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RESEARCH REPORT

No. 363

A DESCRIPTION OF METHODS USED IN THE CORN BELT BRANCH FOR EVALUATING TILLAGE PRACTICES

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A DESCRIPTION OF METHODS USED IN THE CORN BELT BRANCH FOR EVALUATING TILLAGE PRACTICES[1]

R. E. Burwell, R. R. Allmaras and M. Amemiya[2]

INTRODUCTION

Some of the present concepts concerning the evaluation of tillage practices in the Corn Belt are presented by Larson[3]. Briefly, the concepts are based on an analysis of a field of row-cropped corn. The field is divided into two zones; (a) the zone between the rows where water management is the chief concern, and (b) the zone in the corn row where management is directed toward providing soil conditions optimum for germination and early growth of corn. Consequently, the required soil conditions resulting from tillage would not necessarily be the same in both zones.

This report deals primarily with the measurement of soil physical characteristics in the area between the rows. Some of the objectives and measurements at hand have been presented earlier[4], but the measurement procedure is given in more detail in this report. Other measurements considered herein either by reference or discussion are weight of surface residues, percent surface cover of residue, soil and air temperature, and secondary aggregate size.

1/ Contribution from the Corn Belt Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Iowa Agricultural and Home Economics Experiment Station and Minnesota Agricultural Experiment Station.

2/ Research Soil Scientists, USDA, Morris, Minnesota and Ames, Iowa

3/ Larson, W. E. Tillage requirements for corn. J. Soil & Water Cons. 17:3-7. 1962.
Larson, W. E. Soil parameters for evaluating tillage needs and operations. Soil Sci. Soc. Am. Proc. (In press).

4/ Burwell, R. E., Allmaras, R. R. and Amemiya, M. A field measurement of total porosity and surface micro-relief of soils. Soil Sci. Soc. Am. Proc. (In press).

PLOW LAYER POROSITY AND SURFACE ROUGHNESS

Plow layer porosity and surface roughness are measurements of characteristics of the soil physical condition between the rows.

When a soil layer of a given total porosity and thickness is loosened or consolidated by a tillage operation, the total porosity and thickness may be changed. Any changes in the thickness of this layer will change the volume of water and air that the layer may hold. Hence, changes in thickness and total porosity of a plowed layer will bring about differences in the amount of water it can contain.

The surface roughness measurement may be used to describe the depression storage in the soil surface as well as the resistance of the surface to factors that tend to disperse secondary aggregates. In general, the roughness of the soil surface may be divided into two types. In the first type, an oriented roughness is produced by tillage implements. Illustrations of this roughness are ridges and furrows commonly occurring in ridge and lister planting. Other examples are variations in surface relief created by variation among plow furrow-slices, or by discing and cultivating operations. The orientation with respect to slope and the volume of the depressions will affect the amount of water detained. The second type of roughness is merely a random roughness of the surface.

In general, the essential requirements for estimating these two characteristics of the inter-row area are (1) a description of the micro-relief of the surface in question, and (2) an estimate of the bulk density of the plow layer. Many modifications of equipment may be used to make these estimates. Different modifications are presently being used in Minnesota, Iowa and Wisconsin. The method as described has given reasonably accurate estimates of plow-layer porosity and surface roughness.

Procedure of Measurement

Measurements of plow layer porosity and surface roughness are made with the following equipment:

1. Uhland-type core sampler.
2. Engineers' level.
3. Philadelphia rod.
4. A point-quadrant device such as illustrated in Figures 1, 2 and 3.
5. Reference bench-mark set below depth of frost or zone of soil swelling and shrinkage.

The Micro-Relief Meter

The point quadrant device (micro-relief meter) shown in Figures 1 and 2 is an essential part of the equipment. The construction details are shown in Figure 4 for a meter designed for 40-inch spacing of rows. The dimensions may easily be altered prior to construction for experimental use where other row spacings or physical layout of experiments necessitate changes.

The micro-relief meter consists of three essential parts: (a) the scale board and measuring pins, (b) the scale board support frame and (c) the support (steel rods, 5/8-inch diameter and 18 inches long) pins. During the measurement operation, the scale board support frame is maintained in a fixed position on the four support pins. The scale board and measuring pins constitute a single unit, which moves over the scale board support-frame. The starting position is illustrated in Figure 1. Twenty measuring pins spaced 2 inches apart are supported by pin guides attached to the scale board.

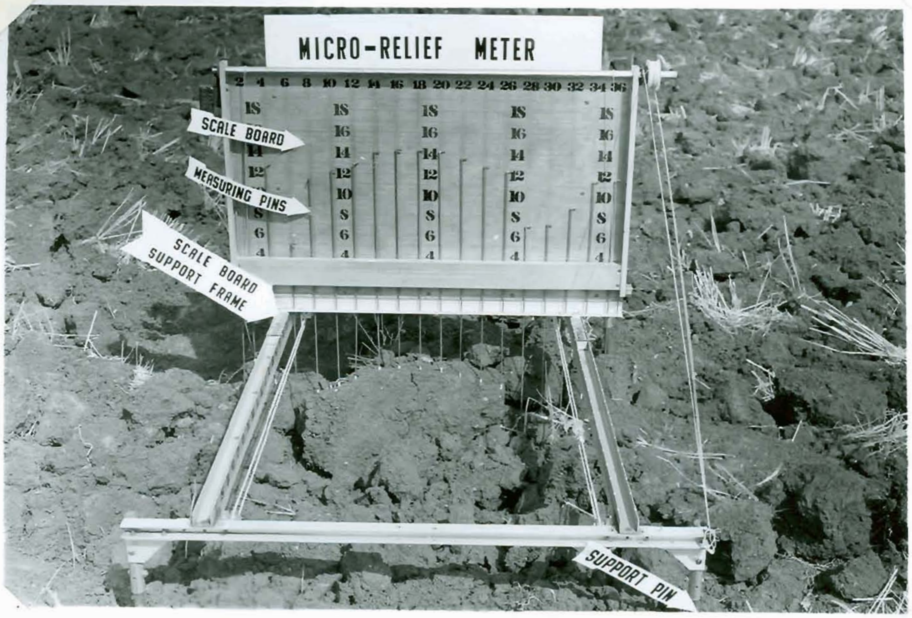

Figure 1.--Micro-relief meter in field measuring position.

Figure 2.--Micro-relief meter showing support pins and support pin guide.

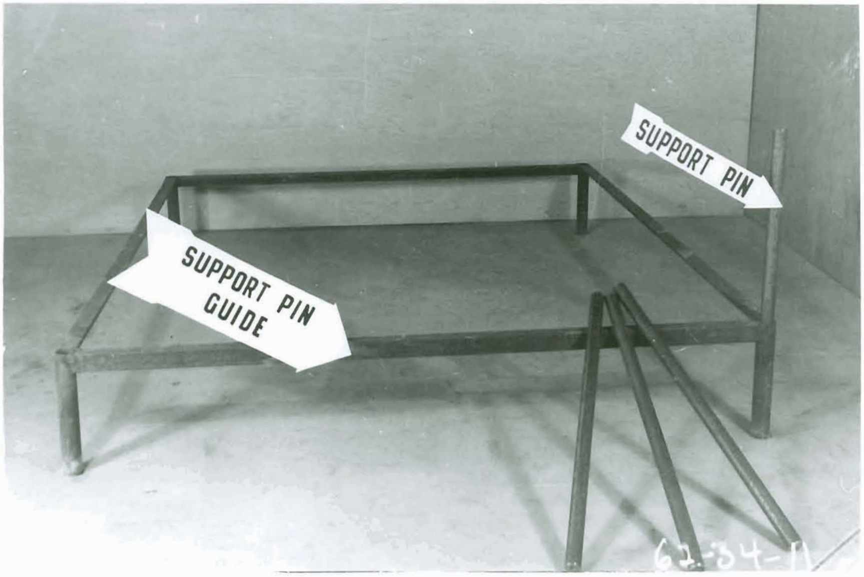

Figure 3.--Support pin guide for setting support pins.

When these measuring pins are resting on the soil surface, heights at the top of the pins are read to the nearest 0.1 inch on the scale board. The measuring pins are raised, the scale board and measuring pins unit is moved 2 inches horizontally on the scale board support frame, the measuring pins are lowered, and height readings are observed. Such a procedure is continued until 20 measurements are made at each of the 20 positions of the scale board and measuring pins unit on the scale board support frame. Thus, 400 height readings can be obtained on a 2- by 2-inch grid over a 40- by 40-inch area between rows spaced 40 inches apart.

Placing the Support Pins

The location and placement of the support pins depends on the physical layout of the field experiment and convenience for tillage operations. The following procedure was suitable for a particular physical layout of tillage experiments. Reference bench-marks (used for the alignment and elevation setting of the support pins) are located in accessible border areas and are protected from disturbance. They should also be deep enough to prevent vertical displacement from freezing and thawing. Alignment of 2 or more reference bench-marks parallel to the long side of the plots provides an axis for locating the support pins along a line perpendicular to the long side of the plot.

An engineers' level is plumbed over one of the reference bench-marks and the telescope is aligned over the other reference bench-marks on the same side of the experiment. The telescope is than turned 90° from the line of sight made up by the reference bench-marks. The micro-relief support pin guide is placed on the plot of interest in a manner such that 2 corners are in the line of sight and a specified distance from the reference bench-marks. This distance is specified to place the support pins in the crop row. The four support pins are then placed into the guide and driven firmly in place, and the guide is removed. Rod readings of the ground elevation at each pin are made, and the pin having the highest ground elevation is driven into the soil until the top of the pin is 6 inches above the surface. The three remaining pins are leveled to the first pin. This elevation is determined and recorded for future use.

After the initial height readings are made with the micro-relief meter as described above, the support pins can be removed, and tillage and planting operations performed. The support pins are then replaced to the same elevation plane as the initial setting using the procedure described above for their initial placement prior to tillage, and they may remain in this position throughout the remainder of the season. The elevation of the pins should be determined again and recorded before height measurements are made. This procedure permits adjustment of heights (obtained with the micro-relief meter) when the support pin height may differ from that in the initial placement. Height readings are thus made with the micro-relief meter, and may be made at any subsequent time.

Measurement of Initial Porosity

Prior to tillage and concurrent with the first height readings of the micro-relief meter, bulk density determinations are made from undisturbed cores taken with a Uhland-type core sampler[5/]. The length of the core is

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5/ Uhland, R. E. Physical properties of soils as modified by crops and management. Soil Sci. Soc. Am. Proc. 14:361-366. 1949.

equal to the depth to which the tillage is to be performed. In a system where the pre-plant tillage involves plowing to a 6-inch depth, the 0- to 6-inch surface layer may be sampled in 3-inch increments by use of a 3-inch Uhland core sampler. Under the conditions of experiments already performed, 3 cores were randomly taken from a plot 40 feet long and 20 feet wide. Where there were 24 plots the coefficient of variation of the mean bulk density was in the order of 2 percent. For an absolute estimate of plow layer porosity, these measurements must be made at some time during the conduct of the experiment. Conditions are generally most favorable for sampling uniformity when the soil is untilled.

Orientation of Records of Height Readings

The starting position of the micro-relief meter in the field is illustrated in Figure 1. The measuring pins are gently lowered by a reel arrangement that lowers the upper pin guide bar. The height measurements are read and recorded from left to right (i.e., 20 readings). The pins are raised, the scale board and measuring pins unit is moved forward toward the observer 2 inches (Figure 1), the pins are lowered, and the heights are recorded on a new line from left to right. This procedure is continued until 20 rows of heights (each having 20 readings) are recorded. Thus, the rows of height readings will each extend in a direction perpendicular to the rows in the field, and the columns of height readings will each extend parallel to the rows in the field. Consistency of orientation of records is needed for making the surface roughness computations.

Parameters of Soil Condition

Plow Layer Porosity

From the undisturbed cores obtained before tillage, the porosity, P_i, for the layer to be tilled is calculated as follows:

$$P_i = \frac{2.65 - D_b}{2.65} \times W \ldots\ldots\ldots\ldots (1)$$

where D_b is the average bulk density in gms. cm.$^{-3}$ obtained from undisturbed cores, and W is the thickness of the sampled layer in inches. (In the case where plowing is 6 inches deep W is 6 inches.)

For any arbitrary time, t_a, at which micro-relief readings are taken, the plow layer porosity in "inches per initial thickness of layer" can be computed. The average height of the measuring pins at a single setting ot the scale board support frame before tillage and at the time the undisturbed cores are taken is computed as:

$$\bar{h}_i = \frac{1}{n} \sum_{i=1}^{n} h_i \ldots\ldots\ldots\ldots (2)$$

where h_i is the individual height reading in inches taken before tillage, and n is the number of readings. (There are 400 readings where the micro-relief meter has the design illustrated in Figures 1 through 4.)

The average height of the measuring pins at a single setting of the scale board support frame taken at a later time, t_a, is:

$$\bar{h}_a = \frac{1}{n} \sum_{a=1}^{n} h_a \ldots\ldots\ldots\ldots (3)$$

where h_a is the individual height reading in inches taken at time, t_a.

The plow layer porosity in "inches per initial thickness of layer" at time, t_a, is given by:

$$P_a = P_i + \bar{h}_a - \bar{h}_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

From measurements performed on replications of the same treatment, the standard error of P_a was approximately 0.28 inch, but differences between tillage treatment averages were in the order of 1.0 inch with a standard error of the difference approximately equal to 0.24 inch[4].

Random Roughness

Although an estimate of random roughness may be used for many purposes, the estimate is presently being evaluated as an index of short term depression storage in the soil surface. Its utility applies in all tillage systems, but particularly where there are only minor oriented tool marks. Such surfaces are created in wheel-track and conventional planting operations in the Corn Belt. Its computation is cumbersome, but is being made with a high speed computer. The index is the standard error among logarithm of heights that have been adjusted for tillage tool marks extending in a direction parallel to the row[4]. From the estimates at hand, differences among treatments are large relative to the differences among replications of the same treatment[4]. Work is underway to relate random roughness to depression storage of water.

Roughness due to Oriented Tillage Tool Marks

When a tillage system such as ridge or lister planting is oriented on the contour, estimates of roughness due to oriented tillage tool marks may be used as an index of potential depression storage. If the data from the micro-relief meter is oriented as discussed in section "Orientation of Records of Height Readings", the diagram of Figure 5 illustrates the order of the data relative to the position in the field from which the data were taken. When the tillage tool marks are parallel to the rows of corn, a description of the average heights may be obtained as in Figure 6. The average for column 1 would be obtained as follows:

$$\bar{c}_j = \frac{1}{k}\sum_{i=1}^{k} h_{ij} \quad ; \quad j = 1 \ldots\ldots (5)$$

where the index $i = 1, 2, \ldots, k$ indexes over rows of the tabulated array of data, j is 1 for column 1, and h_{ij} is the recorded height reading. (In Figure 5, k takes on the value 20.)

Three areas may be distinguished in Figure 6. They are: A_t = ABDF, A_s = AEGF, and $A_w = A_t - A_s$. The $\bar{c}_{max.}$ of Figure 6 is obtained by the use of equation 5, and is an index of the height that will prevent water flow to the left or right off the cross section illustrated by Figure 6. By the use of the trapezoid rule A_s may be estimated as:

$$A_s = 2(\bar{c}_1 + \bar{c}_2 + \bar{c}_3 + \ldots + \bar{c}_k) - (\bar{c}_1 + \bar{c}_k) \ldots\ldots (6)$$

When it is assumed that inter-row areas to the right and left of the diagram of Figure 6 have a $\bar{c}_{max.}' \geq \bar{c}_{max.}$, all of the area, $A_w = A_t - A_s$, will be a depression storage area. Moreover, A_t can be estimated as $2k\,\bar{c}_{max.}$. Thus, the depth of water detention is:

$$D_w = \frac{A_t - A_s}{2k} \ldots\ldots (7)$$

where $2k$ is equal to 40 in Figure 5, because there are 20 columns of readings each spaced 2 inches apart in the left to right direction.

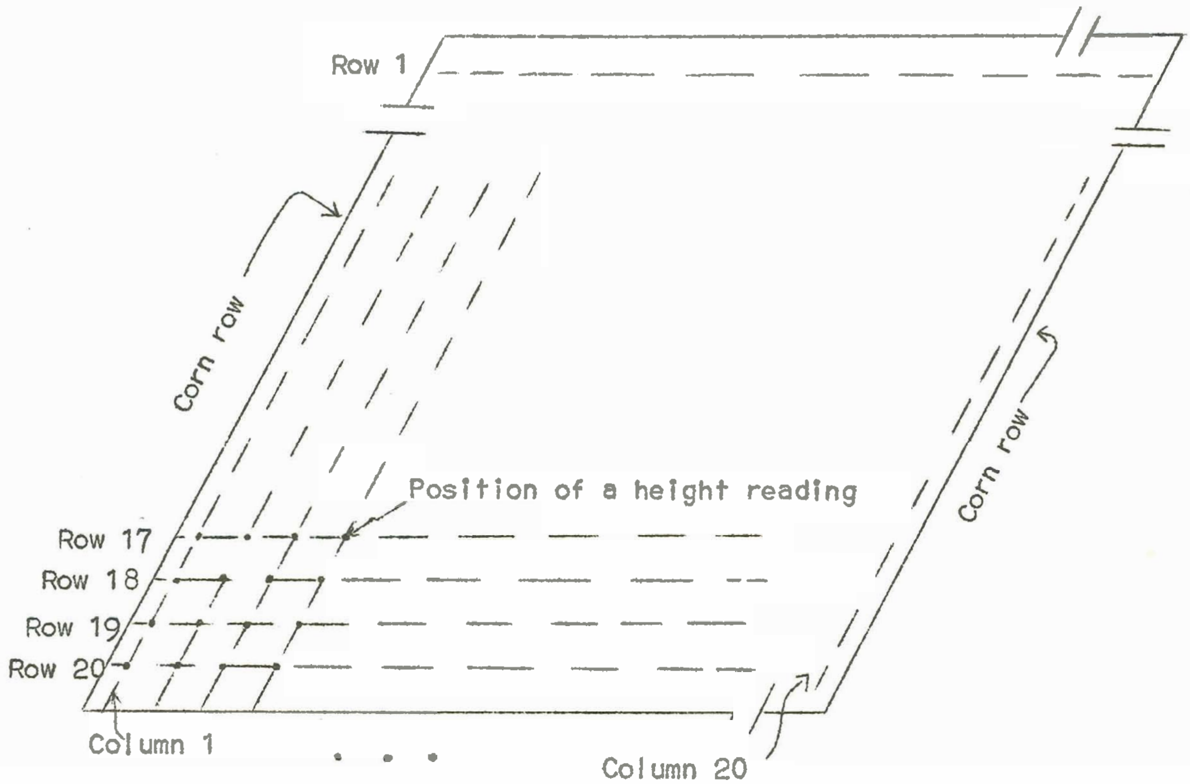

Figure 5.--Illustration of the measured points in a field of 40-inch spaced rows and their relation to the tabulated array of height readings.

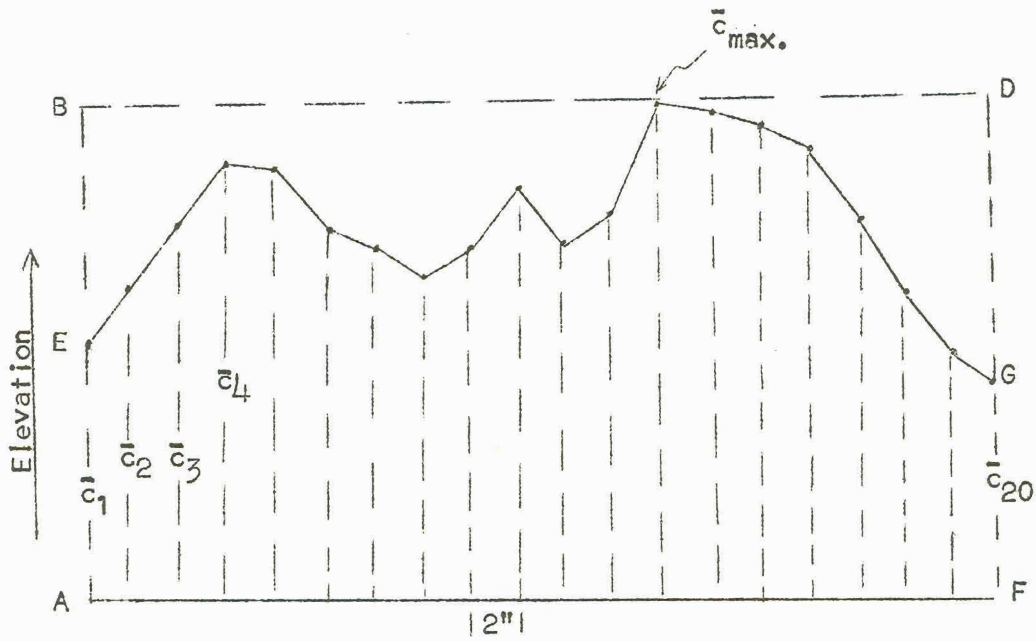

Figure 6.--Outline of a distribution of average heights due to tillage tool marks.

Preliminary results have given depression storage estimates as great as 3.0 inches for ridge and lister planting systems on nearly zero slopes. Further calibration of this index of depression storage of water may reveal that the $\bar{c}_{max.}$ can be estimated more accurately.

Effect of Slope on Parameters of Soil Condition

The slope of the land surface probably does not significantly affect the estimation and significance of the plow layer porosity and random roughness parameters discussed. The slope, however, is significant in the measurement technique and in the indexes of depression storage due to tillage marks oriented on the contour.

Although the performance of the micro-relief measurement on sloping surfaces has not been investigated, it is suggested that the micro-relief meter be operated on a level plane over the support pins. The amount and direction of slope must be measured and used to correct height readings. If the columns of height readings (Figure 5) each extend in a direction perpendicular to the land slope and column 1 is on the upper side of the slope, then height readings in columns 2 to 20 must be decreased approximately in accordance with the equation.

$$\hat{h}_j = h_j - (0.02)(j - 1)\ (\%\ \text{slope}) \quad \ldots\ldots\ldots\ldots\ldots (8)$$

where $\hat{h}_j$ is the adjusted height reading in the $j^{\underline{th}}$ column,

h_j is the observed height reading in the $j^{\underline{th}}$ column,

j is the index number for the column, and

the constant 0.02 is the product of the constants 2 (due to 2-inch spacing between columns) and 0.01, that reduce the right hand term to the same units as h_j.

For depression storage of water due to oriented tillage tool marks perpendicular to the stope, an additional quantity must be subtracted from the numerator of equation (7). This factor may be illustrated by considering the amount of water in $\bar{c}_{max.}BB'$ and $\bar{c}_{max.}H'D$ of Figure 7. This is the amount of water that will be drained due to a slope of decreasing elevation to the right, and may be visualized if the model of Figure 6 is rotated 5° in a clockwise direction using point F as the axis for rotation. Lines $\bar{c}_{max.}B'$ and $H'D$ describe approximately the new water level line. Thus, A_W will be decreased by the quantity:

$$S = \tfrac{1}{2}(B'B)(\bar{c}_{max.}B) + \tfrac{1}{2}(H'H)(H\bar{c}_{max.}) + \tfrac{1}{2}(H'H)(HD)$$

Then

$$D_W' = \frac{A_t - A_s - S}{2k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The surface depression storage due to tillage marks calculated at grades other than those measured assumes that the surface condition produced by the tillage is independent of slope. Generally, this effect is not true and, hence, such computations at slopes greatly different than the measured slope can be in error.

OTHER MEASUREMENTS

Weight of Surface Residues

A standardized procedure for sampling, cleaning, drying and weighing surface residues has been outlined by Whitfield[6].

6/ Whitfield, C. J., Chairman. A standardized procedure for residue sampling. USDA, ARS 41-68. July 1962.

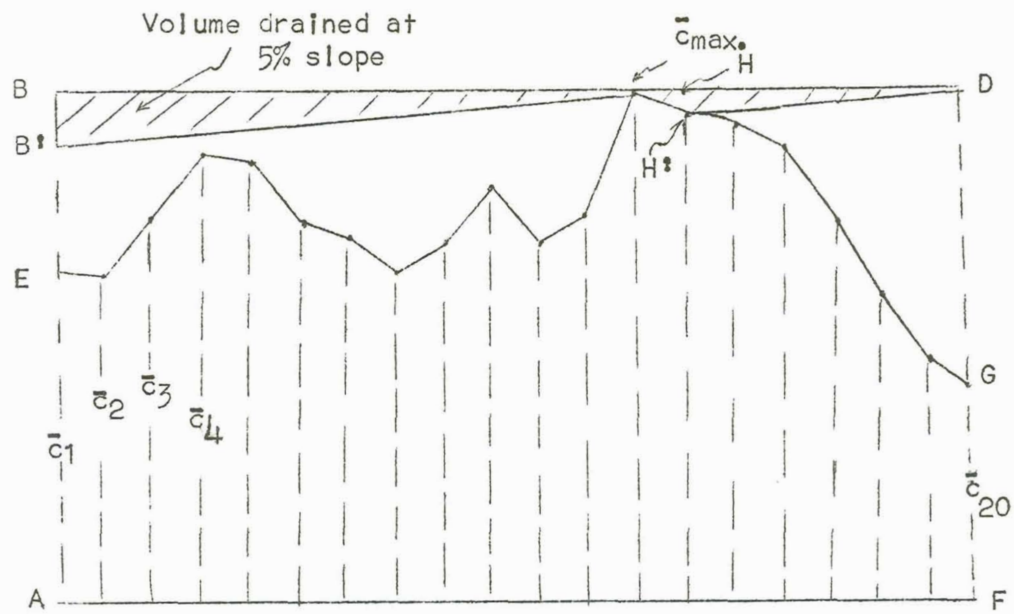

Figure 7.--Effect of land slope on the outline of a distribution of average heights due to tillage tool marks in 40-inch row spacing.

Percent Surface Cover of Residue

Mannering[7] has developed a method for measuring surface cover, which employs a 12- by 12-inch piece of lucite through which 100 nails are driven on 1-inch centers. The lucite is placed at random locations and the number of nails touching residue is directly the percent surface cover. The number of samplings needed per plot has not been statistically evaluated, but about 4 to 6 samples per plot are tentatively judged sufficient.

Where surface residues are oriented with respect to rows, perhaps a larger area should be sampled with a greater distance between the points or nails. In this respect, the micro-relief meter may be used by merely noting the number of measuring pins impinging on residue fragments. This alternative for noting percent surface residue cover has not been investigated.

Soil and Air Temperature

The growth response of young corn plants to average soil temperature in the field has been discussed[3]. Briefly, the response to soil temperature was related to the reference average soil temperature (temperature on a bare plot with smooth micro-relief) and the change in average soil temperature. This change in soil temperature may result from a soil management alteration. The amount of surface residue and the shape of the soil surface over the row will exert an influence on soil temperature and, therefore, on early growth of crops.

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[7] Mannering, J. V. and Meyer, L. D. The effects of various rates of surface mulch on infiltration and erosion. Soil Sci. Soc. Am. Proc. 27:84-86. 1963.

In tillage experiments, daily maximum and minimum soil temperature at a 10-cm. depth should be measured on the bare soil with smooth micro-relief, and on the tillage in question that does not have a bare soil or smooth micro-relief. The average soil temperatures are then taken as the mean of the maximum and minimum readings averaged over a period extending from planting to the date on which inferences are made about plant growth. The maximum and minimum readings can be made with an ordinary maximum-minimum bimetal thermometer. From a series of readings of maximum and minimum readings of 4-inch soil temperature, the standard error of a maximum or minimum reading was about 2° F. With 40 days of readings from a single thermometer, the 5 percent confidence interval for the average temperature would be ± 0.45° F. Two thermometers would reduce this interval to ± 0.32°F.

There are instances where daily maximum and minimum air temperatures at 20 cm. and 40 cm. above the ground surface may be helpful in tillage experiments. These measurements may aid to estimate missing soil temperature measurements, or they may be necessary for instance, if an interpretation is based on amplitude of temperature variation.

Secondary Aggregate Size

Secondary aggregate size is one of the parameters that describes the physical condition of the soil in the row zone. As pointed out by Larson[3/], two consequences of aggregate size can be expected to control the moisture supply to the seedlings. If secondary aggregate size is large, the volumetric fraction of water is low and a poor contact among aggregates and between aggregates and the seedling root may limit the transmission of water to the seedling. Moreover, the voids between the aggregates may be sufficiently large to permit excessive evaporation. Preliminary measurements reveal that the average aggregate size can be affected by tillage systems and this effect of tillage can alter early corn growth.

The sampling device of Figure 8 is used to obtain secondary aggregate samples from row areas of different tillage systems. A cylinder at least 4 inches in diameter and 6 inches long is sharpened on one end. A slot is cut in the cylinder to accommodate a cutting knife. After the cylinder is forced into the soil, it is lifted with a shovel, excess soil is trimmed off the lower end, and the cutting knife is inserted. Thus, the 0- to 3-inch layer is separated from the 3- to 6-inch layer. The samples are air dried, and the amounts of oven dry aggregates in 7 sieve sizes are obtained by sieving with a rotary sieve[8] modified to use the following screen sizes in mm.: 12, 9, 5, 3, 2, 1 and 0.5. The geometric mean diameter of the aggregates in the seedbed area can then be described.

Perhaps the best time (accuracy of the method) to obtain the samples is just after the planting operation. For observing a relation between aggregate size and plant growth, the best time of sampling may not be just after the planting operation. The number of samples of a given treatment required for a given level of precision has not been investigated, but preliminary considerations suggest that at least 6 samples be taken per geometric-mean-diameter expression.

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[8] Chepil, W. S. Improved rotary sieve for measuring state and stability of dry soil structure. Soil Sci. Soc. Am. Proc. 16:113-117. 1952.

Chepil, W. S. A compact rotary sieve and the importance of dry sieving in physical soil analysis. Soil Sci. Soc. Am. Proc. 26:4-6. 1962.

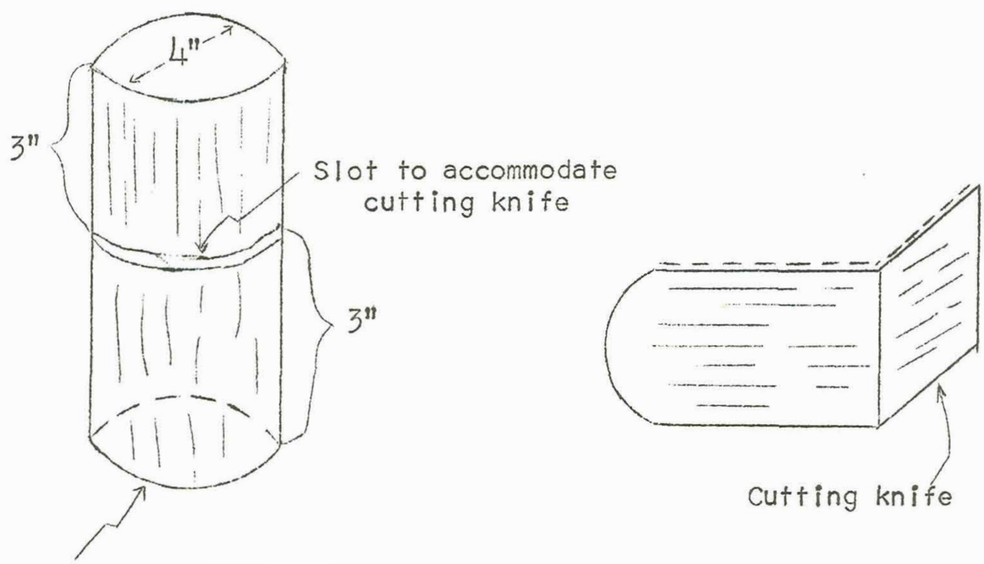
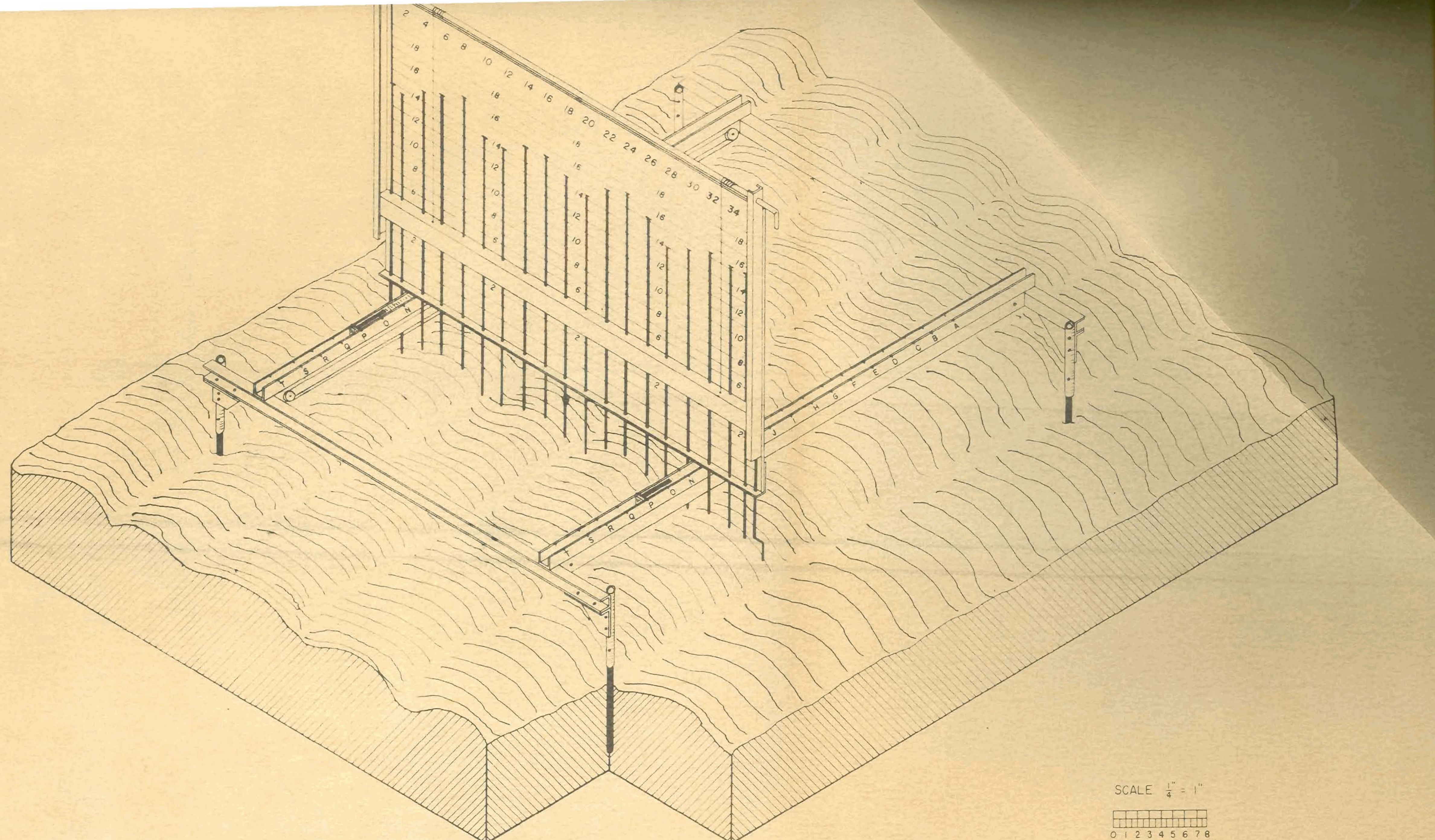


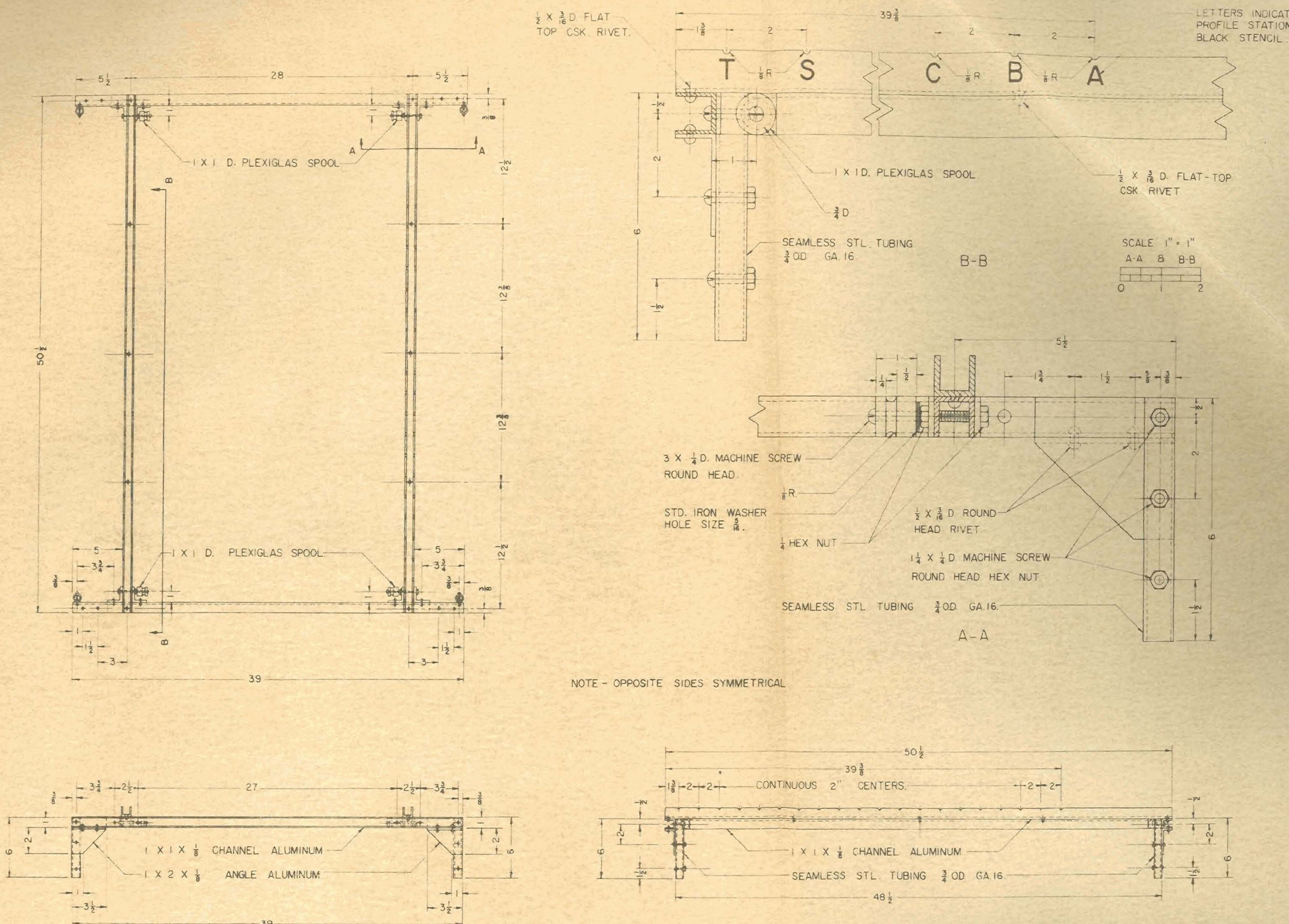
Figure 8.--Diagram of cylinder for sampling secondary aggregates in the field.

CONSTRUCTION DETAILS FOR MICRO-RELIEF METER

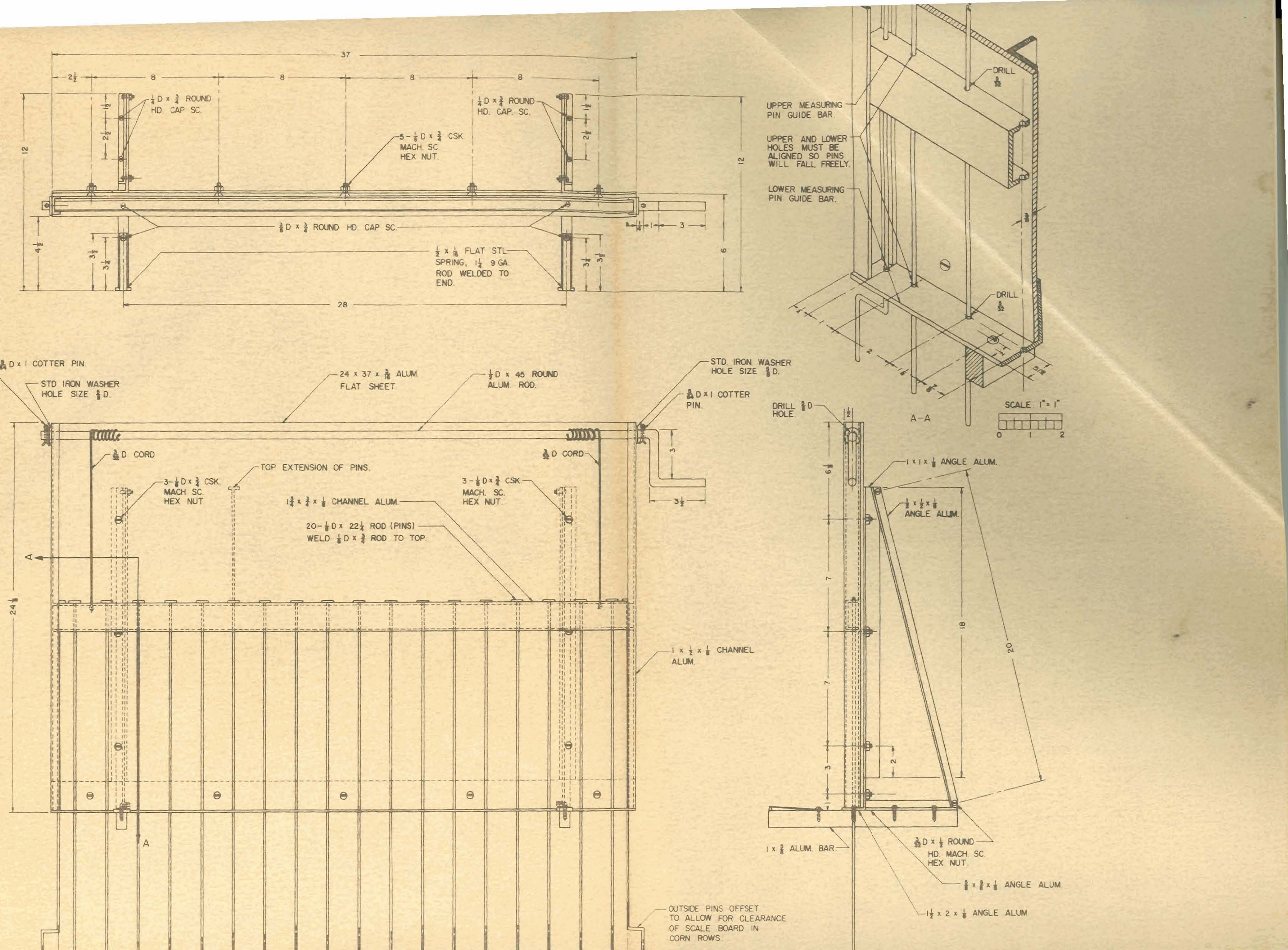
Figure 4 shows construction details for micro-relief meter.



DRAWING 1 – MICRO-RELIEFMETER, ISOMETRIC VIEW



1/2 X 3/16 D. FLAT TOP CSK. RIVET.
LETTERS INDICATE PROFILE STATION BLACK STENCIL.
T S C B A
1 X 1 D. PLEXIGLAS SPOOL
1 X 1 D. PLEXIGLAS SPOOL
1/2 X 3/16 D. FLAT-TOP CSK. RIVET
3/4 D
SEAMLESS STL. TUBING 3/4 O.D. GA. 16
B-B
SCALE 1" = 1"
A-A & B-B
3 X 1/4 D. MACHINE SCREW ROUND HEAD.
1/8 R.
STD. IRON WASHER HOLE SIZE 5/16.
1/4 HEX NUT
1/2 X 3/16 D. ROUND HEAD RIVET
1 1/4 X 1/4 D. MACHINE SCREW ROUND HEAD HEX NUT
SEAMLESS STL. TUBING 3/4 O.D. GA. 16.
A-A
1 X 1 D. PLEXIGLAS SPOOL
NOTE - OPPOSITE SIDES SYMMETRICAL
1 X 1 X 1/8 CHANNEL ALUMINUM
1 X 2 X 1/8 ANGLE ALUMINUM
CONTINUOUS 2" CENTERS.
1 X 1 X 1/8 CHANNEL ALUMINUM
SEAMLESS STL. TUBING 3/4 OD GA. 16



37
2½
8
8
8
8
¼ D x ¾ ROUND HD. CAP SC.
¼ D x ¾ ROUND HD. CAP. SC.
5 - ⅛ D x ¾ CSK. MACH. SC. HEX NUT.
⅜ D x ¾ ROUND HD. CAP SC.
½ x ⅛ FLAT STL. SPRING, 1½ 9 GA. ROD WELDED TO END.
12
4½
3½
6
28
3
UPPER MEASURING PIN GUIDE BAR.
UPPER AND LOWER HOLES MUST BE ALIGNED SO PINS WILL FALL FREELY.
LOWER MEASURING PIN GUIDE BAR.
DRILL 9/32
DRILL 9/32
A-A
SCALE 1" = 1"
0
1
2
3/64 D x 1 COTTER PIN.
STD IRON WASHER HOLE SIZE ⅜ D.
24 x 37 x 1/16 ALUM. FLAT SHEET.
½ D x 45 ROUND ALUM. ROD.
STD. IRON WASHER HOLE SIZE ⅜ D.
3/64 D x 1 COTTER PIN.
DRILL ⅜ D HOLE.
1/16 D CORD
1/16 D CORD
3 - ⅛ D x ¾ CSK. MACH. SC. HEX NUT
TOP EXTENSION OF PINS.
3 - ⅛ D x ¾ CSK. MACH. SC. HEX NUT.
1¾ x ¾ x ⅛ CHANNEL ALUM.
20 - ⅛ D x 22¼ ROD (PINS) WELD ⅛ D x ¾ ROD TO TOP.
1 x 1 x ⅛ ANGLE ALUM.
½ x ½ x ⅛ ANGLE ALUM.
24⅛
A
A
1 x ½ x ⅛ CHANNEL ALUM.
6⅛
7
7
3
2
18
20
3½
1 x ⅜ ALUM. BAR.
3/32 D x ½ ROUND HD. MACH. SC. HEX NUT.
⅜ x ⅜ x ⅛ ANGLE ALUM.
1½ x 2 x ⅛ ANGLE ALUM.
OUTSIDE PINS OFFSET TO ALLOW FOR CLEARANCE OF SCALE BOARD IN CORN ROWS.