THE INFLUENCE OF HITCH ADJUSTMENT, SOIL MOISTURE, SOIL HARDNESS, AND SOIL STRUCTURE ON THE DRAFT REQUIREMENT OF A ONE-WAY PLOW

by

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INTRODUCTION

The development of the one-way disk plow or wheat-land disk plow has had a marked effect upon the tillage practices in the small-grain growing section of the High Plains Area. This is also true in other areas where a disk-type plow is adapted.

This implement is not new but merely an improvement of an older machine of similar basic design. The chief improvements include larger diameter disks with a greater degree of concavity, improved bearings in both disk gang and in the supporting wheels, pneumatic tires and hydraulic depth control.

Due to these improvements, the draft requirement of the newer one-way plow is much less per foot of cut than in the older plows. This has resulted in plows of much wider cuts being pulled by average sized farm tractors. In some cases a large tractor will pull two or more plows. This greatly increased daily capacity of each tractor and operator permits tillage of the soil under more favorable moisture conditions.

Also of importance, is the fact that these improvements in the one-way plow are applicable to a certain extent to the disk harrow, tandem disk and the off-set disk harrow. All of these disk tillage tools utilize disk gangs. Disks in a vertical position are separated by spacers and held together by a shaft through the disk and spacers. These disks are said to be in a "gang" and turn as a unit. Hence, an improvement in one machine may be applied where applicable to all other disk tillage tools.

With these improvements in disk plow design, simplicity of construction is increasing. The number of levers and other means of adjustment have been reduced. In some one-way disk plows the number of adjustments that the operator can make in the field are limited to depth only.

The question has been raised as to the draft requirement of such a simplified one-way plow under varying soil conditions, such as moisture content, soil hardness, and soil structure. Also how the hitch adjustment, both horizontal and vertical will affect the draft requirement.

The objects of this investigation were:

1. To determine the influence of horizontal and vertical hitch adjustment on the draft requirement of a one-way disk plow of recent design at a particular moisture content and soil hardness index.

2. To determine the influence of soil moisture and soil hardness at the optimum hitch position for minimum draft requirement.

REVIEW OF LITERATURE

Clyde and McCall (1) reported the results of testing disk harrows of several disk diameters and different spacings in the gang, tandem bumper disk harrows and off-set disk harrows on a special type of dynamometer. Clyde (2) also analyzed a 24 inch wheatland type disk on the same dynamometer. He gave a generalized vector diagram of the forces acting on a one-way disk plow, but did not include an actual field test on a complete plow.

Gordon (3) stated that soil type and conditions produce most pronounced differences in soil reactions on disks. Draft increases with speed. Draft and upward thrust increased with concavity. He reported a slight difference in draft in favor of large disks.

Murdock (4) ran dynamometer tests on disk tillage tools but did not report any effect of hitch adjustment or soil moisture content.

Promersberger (5) built a recording hydraulic dynamometer for his tests on the power requirement of summer fallow machines. Plans for this machine are included in his report. He reported making and using a penetrometer for testing soil hardness. This device was developed by Stone and Williams (6).

Culpin (7) made some investigations in soil hardness in 1935 in England. He measured the resistance of a vertical probe through the soil. Also, he used the penetration of a revolver bullet as a test of soil consolidation. Soil structure was determined by sieving a "composite un-disturbed sample" through the following sized sieves; 1½ inch, 5/8 inch, 1/4 inch square openings and 3 mm round openings. The per cent retained on each sieve was recorded.

Davidson, Fletcher and Collins (8) stated, "Moisture has a decided influence upon draft, and as most observers agree, may reach an optimum amount from which either an increase or a decrease results in added draft".

Smith (9) made this statement, "Plowing is recognized as the greatest labor consuming operation in the world". He lists seven reasons for plowing:

1. To obtain a deep seedbed of good texture.

2. To add more humus and fertility to the soil by covering vegetation and manure.

3. To destroy and prevent weeds.

4. To leave the soil in such a condition that air will circulate.

5. To leave the soil in such a condition as to retain moisture from rainfall.

6. To destroy insects, as well as their eggs, larvae, and breeding places.

7. To leave the surface in a condition to prevent erosion by winds.

EQUIPMENT CONSTRUCTED

Dynamometer

The cart-type hydraulic drawbar dynamometer was constructed at the Agricultural Engineering shops at Texas Technological College. Plan and elevation views are shown on Plate I.

The front axle and hubs from a Ford car, fitted with sixteen inch wheel and tires, supports the dynamometer cart. The axle was inverted to give more clearance, it was saved through to the lower web and bent to give the wheels zero camber and then welded. The frame of the cart was constructed from welded structural steel sections that were salvaged from discarded equipment. The hydraulic cylinder was taken from a Caterpillar bull-dozer. The cylinder was completely dis-assembled, the bore was thoroughly cleaned, all rust spots and other irregularities were honed out. The piston was reversed on the piston rod, so that pressure could be created between the piston and the gland end of the cylinder. The bore of the cylinder and the diameter of the piston rod were carefully measured with a micrometer caliper, in order that the net effective area of the piston could be accurately computed. The cylinder was re-assembled and mounted in the cylinder mount located at the rear of the dynamometer cart. This mount was constructed so that the cylinder could be raised or lowered by its pivot bearings in a vertical guide by a screw from a bench vise, equipped with a ball thrust bearing. The hinged hitch at the outer end of the piston rod, may be raised from seven inches to about eighteen inches, depending on the length of the hitch of the pulled tool.

The piston was pushed as far as possible toward the closed end of the cylinder and filled with S. A. E. 20 oil.

EXPLANATION OF PLATE I

1. Indicator mechanism
2. Chart-strip drive
3. Start-stop pencil
4. Six volt solenoid
5. Hitch for pulled tool
6. Hydraulic cylinder
7. Spring for counter balancing hydraulic cylinder when no load is attached
8. Electrically operated stop watch
9. Gear drive for flexible shaft to chart-strip drive
10. Direct reading pressure gauge
11. Valve between pressure gauge and recording unit
12. Six volt battery
13. Flexible shaft driving chart-strip
14. Foot controlled switch for horn
15. Automotive type horn for signalling tractor driver
16. Push button switch for operating electrically controlled stop watch and start-stop pencil
17. Combination tool box and operator's seat
18. Guard rail
19. Screw for raising and lowering hydraulic cylinder

PLATE I

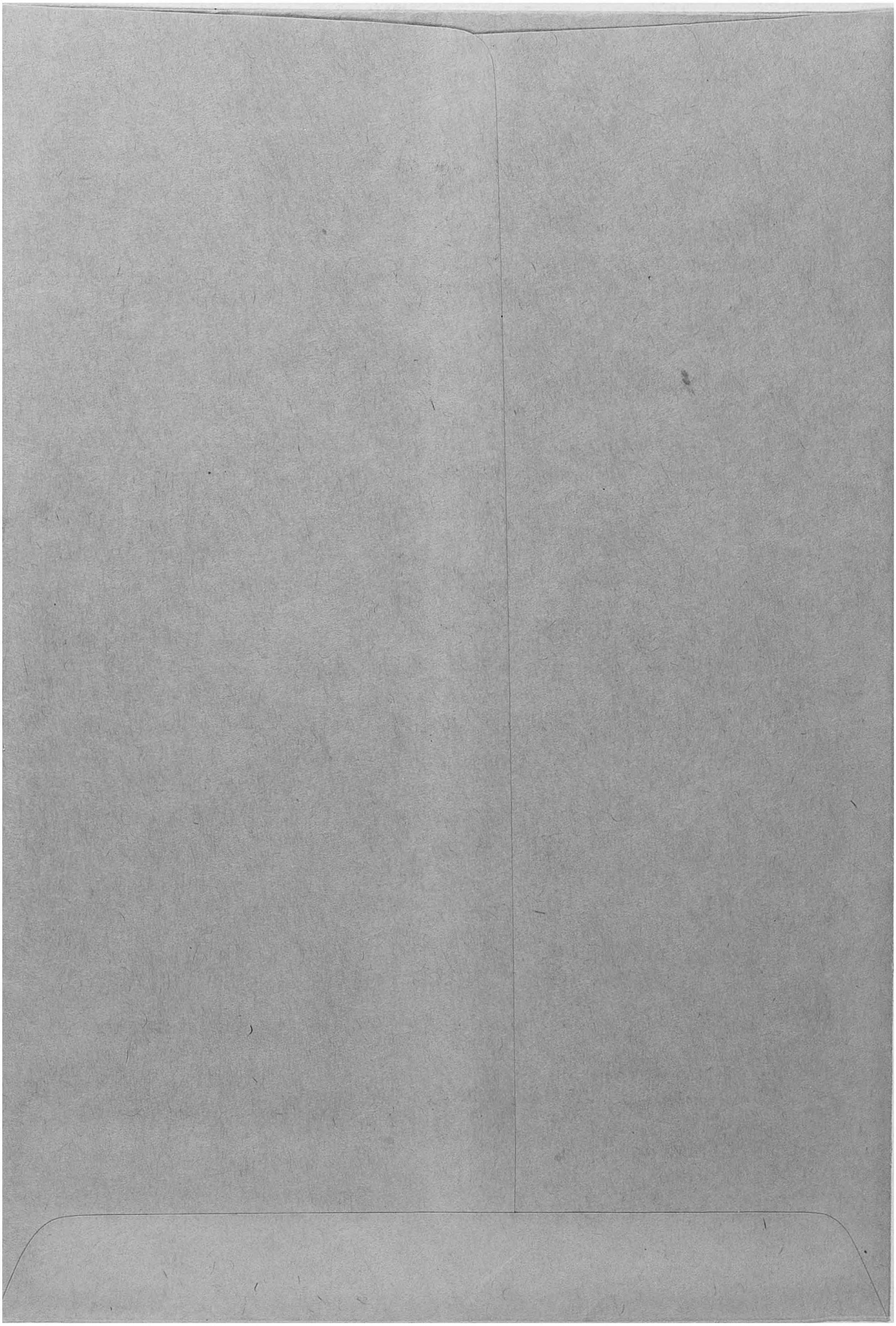
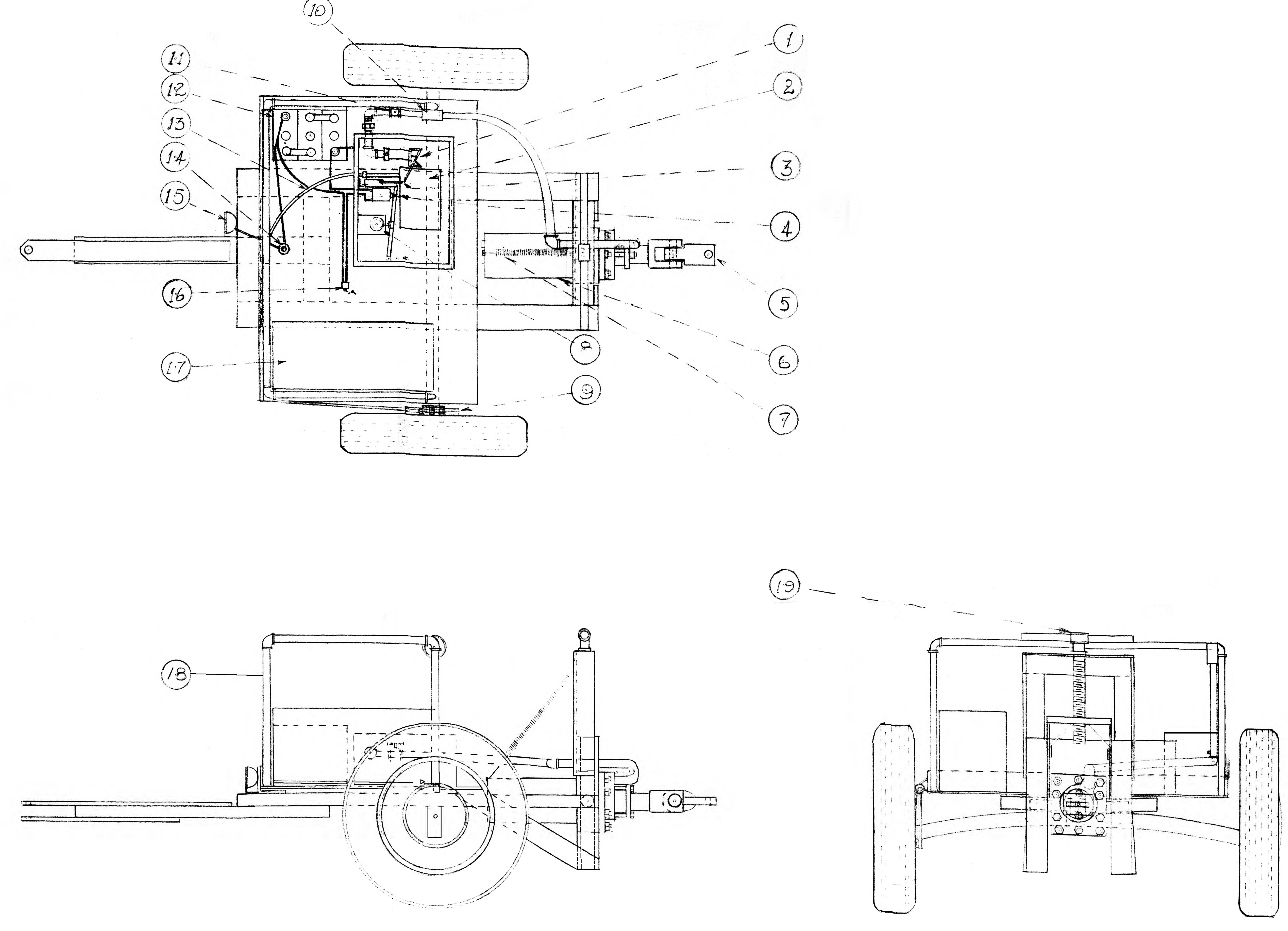


PLATE I



A high pressure hydraulic hose connected the cylinder to the pressure indicating mechanism. The pressure indicator was made from a steam pressure indicator. An Esterline-Angus phantom chart drive, with a gear ratio of three inches of chart travel per revolution of the drive shaft, recorded the tracing of the pressure indicating pen. The drive shaft was driven by a flexible shaft (speedometer cable) from the left wheel of the cart. A three inch section of eight inch O. D. steel tubing was welded to the inside of the left hub. Threads or teeth were cut in this section of tubing to mesh with the teeth of the transmission speedometer pinion from an International truck. This pinion was mounted in two bearings and hinged so that it might be engaged and dis-engaged. With this arrangement, the speedometer pinion made one revolution for every one hundred feet of ground travel of the ground driven cart wheel. This caused the chart drive to make one revolution per one hundred feet of ground travel or a horizontal scale of 3 inches equal to 100 feet.

The spring of the indicator mechanism was calibrated on Crosby Dead Weight Tester No. 8619 on January 19, 1950. Using the eighty pound spring, it was found that a pressure of 100 pounds per square inch gave a pen deflection of 1.50 inches. An extension was attached to the recorder arm in order to attach a pen. Figure 1 is the calibration curve of this spring. This pen recorded the fluctuations in pressure of the hydraulic cylinder on the paper chart strip at a vertical scale of one inch equal to 66.67 pounds per square inch.

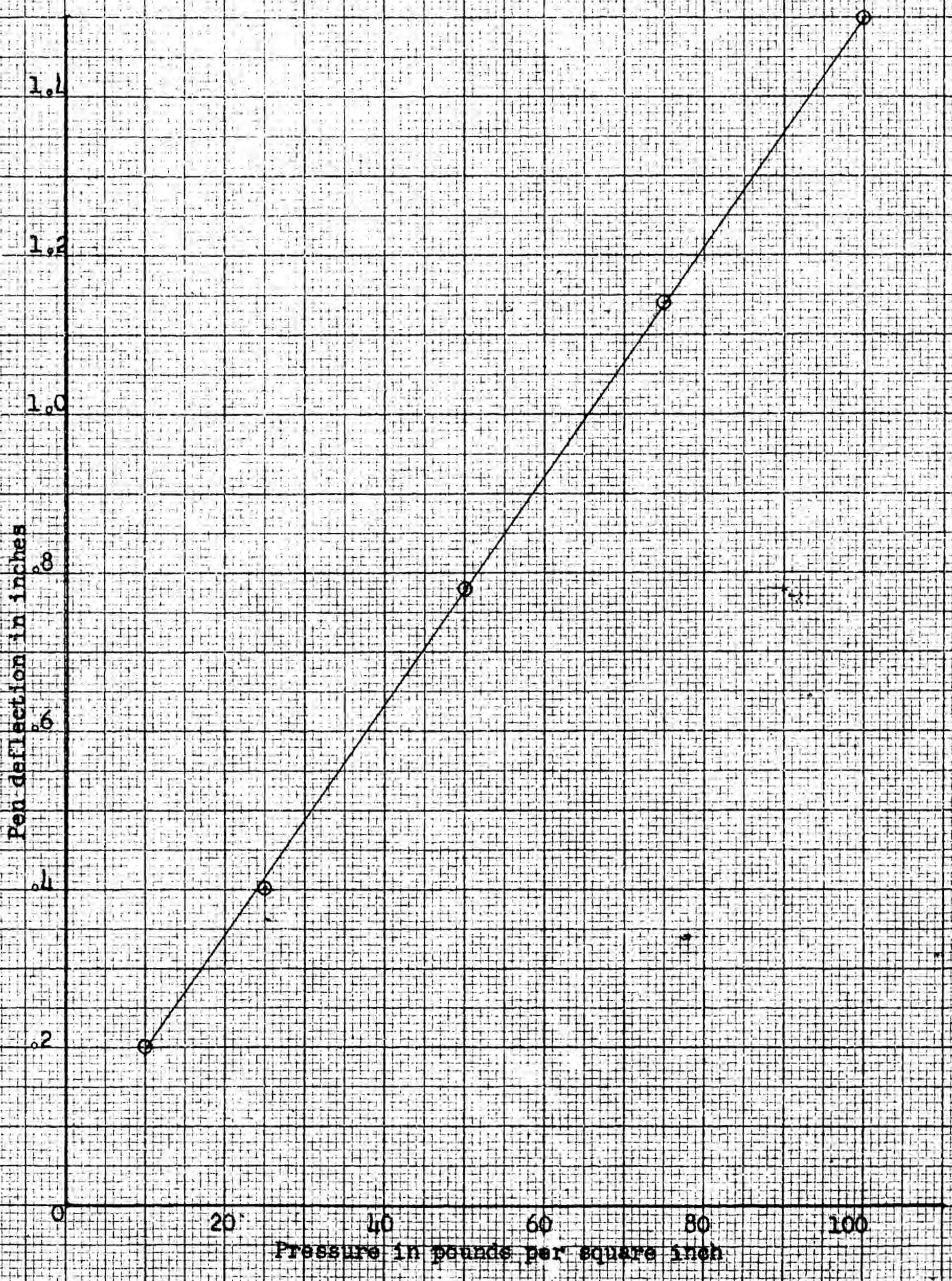


Fig. 1. Calibration curve for Trill Indicator MZN-3, with 80 pound spring, used on dynamometer hydraulic pressure recording mechanism.

In order to provide a means of actuating the start-stop pencil and the stop watch, a Minneapolis-Honeywell six volt solenoid was arranged with a system of levers to re-set the stop-watch and make a mark on the edge of the chart simultaneously. At the end of the test period, the elapsed time was noted, the solenoid switch was again momentarily closed and opened, making another mark on the edge of the chart and re-setting the stop-watch to zero. Plate II shows this indicating and recording mechanism. A three inch pressure gauge is connected between the recording mechanism and the hydraulic cylinder. This provides an easy means of checking draft and is visible for demonstration purposes. A valve is located between this gauge and the recording unit, so that the recording unit may be removed for road travel or for the machine to be used with the pressure gauge alone.

A 1/4 inch steel plate makes the floor of the cart and a 3/4 inch pipe rail at the front and sides protects the operator from sudden starts and stops. A combination tool box and seat is mounted opposite the recorder box. A foot operated switch controls an auto type horn for signalling the tractor operator for starts and stops. A six volt battery mounted on the cart provides electrical current for the solenoid and the horn. Plate III shows the dynamometer in operating position.

Penetrometer

A penetrometer to measure soil hardness was constructed. It is patterned after one made by Rototiller, Inc., Troy, New York. It consists of a penetrator, made from 1 1/8 inch cold rolled steel, 22 inches long with an 18 inch taper. The taper is 1 1/8 inches at the upper end 1/4 inch at the lower end. The lower end that penetrates the soil is round and was cynanide hardened to prevent wear. The penetrator is supported by a cylinderical tube 1 1/4 inch inside diameter, 54 inches long and mounted on a 1/8 inch steel plate 10 inches square. At the lower end of the tube is a slot and a scale graduated in inches and tenths of inches, which permits reading the depth the penetrator has entered the soil. At the upper end of the tube, a retaining device for holding the penetrator in place with its point 36 inches above the ground and releasing it for free fall. A soil hardness reading is taken by releasing the penetrator and noting the depth of soil penetration on the scale. Plate IV shows the penetrator depth reading.

Horizontal Profile Hardness Tester

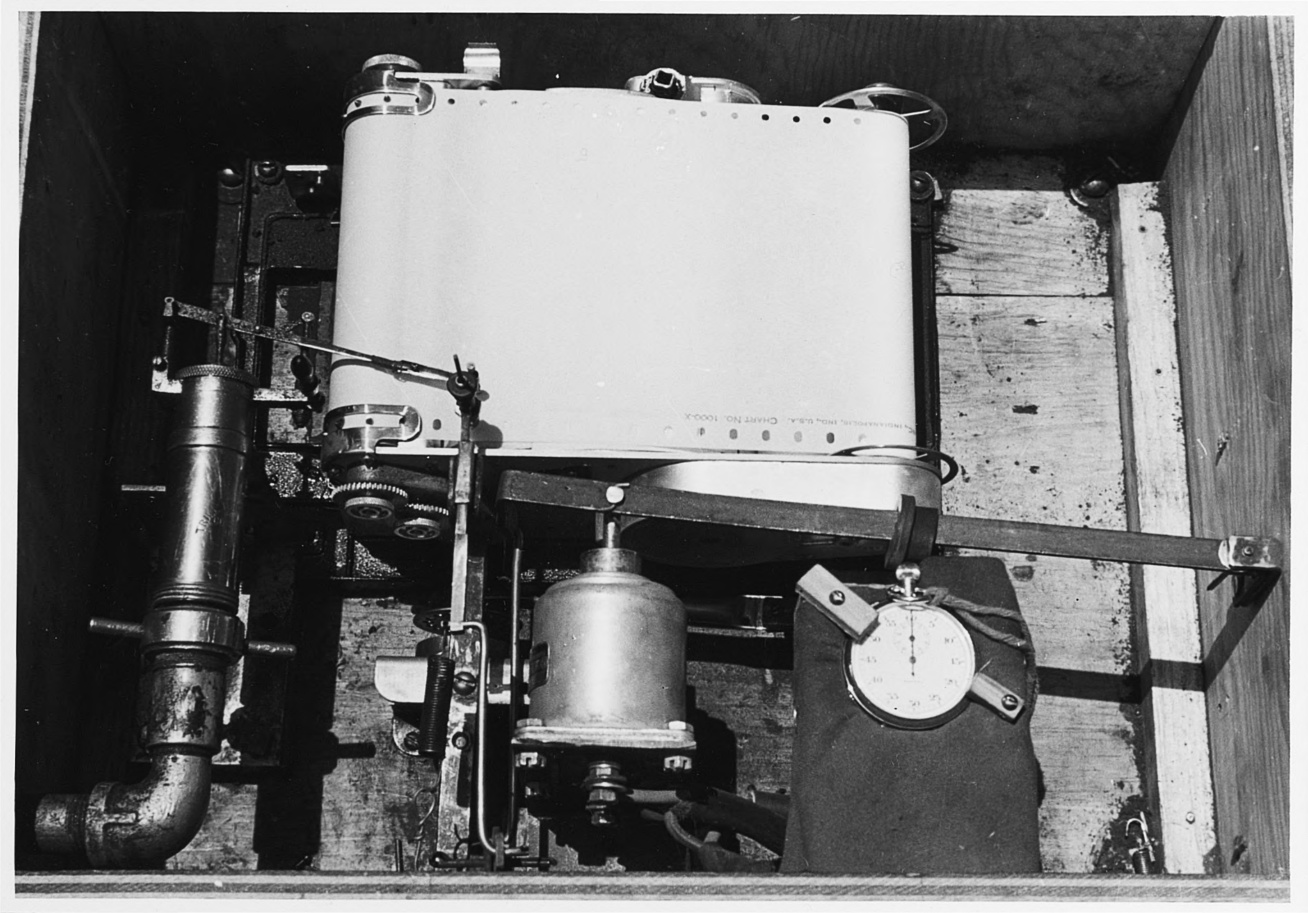
A method of determining the resistance of a soil profile to shear in a vertical plane, from the surface of the soil to the plowing depth was devised.

Basically, this method consists of forcing a round-edged plate, 0.187 inches thick, into the soil profile by means of a constant force and determining the distance of the plate movement in inches. Figure 2 shows the principle of operation. An 8 1/2 inch section of 4 inch O. D. steel pipe forms the outside shell for this tester. A slot is cut in one side of the

EXPLANATION OF PLATE II

Plate II is a close-up view of the pressure indication and recording mechanism for the hydraulic dynamometer, showing pressure indicating pen, chart drive and electric solenoid for operating start-stop pencil and stop-watch.

PLATE II



EXPLANATION OF PLATE III

Plate III shows the cart type, hydraulic dynamometer in operating position.

PLATE III

pipe to permit the round edged plate to contact the soil profile. This plate is forced into the soil horizontally by the wedging action of a ram and a drop-hammer fitted into a guide on the opposite side of the pipe. The angle of the wedge is 16 degrees. Plate V shows the relative position of the component part after release of the drop-hammer. Plate VI shows a field test of the horizontal soil profile hardness tester, the vertical ram movement scale and the resulting plate movement are indicated. The drop-hammer is made from an 8 1/2 inch section of 3 inch diameter round steel stock, with a hole through the center to fit loosely over the guide. The drop-hammer weighs 15.75 pounds. A releasing device is attached to the guide to permit the hammer to be dropped from an exact height of either 1 foot or 2 feet. A scale graduated in inches and tenths is located on the ram. An adjustable index pointer is provided for indicating the initial position of the ram.

To use this tester, a hole is drilled in the soil with a 4 inch Iwan type auger, approximately 1 inch deeper than the anticipated plowing depth. The tester is placed in the hole so that the bottom edge of the plate is at plowing depth and the round edge is firmly against the soil profile. The ram is carefully lowered into the guide until it contacts the plate. The movable index pointer is placed at zero on the ram scale. The drop-hammer is placed in position over the guide, making sure that the guide is vertical, and dropped from the releasing

EXPLANATION OF PLATE IV

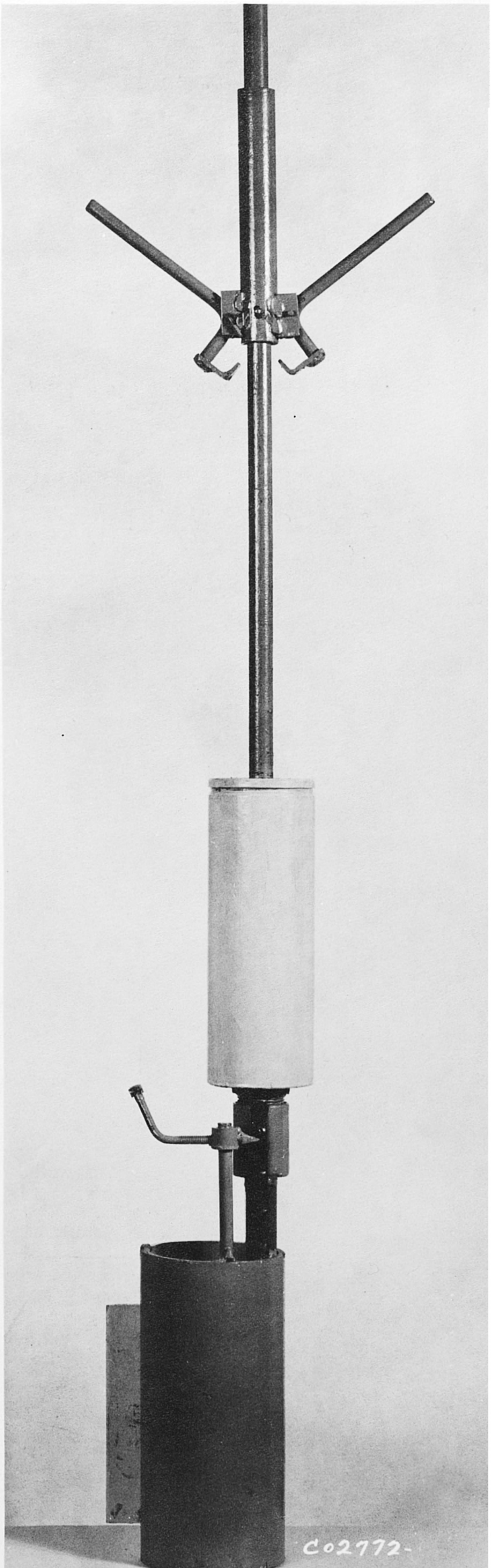
Plate IV is a close-up view of the lower portion of the Penetrometer, showing depth of penetration of penetrator.

PLATE IV

EXPLANATION OF PLATE V

Plate V is an elevation view of the Horizontal Soil Profile Hardness Tester, showing relative position of component parts after release of drop-hammer.

PLATE V



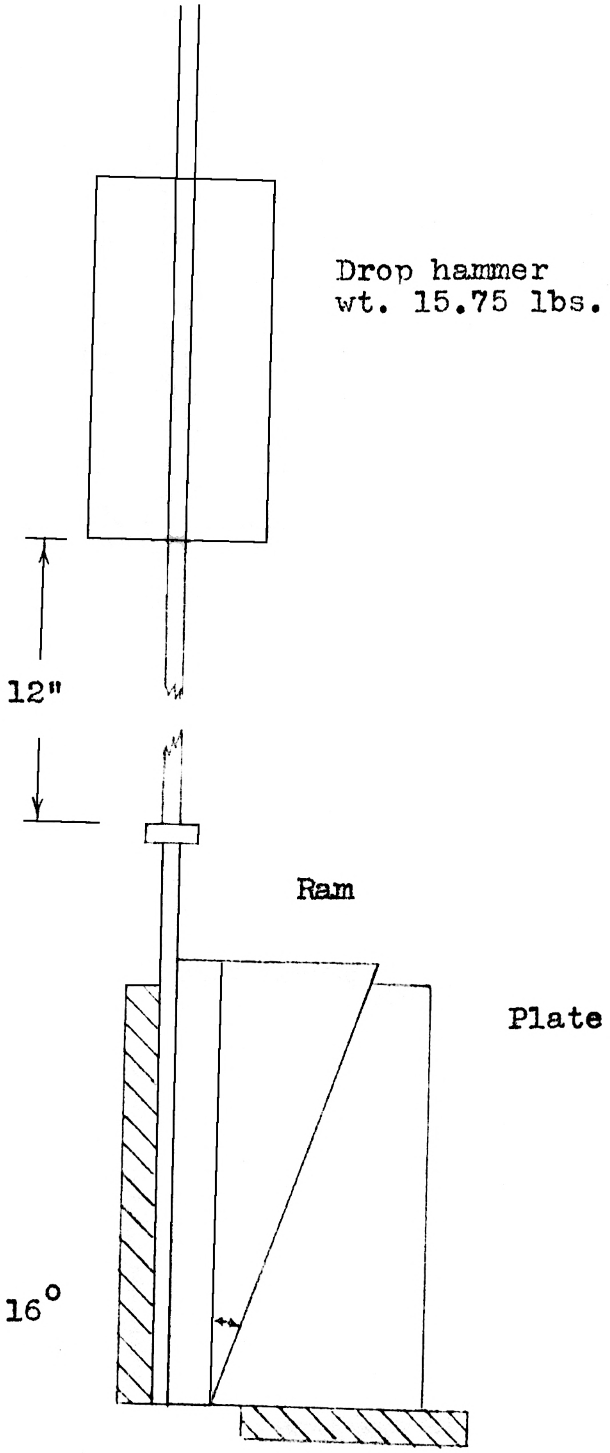


Fig. 2. Diagram of principle of operation of Horizontal Profile Hardness Tester.

EXPLANATION OF PLATE VI

Plate VI is a close-up view of a field test of Horizontal Soil Profile Hardness Tester, showing vertical ram movement scale reading and the resulting horizontal plate movement.

PLATE VI

catch at the 1 or 2 foot position. The vertical distance that the ram moved is noted on the scale. This distance multiplied by the tangent of 16 degrees is the distance of plate movement in inches.

Depth Gauge

A depth gauge to determine the depth of cut of the plowing test has been constructed. This device consists of a straight piece of oak hardwood 1 inch by 2 inches in cross-section and six feet long, with a sliding scale at right angles on one end. This gauge is placed on its edge on the unplowed ground surface, with the scale perpendicular to the bottom of the furrow, the plowing depth is read on the scale in tenths of feet. Plate VII shows this device in use.

EXPLANATION OF COMPUTATIONS AND TERMS USED

Mean Draft

Mean draft was determined from the dynamometer pressure and distance recorder chart (Plate II). The net chart area is the area between the pressure indicating pen tracing and the base line, between the start-stop pencil marks at the beginning and the end of the draft trial. This area is measured in square inches with a planimeter. The net area divided by the measured chart length in inches and tenths and multiplied by a constant is the mean draft in pounds. The constant was computed by multiplying the net area of the hydraulic cylinder piston (23.38 square inches) by the number of pounds per square inch required to give an indicator pen deflection of one inch (66.67 pounds per square inch). The product is 1558.74

Horsepower

The horsepower required to pull the plow was computed by the formula:

$$H.\ P. = \frac{\text{Mean draft in lbs. x distance in feet}}{\text{time in minutes} \quad \text{x} \quad 33{,}000}.$$

The mean draft determination was described in the preceding paragraph. The distance in feet is obtained from the length of the chart, which has a scale of 3 inches of chart travel equal to 100 feet of ground travel. The length of the chart is the distance in inches between the marks made by the start-stop pencil at the beginning and end of the individual trial. The elapsed time is the amount of time between the beginning and the end of the trial as noted on the electrically operated stop-watch mounted in the recorder box (Plate II). The factor, 33,000, is the number of foot pounds per minute per horse power.

Soil Hardness Index

Soil hardness index was computed by averaging the ten penetration readings of the penetrometer along the strip to be plowed, dividing this average into ten. (Plate IV) Soil Hardness Index =

$$\frac{10}{\text{Average Penetration}}.$$

EXPLANATION OF PLATE VII

Plate VII shows the method of measuring depth of plow cut with the depth gauge.

PLATE VII

Horizontal Profile Hardness Test Plate Movement

The horizontal soil profile hardness tester plate movement was computed by multiplying the observed vertical ram movement in inches by the tangent of the angle between the ram and the plate (Fig. 2).

Soil Moisture Determination

The soil moisture content determination was made by taking three representative samples along the strip to be plowed from the surface to 0.4 feet deep. These samples were placed in glass jars and sealed with air-tight lids. The jars were taken to the Soils Laboratory and the three samples mixed thoroughly. Three samples of about 50 grams each were weighed out of this well mixed lot. The individual samples were placed in metal moisture sample containers for drying in the oven. The samples were placed in an electric oven and left for 24 hours at 100 degrees Centigrade. The oven was turned off and allowed to cool, when the oven reached room temperature, the samples were re-weighed and the moisture content computed on a dry weight basis.

ANALYSIS OF SOIL REACTION ON A ONE-WAY PLOW

The analysis of the soil reaction on a one-way disk plow is difficult when using a dynamometer that records only the force necessary to pull the plow along the furrow. Some of the symbols and the terminology presented by A. W. Clyde (2) in his analysis of soil reaction on various tillage tools with his "tillage meter" have been used (refer to Fig. 3&4).

L, S, and V appear to be functions of the depth of penetration, Clyde (2) reported. In this investigation, the depth was held as nearly constant as possible at 0.4 of a foot. There is no particular reason for selecting this value other than the fact that during the preliminary plowing tests the plow seemed to operate better at this depth in hard, dry soils. This is considered an average plowing depth in the area in which the tests were made.

Disks used in an upright position have an upward vertical soil reaction, V. They must be forced into the ground. The amount of weight required to accomplish this is hard to compute, in the case of the one-way plow. It must be numerically greater than V, since the supporting wheels must have some weight on them in order to perform their function of absorbing all or part of S, the lateral force. This weight W, is not necessarily the static weight of the implement, since the pulling force or a transfer of weight may cause it to be considerably more or less than the static weight, as will be discussed later.

The "center of resistance" of an average disk of a one-way disk plow varies with the soil moisture, soil structure, and hardness of the soil being plowed. It is also influenced by the diameter of the disks, degree of concavity and the angle

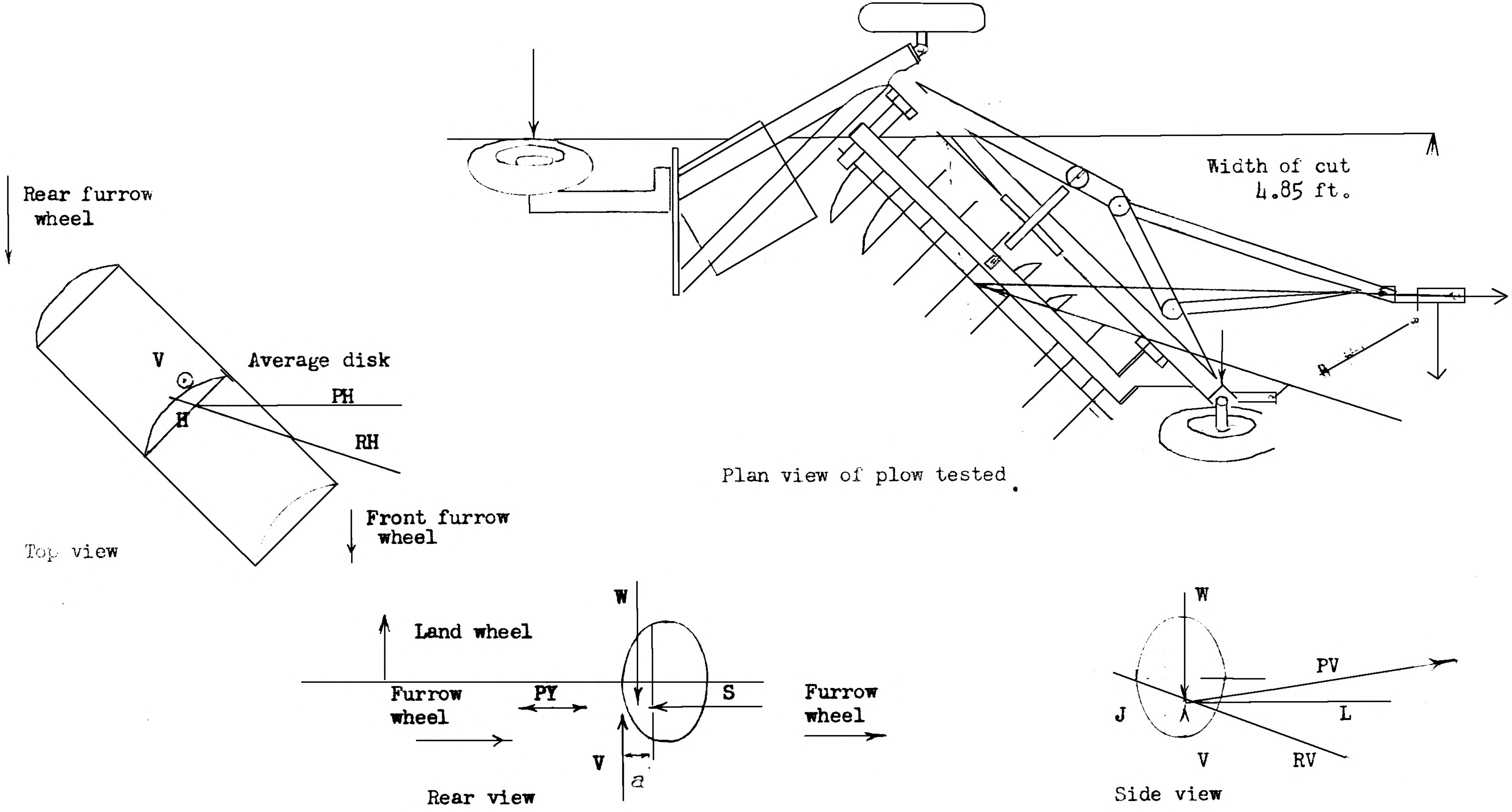
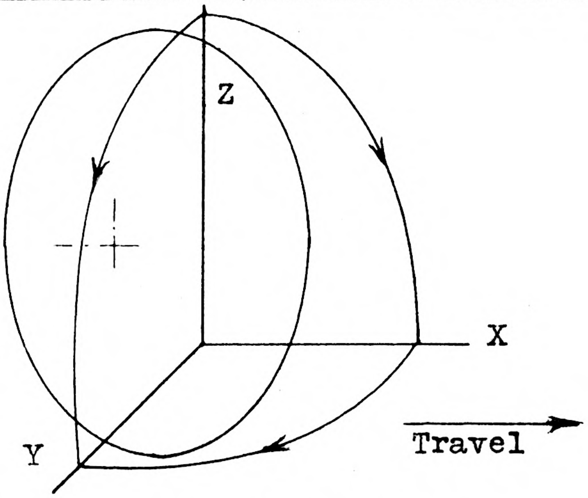


Fig. 3. Vector analysis and plan view of plow tested.

SOIL FORCE ON TOOL			COUPLE OR MOMENT		
Designation	Symbol	Parallel to axis	Axis	Symbol	Positive direction
Longitudinal	L	X	X	MX	Z ->Y, clockwise looking ahead
Side	S	Y	Y	MY	Z ->X, clockwise looking left
Vertical	V	Z	Z	MZ	X->Y, clockwise looking down



Arrows show positive directions of L,S,V, and couples.

R, resultant of L,S,&V.
RH, " " L&S
RV, " " L&V
PX, component of P parallel to X
PY, " " " " Y
PZ, " " " " Z

PH, resultant of PX & PY
PV, " " PX & PZ
W, weight
P, pulling force
Va= MX

Fig. 4. Symbols used in vector analysis of soil forces acting on plow tested.

of the disk with the direction of travel. Without special equipment such as a "Tillage meter", its exact location can not be determined. Since it varies with changing soil conditions, this investigation did not supply data to determine its exact location.

In the side view of an average disk (Fig. 3) the relative position and direction of the forces W, V, PV, RV, and L are shown. Their junction point J is the center of resistance. This center of resistance seems to vary from a point near the surface of the ground and slightly in front of the center line of the disk to a point at the edge of the disk along the line RV, which is the resultant of the forces L and V. This variation is thought to be due to differences in soil resistance, when plowing at a constant depth with the same plow. Martin and Stephanson (10) are of the opinion that the center of resistance is located at the edge of the disk at a point tangent to a line drawn from the center of pull of the tractor.

An examination of the factors involved in the horizontal forces acting on the disk plow shows that if H is placed differently on RH by shifting the pulling force sideways, the side force S, will be divided differently between the furrow wheels. In order for the average one-way plow to operate properly, with most of the side force S, being carried by the rear furrow wheel, the line of horizontal draft should be along a line between the center disks to the center of pull of the tractor, with the tractor in its proper position for normal operation. The forces acting in a vertical plane are shown in Fig. 2. The force PV, is the force recorded by the dynamometer, since the hinged hydraulic cylinder permits the drawbar to assume the angle of draft (Plate I). The vertical adjustment of the plow tongue at the tractor end will change the angle of PV. Vertical adjustment of the tongue at the plow end will cause the weight carried by the wheels to be redivided. This will also cause the side-thrust S, to raise or lower. This in turn will change the position of the couple S PY and the side-reaction on the wheels. If this division of weight, transfers part of the weight that was on the rear furrow wheel to the other wheels, it will have a tendency to ride up on the furrow wall and leave the furrow. This is due to the combined action of the couple MX and the side-thrust S.

Clyde (2) reported that in all disk tillage tools, there was a moment MX. This moment has a tendency to raise the left end of a right hand disk tillage tool when viewed from the rear. This moment, MX, is equal to Va, where V is the vertical soil reaction on an average disk and "a" is the lateral distance that V is displaced from the junction of the horizontal forces.

The vertical position of the force PV will affect the transfer of both static and dynamic weight, thus changing the amount of weight available to overcome V.

INTERPRETATION OF HITCH ADJUSTMENT DRAFT TESTS

The field work of this investigation was done at Texas Technological College, Lubbock, Texas. All of the plowing tests were made on the College Farm. These tests were begun in April 1950 and finished in April 1951.

The first objective of this investigation was to determine the influence of horizontal and vertical hitch adjustment on the draft requirement of a one-way plow at a particular moisture content and soil hardness index.

Variable Horizontal Angle Draft Test

Several tests were made in which the line of pull was shifted to either side of the line of draft normally used. Very little difference in draft could be observed, when the furrow wheels stayed in their correct positions.

Variable Vertical Angle Draft Tests

In the preliminary draft tests made in 1950, the horsepower required to pull the plow at dynamometer drawbar heights of 0.6 feet to 1.5 feet did not appear to fluctuate in any regular pattern. A seven foot Krause plow was used for these tests.

In the fall of 1950 when draft tests were resumed, a Krause plow was not available. The only plow that could be obtained at that time was a 1950 model, (8 disks, 10" spacing) Schafer plow. An extension was made so that the plow hitch point or tongue could be lowered from the point provided by the manufacturer (Fig. 5). With the plow operating at a depth of 0.4 feet, this extension provided a range of hitchpoints from 0.23 feet above the ground to the regular hitchpoint 1.11

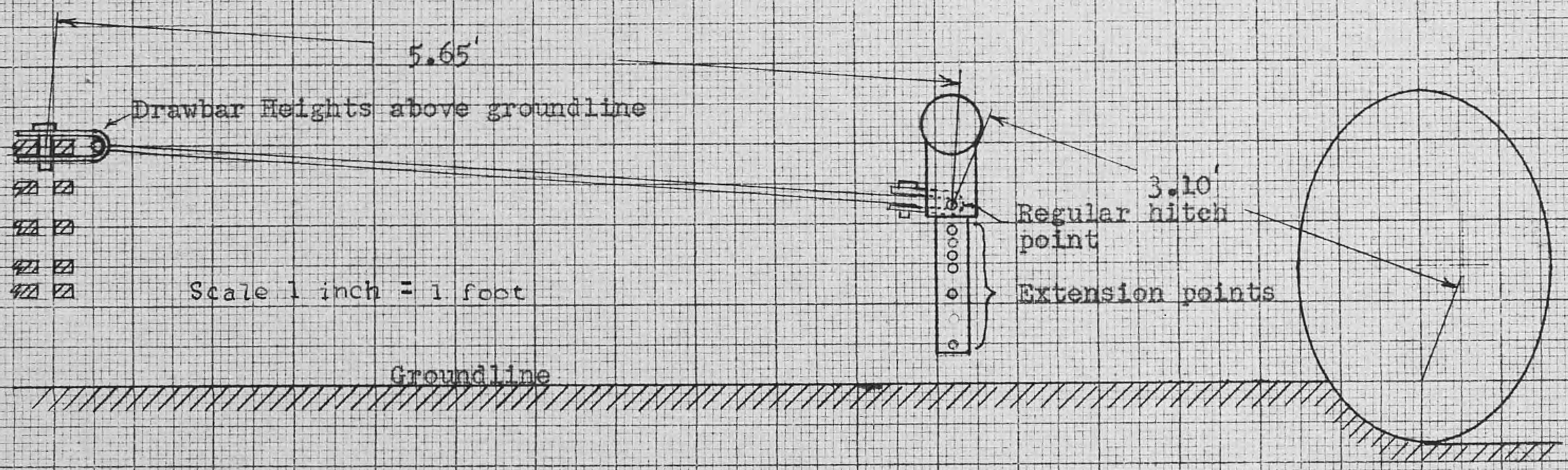


Fig. 5. Vertical hitch diagram, showing tongue hitch points on plow and drawbar heights.

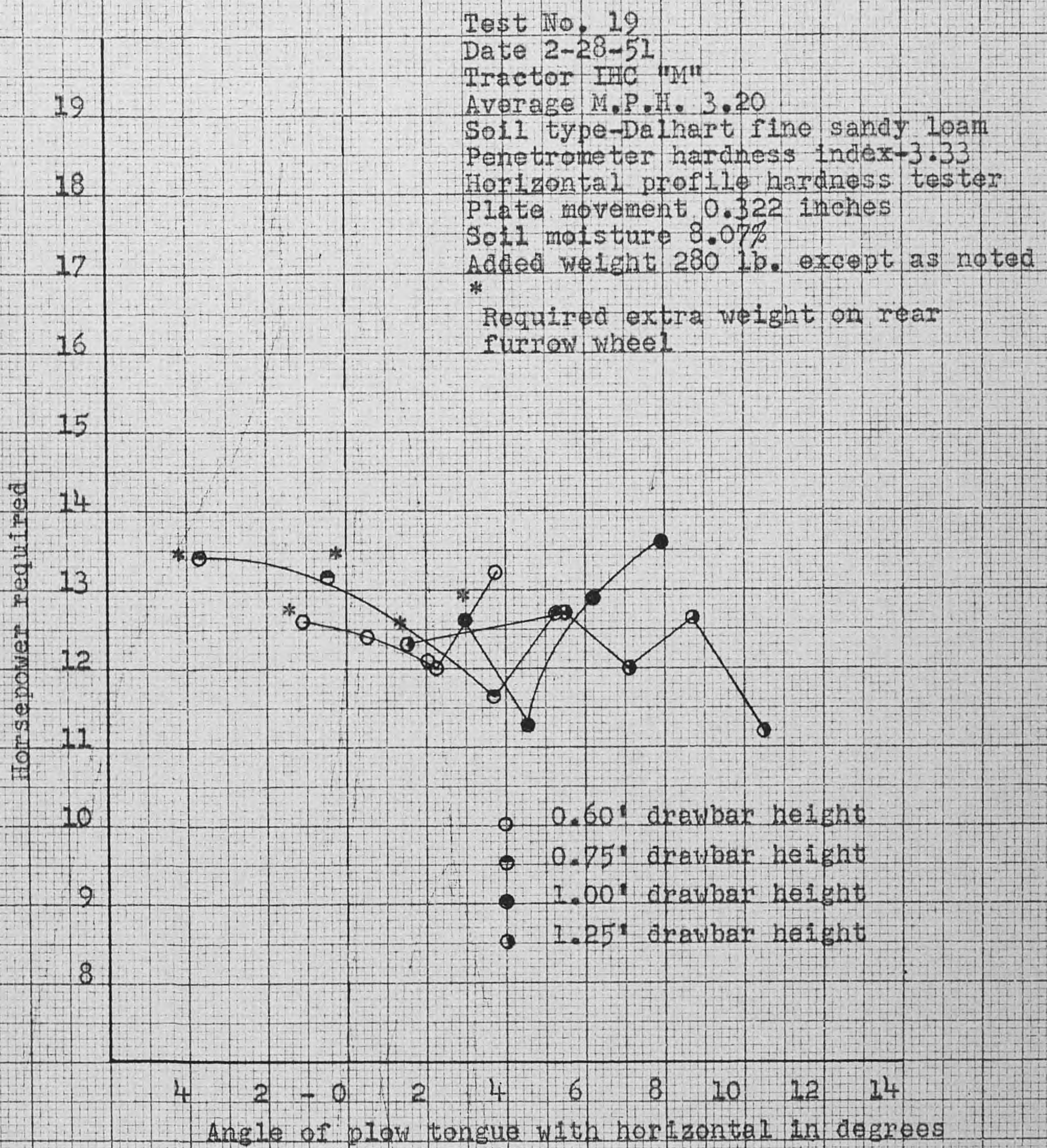


Fig. 6. Relation between horsepower required to pull plow and angle of plow tongue with the horizontal in degrees.

feet above the ground. The three lowest holes are 2 inches apart and the 4 upper holes are one inch apart.

This extension makes possible a greater variation in the angle of the force PV, with the horizontal.

In Fig. 6 the results of changing the angle of the pulling force is compared with the horsepower required to pull the plow at a depth of 0.4 feet and a width of 4.85 feet. The dynamometer draw-bar height was held constant for each series of trials beginning in the lowest hole of the extension and being moved upward for each successive run. Note that the horse power required is high at the largest angle observed and as the angle decreases, the horse power requirement becomes less until a minimum is reached and then rises. This appears to be caused by a shifting of forces on the disks in such a manner as to cause a major portion of the side-thrust S, to be carried by the back side of the disk blades against the furrow wall. Clyde (2) reports observation of this occurrence under certain conditions. It was also noticed that when a high draw-bar angle was used, there appeared to be little side-thrust on the rear furrow wheel, and as the angle was decreased the rear furrow wheel seemed to receive more of the side-thrust. The points marked with an asterisk (*) indicate tests which required extra weight in the weight box to hold the rear furrow wheel in position. The points near the horizontal line that show a marked decrease in required horsepower were caused by the rear furrow wheel leaving the furrow one or more times, thus decreasing the depth of plowing and power requirement.

Note that the general shape of the 1.25 foot draw-bar height curve is different from the others. This may be due to two reasons; first, the 10° 20' reading may be too low, due to an error in recording the power requirement or, there is a possibility that the soil condition was similar to that in Fig. 7. There is a marked similarity in this curve and the curves for the higher draw-bar heights. Comparison of the two tests shows that in general; Test 19 has a lower mean power requirement occurring at a smaller tongue angle than Test 20.

The vegetative cover in the field used for these tests was sudan grass stubble. The soil was well consolidated due to cattle grazing in the field during the summer months. The soil type was Dalhart fine sandy loam.

Variable Vertical Angle, Constant Speed Draft Tests

During Tests No. 19 and 20, considerable slippage was noted, especially at the hitch combinations producing the greatest draft. A decision was made at this point to pull the plow at as nearly a constant speed as possible. Four miles per hour was selected for this speed. Several plow instruction manuals state that this speed is the optimum for their plows.

An International Harvester Company Model TD-14 tractor was used for these constant speed tests. The tractor speed was determined by measuring the length of the recorder paper strip for an elapsed time of one minute during practice plowing trials. The throttle stop on the tractor was adjusted until the ground travel was 352 feet per minute or 4 miles per hour.

The field used in Tests No. 19 and No. 20 was not available for plowing when the constant speed tests were made. The field used was plowed early in September of 1950 and had no other treatment other than settling and compacting effect of the rainfall. The soil type was Dalhart clay loam. It was not as hard nor as well consolidated as the Dalhart fine sandy loam.

Tests No. 23 and No. 24 (Figs. 8 and 9) were made at nearly constant speed and the depth of cut maintained as nearly as possible at 0.4 feet. The width of cut was 4.85 feet as in previous tests. The plotted data shows the relation between horsepower required and angle of plow tongue in degrees to be of the same general nature as those in Tests No. 19 and No. 20. The chief difference is that there is a greater difference in the maximum and minimum horsepower requirements due to the elimination of most of the slippage. The reason for the greater horsepower requirement in Test No. 24 than Test No. 23 is questionable. Test No. 24 has a higher soil moisture percentage than Test No. 23. This condition would normally indicate less horsepower requirement. The probable reason is a greater soil resistance. Insufficient soil hardness and soil structure data was taken on these tests to substantiate this reason.

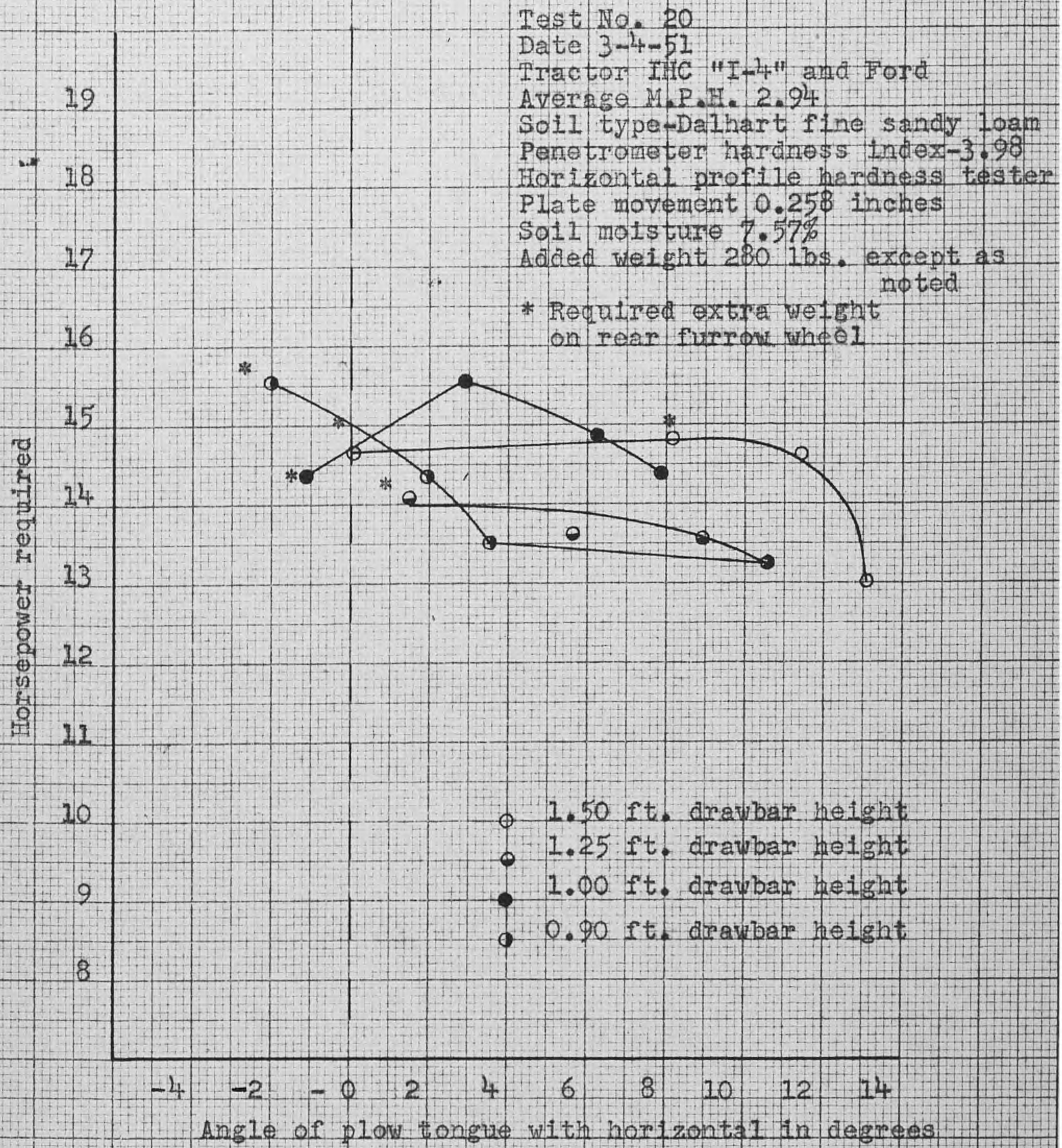


Fig. 7. Relation between horsepower required to pull plow and angle of plow tongue with the horizontal in degrees.

Constant Angle, Variable Drawbar Height Draft Tests

Figure 10 was prepared from the data taken from Tests Nos. 19, 20, 23, and 24. It shows the relation between the horsepower required to pull the plow and the height of the plow end of the tongue above the ground line in feet, with the tongue at a constant angle of 3° 45' with the horizontal. This is the angle that the tongue makes with the horizontal when the drawbar height is 0.6 ft. and the tongue is in the lowest extension hitch point. (Fig. 5.) These curves are of the same general shape, with the exception of Test No. 20. If additional data had been taken, it would probably show the same characteristics as the others. Note that under different soil and moisture conditions and varying speeds, the point of minimum horsepower requirement for these observations is a plow hitch point between .460 and .585 feet above the ground line.

Optimum Drawbar Height Draft Tests

Figure 11 shows the effect of vertical adjustment of the drawbar on horsepower requirement at the indicated plow tongue adjustment points. These curves are similar with the exception of the No. 1 hitch point curve. The 1.5 foot drawbar height point appears to be either too low or an error was made in its observation and computation. From this information it appears that the optimum drawbar height for minimum horsepower requirement

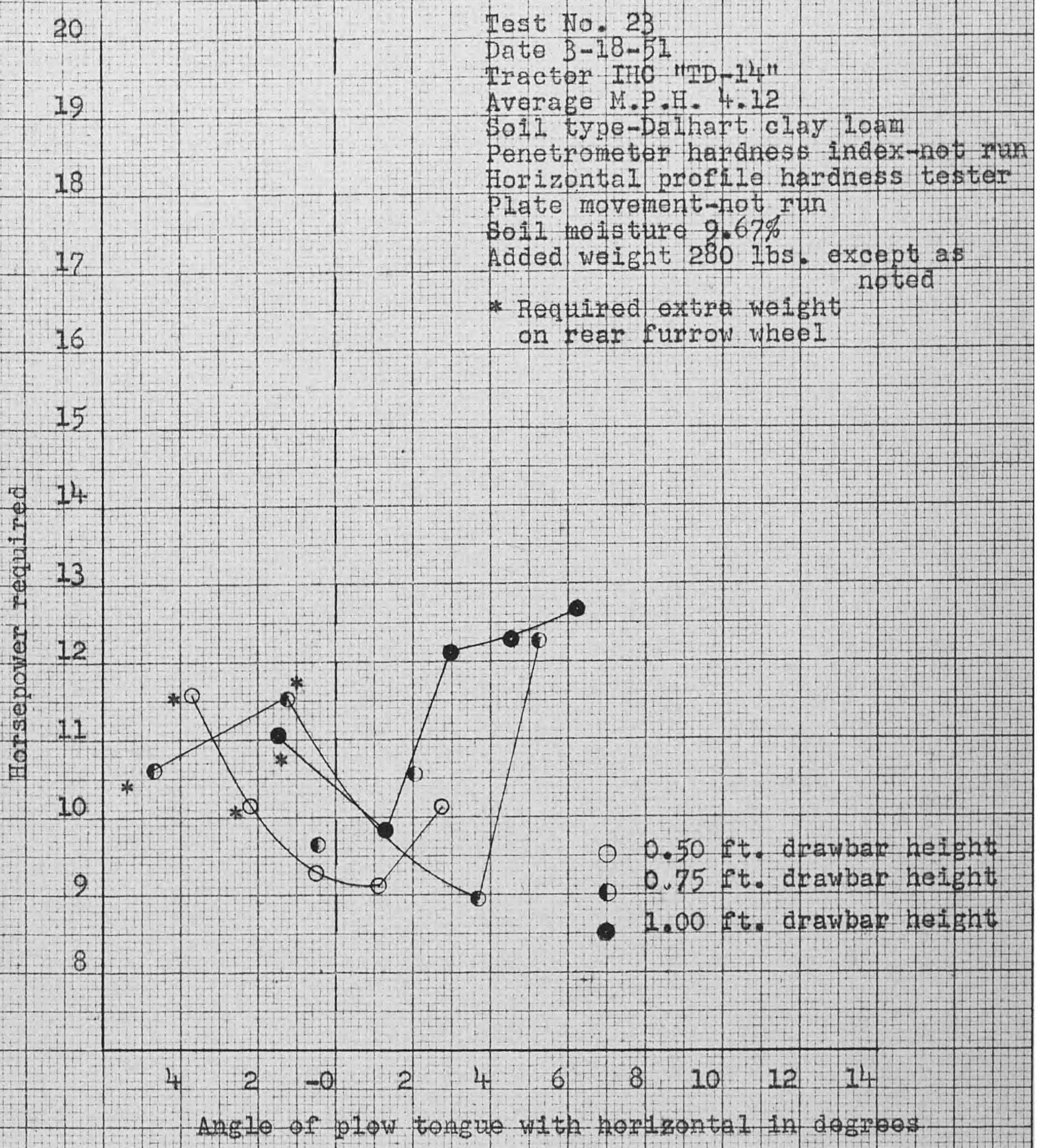


Fig. 8. Relation between horsepower required to pull plow and angle of plow tongue in degrees.

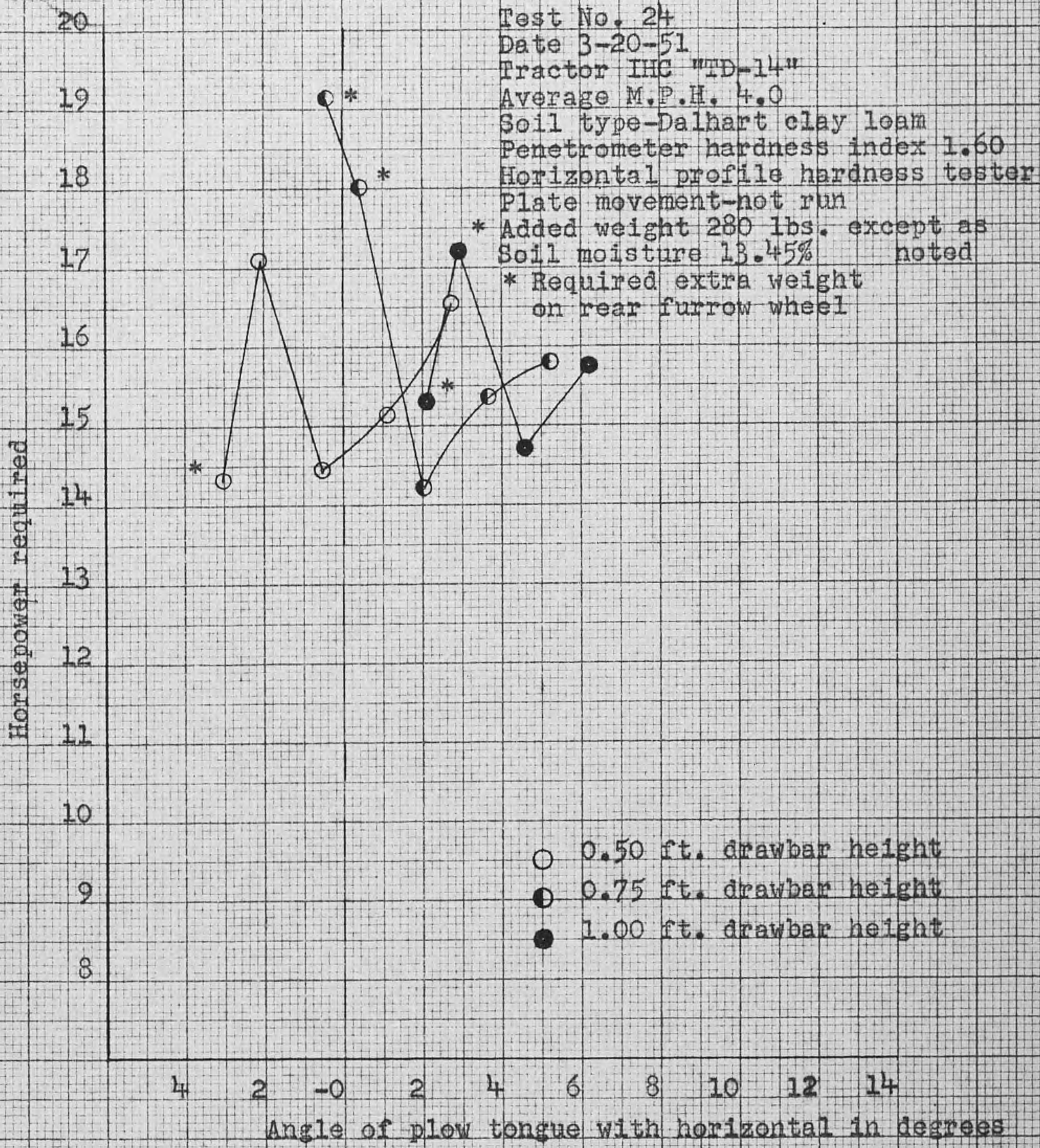


Fig. 9. Relation between horsepower required to pull plow and angle of plow tongue in degrees.

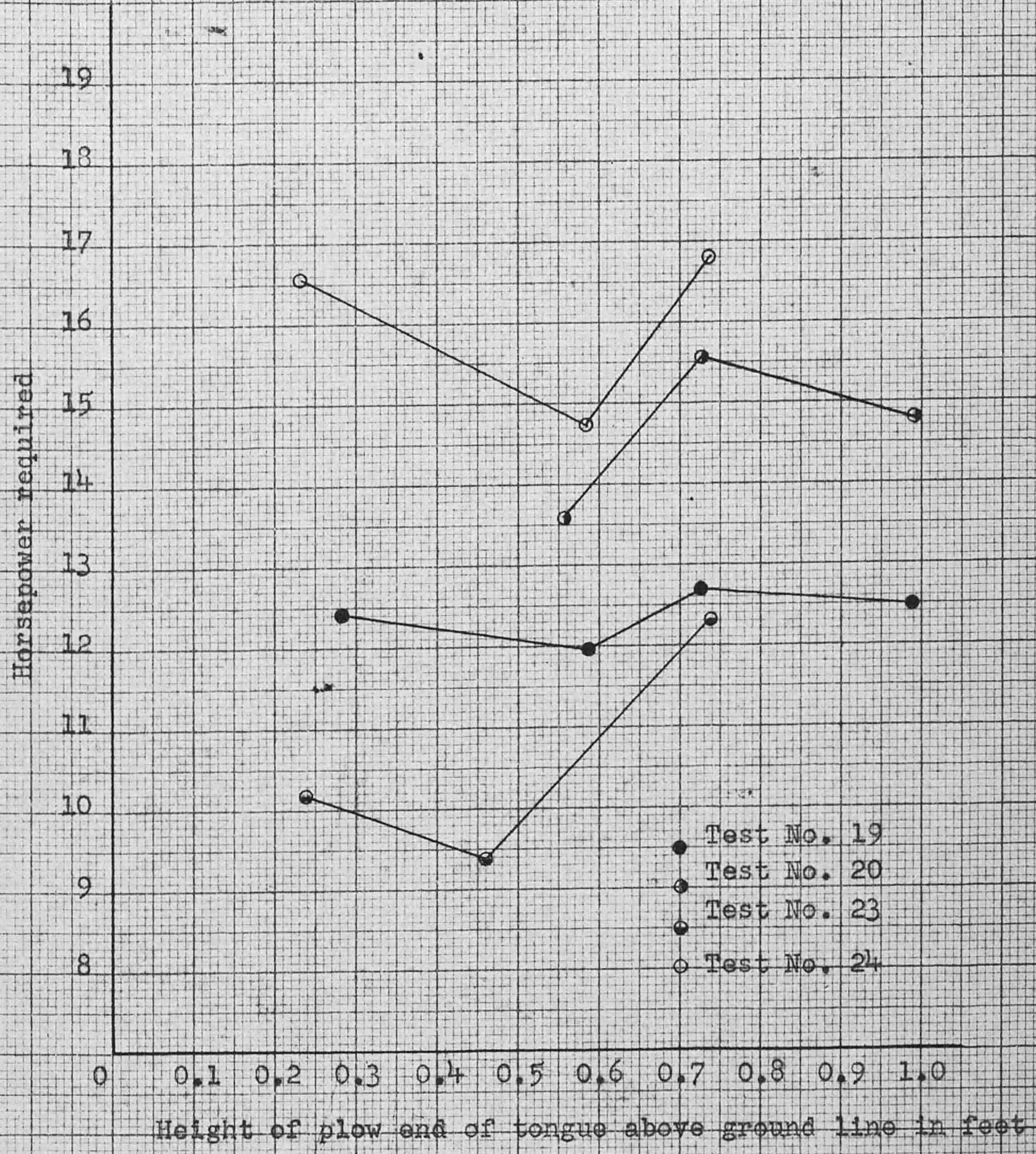


Fig. 10. Relation between horsepower required to pull plow and height of plow end of tongue above ground line in feet at constant angle.

is 1.25 feet. The lower plow tongue hitch points show an advantage in less draft than the regular hitch.

In order to further determine the effect of vertical hitch adjustment on horsepower required to pull the plow, Test No. 25 was run. In this test, a high and a low drawbar height was used. The greatest possible range of plow tongue hitchpoints was used for each of the drawbar heights. The depth of cut and the width of cut was held as nearly constant as possible as in the previous tests. The same field was used in Tests No. 23 and 24. Care was taken to keep the individual trials as uniform as possible. Speed was constant at 4 m. p. h. Several trials were made for each hitch point and their mean value plotted in Fig. 12. These two curves have the same general trend as those in previous tests. A reduction in horsepower requirement as the plow tongue angle is decreased until a minimum is reached, and then an increase in horsepower requirement as the plow tongue approaches and passes the horizontal line. Note there is but little difference in the two mean minimum values for the 1.5 ft. drawbar height and the 0.6 ft. drawbar height. The most noticeable difference in the two curves is their shape. The 1.5 ft. draw bar height curve shows a relatively high horsepower requirement at the largest tongue angle observed, with a sharp decrease to the minimum. The curve then rises gradually as the tongue angle is decreased. In the 0.6 ft. drawbar height curve, there is a slight decrease in the horsepower requirement as the tongue angle decreases. After the minimum point is reached, the curve rises abruptly, reaching a higher maximum horsepower requirement than the 1.5 ft. drawbar height curve. The curve drops sharply as the rear furrow wheel came out of the furrow, reducing the horsepower requirement. The 1.5 ft. drawbar height would be better from a practical standpoint than the 0.6 ft. drawbar height. It does not change so rapidly, nor rise to as high a maximum as the 0.6 ft. drawbar height.

INTERPRETATION OF SOIL MOISTURE, SOIL HARDNESS, AND SOIL STRUCTURE DETERMINATIONS

Soil moisture samples were taken and per cent moisture computed on a dry basis as described previously. No definite relationship was found between the horsepower required to pull the plow and the per cent of moisture of the soil for the conditions tested.

The penetrometer was used to obtain a hardness index of the soil (Plate IV). This had previously been used by Promersberger (5), who reported a definite relationship between the soil hardness index and the draft requirement of summer fallow tools. However, when the soil is so hard that the penetrometer does not penetrate it to the plowing depth, its accuracy may be questioned. No definite relation between the hardness index and horsepower requirement was found.

In order to provide a measurement of soil hardness in the horizontal profile of the soil being plowed, the Horizontal Profile Hardness Tester was used. This method of measuring soil

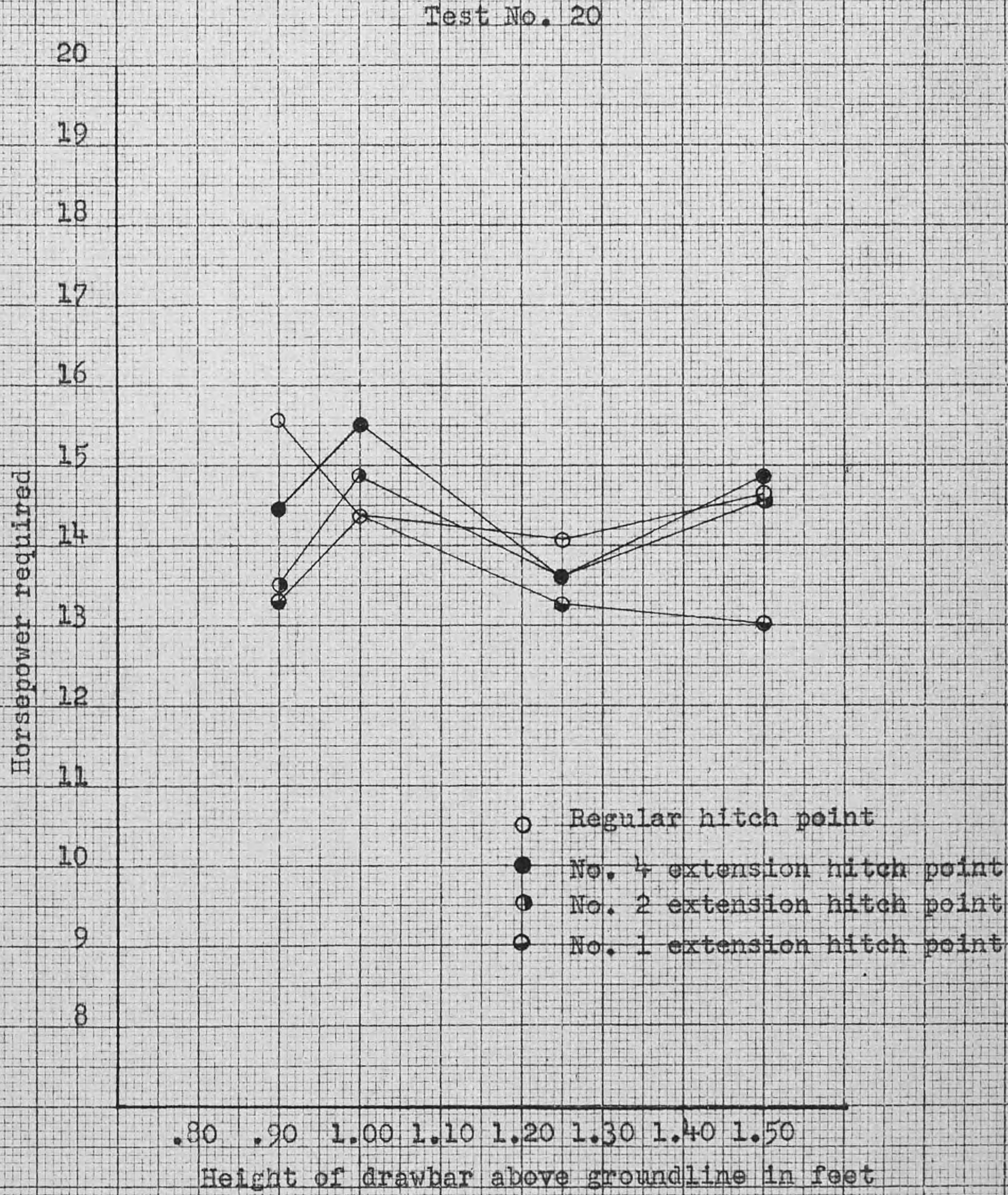


Fig. 11. Relation between horsepower required to pull plow and vertical adjustment of drawbar at indicated plow tongue adjustment points.

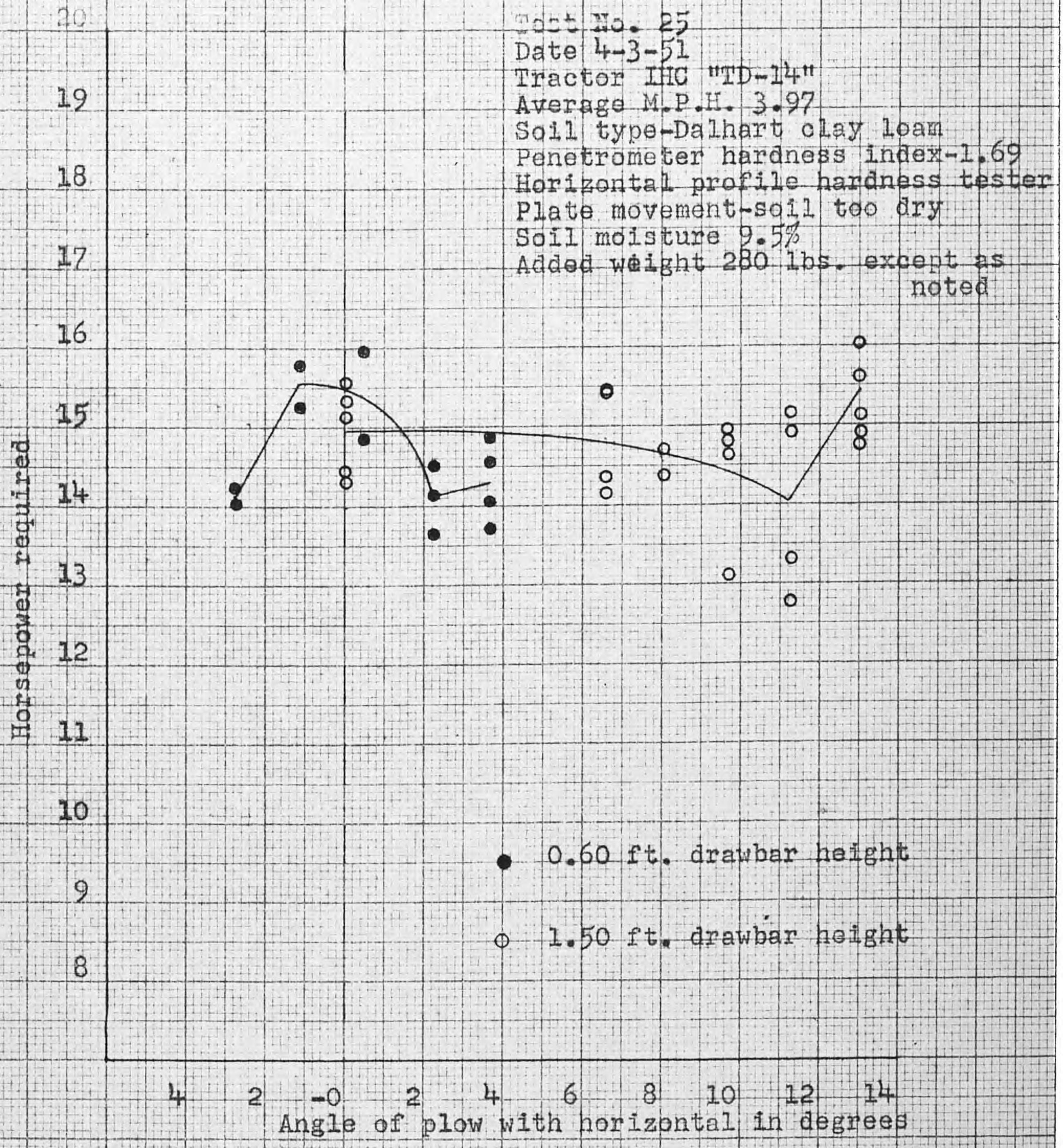


Fig. 12. Relation between horsepower required to pull plow and angle of plow tongue in degrees at 0.60 ft. and 1.50 ft. drawbar heights (mean of several tests).

hardness utilizes as an index, the distance a plate of known thickness is forced into the soil profile from the ground surface to the depth of plowing, by a constant force (Plate V). This plate movement was recorded for most of the tests made. The accuracy of this test is dependent upon securing a smooth auger hole in which to place the body of the tester. Under very dry and hard soil conditions, such a hole is difficult to secure, thus affecting the accuracy of the soil hardness measurement. Only two soil types were tested with a limited range of soil moisture contents. This data was insufficient to make a definite determination of its value as a method of testing soil hardness.

SUMMARY

1. Limited horizontal movement of the line of draft had little effect on the draft requirements of the one-way plow tested.

2. Variation in vertical tongue angle with the horizontal affected the horsepower requirement. A high tongue angle caused a high horsepower requirement. As the angle decreased, the horsepower requirement also decreased until it reached a minimum in the range of approximately 2 to 12 degrees. As the vertical tongue angle was decreased below this angle, the horsepower requirement began to rise. In some cases the rear furrow wheel left the furrow causing a sharp reduction in the draft requirement, in the low angle tongue position.

3. Variation in the vertical tongue angle in the constant speed tests produced similar results, with the exception that the range between maximum and minimum horsepower requirement was greater. This was due to the elimination of most of the slippage.

4. Comparative drawbar height and plow hitch point height draft tests indicate that the optimum drawbar height for all the plow hitch points used was 1.25 feet above the ground line.

5. Tests of high and low drawbar heights, in which the mean of several trials was determined, indicated the high drawbar height appeared to be more practical.

6. Insufficient data were taken, due to circumstance beyond control, to make any definite determination of the influence of soil moisture, soil hardness, and soil structure on the draft requirement of the plow tested.

ACKNOWLEDGMENTS

The author wishes to express appreciation to Professor F. C. Fenton and to Professor G. E. Fairbanks for their suggestions and assistance in directing this investigation. Indebtedness is also acknowledged to the Lubbock Implement Company and the C. H. Scales Implement Company of Lubbock, Texas, for the plows used in this investigation.

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THE INFLUENCE OF HITCH ADJUSTMENT, SOIL MOISTURE, SOIL HARDNESS, AND SOIL STRUCTURE ON THE DRAFT REQUIREMENT OF A ONE-WAY PLOW

by

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1951

In order to investigate, THE INFLUENCE OF HITCH ADJUSTMENT, SOIL MOISTURE, SOIL HARDNESS, AND SOIL STRUCTURE ON THE DRAFT REQUIREMENT OF A ONE-WAY PLOW, a hydraulic dynamometer, a penetrometer, a horizontal soil profile hardness tester and a depth gauge were constructed.

This investigation revealed the following relationships:

1. Limited horizontal movement of the line of draft had little effect on the draft requirements of the one-way plow tested.

2. Variation in the vertical tongue angle with the horizontal affected the horsepower requirement. A large tongue angle caused a higher horsepower requirement. As the angle decreased, the horsepower requirement also decreased until it reached a minimum in the range of approximately 2 to 12 degrees. As the vertical tongue angle was decreased below this angle, the horsepower requirement began to rise. In some cases the rear furrow wheel left the furrow causing a sharp reduction in the draft requirement, in the low angle tongue position.

3. Variation in the tongue angle in constant speed (4 M. P. H.) tests produced similar results, with the exception that the range between maximum and minimum horsepower requirement was greater. This was due to the elimination of part of the slippage.

4. Comparative drawbar and plow tongue hitch height draft tests indicate that the optimum drawbar height for all the plow hitch points used was 1.25 feet above the ground line.

5. Tests of high and low drawbar heights, in which the mean of several trials was determined, the high drawbar height appeared to be more practical.

6. Insufficient data were taken to make any definite determination of the influence of soil moisture, soil hardness, or soil structure on the draft requirement of the plow tested.