam	15.57	6.57	9.00	1.58	44.0	1.46	13.5	-----	23.00	14.79
4	Sandy Loam	17.02	6.86	10.26	1.91	40.6	1.55	12.0	-----	25.00	15.34
5	Sandy Loam	16.80	6.30	10.50	2.02	39.3	1.60	15.0	-----	20.60	14.38
6	Sandy Loam	21.72	9.92	11.80	2.14	42.5	1.51	18.0	-----	29.00	19.63
7	Sandy Loam	23.11	9.30	13.81	2.17	49.9	1.31	17.0	-----	29.00	19.79
8	Sandy Loam	19.19	7.18	12.01	2.21	41.8	1.53	15.5	-----	25.20	16.96
9	Sandy Clay Loam	22.81	9.86	12.95	2.21	45.4	1.42	20.5	15.35	29.80	19.88
10	Sandy Clay Loam	31.34	16.04	15.30	2.64	43.7	1.44	25.0	24.34	43.90	27.66
11	Clay Loam	25.83	11.47	14.36	2.41	46.8	1.40	27.0	15.38	28.20	21.60
12	Clay Loam	27.43	12.85	14.48	2.68	40.7	1.53	23.0	17.50	35.50	23.60
13	Clay	30.43	14.08	15.57	2.69	43.7	1.44	35.0	19.28	37.60	25.17
14	Clay	34.04	16.06	17.98	3.02	46.3	1.41	34.0	18.72	41.40	28.04
15	Clay	35.43	16.06	19.37	3.21	46.9	1.38	33.0	20.62	43.60	29.43

Table 2. Temperature effect of pressure membrane apparatus tests of some irrigated soils of Oklahoma.

Soil No.	Pressure (Atmos.) Temp. °F	Percent Moisture Retained by Soil					
		3		8		15	
		65	80-100	65	80-100	65	80-100
1		3.13	3.08	2.77	2.65	2.49	2.37
2		6.16	6.12	5.52	5.06	4.78	4.56
3		8.54	8.87	7.40	7.16	6.57	6.43
4		8.77	8.29	7.60	6.60	6.86	5.92
5		8.33	8.02	7.08	6.44	6.30	6.14
6		12.52	11.61	11.05	9.62	9.92	8.99
7		12.30	12.57	10.61	10.11	9.30	9.06
8		9.60	9.69	8.09	7.45	7.18	6.92
9		12.51	13.65	11.11	11.02	9.86	9.80
10		20.26	20.83	17.65	17.66	16.04	15.97
11		14.44	13.99	12.76	11.38	11.47	10.08
12		16.21	16.18	13.35	13.48	12.85	11.82
13		17.56	18.20	15.55	14.72	14.08	13.33
14		19.96	21.71	17.87	17.35	16.06	15.51
15		21.70	20.98	19.11	16.90	16.06	16.15

Table 3. Moisture-tension data at constant temperature for some irrigated soils of Oklahoma.

Soil No.	Atmos. Tension	Percent Moisture Content				
		1/3*	0.8*	3+	8+	15+
1		6.24	4.36	3.13	2.77	2.49
2		12.50	8.76	6.16	5.52	4.78
3		15.57	12.18	8.54	7.40	6.57
4		17.02	12.41	8.77	7.60	6.86
5		16.80	12.59	8.33	7.08	6.30
6		21.72	17.14	12.52	11.05	9.92
7		23.11	17.42	12.30	10.61	9.30
8		19.19	14.40	9.60	8.09	7.18
9		22.81	13.78	12.51	11.11	9.86
10		31.34	26.00	20.26	17.65	16.04
11		25.83	19.32	14.44	12.76	11.47
12		27.43	21.45	16.21	14.35	12.85
13		30.43	24.15	17.56	15.55	14.08
14		34.04	26.75	19.96	17.87	16.06
15		35.43	30.11	21.70	19.11	16.06

*Ceramic plate apparatus

+Pressure membrane apparatus

Table 4. Coefficients of correlation between various properties of some irrigated soils of Oklahoma.

Related Properties	Correlation Coefficient
P_{FC} & P_{WP}	0.988
P_{FC} & S%	0.951
P_{FC} & C% $\leqslant$ .005 mm.	0.953
P_{FC} & C% $\leqslant$ .0055 mm.	0.954
P_{FC} & C% $\leqslant$ .006 mm.	0.953
P_{FC} & C% $\leqslant$ .002 mm.	0.918
P_{FC} & A_s	-0.562
P_{WP} & S%	0.636
P_{WP} & C% $\leqslant$ .005 mm.	0.939
P_{WP} & C% $\leqslant$ .006 mm.	0.938
P_{WP} & C% $\leqslant$ .002 mm.	0.905
P_{WP} & A_s	-0.640
d & P_{FC}	0.973
d & P_{WP}	0.935
d & S%	0.982
d & C% $\leqslant$ .005 mm.	0.920
d & C% $\leqslant$ .006 mm.	0.921
d & C% $\leqslant$ .002 mm.	0.765
M. E. & P_{FC}	0.995
M. E. & P_{WP}	0.997
W_P & C% $\leqslant$ .005 mm.	0.352
W_L & C% $\leqslant$ .005 mm.	0.870
d & S%, C% $\leqslant$ .005 mm.	0.922

Table 5. Soil numbers and corresponding land owners or operators and state locations of the irrigated soils tested.

Soil No.	Owner or Operator	State Location
1	Bill Kenyon	S. of Dover
2	Horticulture Experiment Station	N. E. of Blair
3	August Mueller	N. W. of Hooker
4	Ft. Reno Experiment Station (Irr. Corn)	N. W. of El Reno
5	Herman Watts	N. of Martha
6	Gordon Thomas	S. E. of Altus
7	Frank Hefner	S. W. of Altus
8	Cotton Research Experiment Station	E. of Chickasha
9	Bryce Henderson	N. of Altus
10	Alonzo Philippe	S. of Guymon
11	Irrigation Experiment Station	S. of Altus
12	Elmo Jones	S. W. of Goodwell
13	Ft. Reno Experiment Station (Alfalfa)	N. W. of El Reno
14	Panhandle A & M College	E. of Goodwell
15	Ft. Reno Experiment Station (Irr. Grass)	N. W. of El Reno

Table 6. Definitions of symbols used.

P_{FC}	Percent moisture content on a dry weight basis at field capacity.
P_{WP}	Percent moisture content on a dry weight basis at wilting point.
S%	Percent total pore space.
C%	Percent clay.
A_s	Apparent specific gravity.
d	Depth of water in inches.
D	Depth of soil in inches.
W_L	Percent moisture content on a dry weight basis at the liquid limit.
W_P	Percent moisture content on a dry weight basis at the plastic limit.
M.E.	Moisture equivalent.

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