Test Procedures for Agricultural Equipment

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Technical Manual No. 8

INSTITUTE OF AGRICULTURAL RESEARCH
Test Procedures for Agricultural Equipment
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Moldboard Plow
Disk Plow
Disk Harrow
Leveler
Ridger
Foreword

Agricultural equipment should be tested before they are introduced to the agricultural community. The technical suitability, durability and interchangability of an equipment can be duly confirmed after undergoing a thorough evaluation. To assess these qualities standard test procedures are essential to safeguard users, to give feedback to manufactures, and to help educational institutions in training their students.

Furthermore, it will help policymakers set the cutoff line as to the kind and quality of agricultural equipment intended to be introduced to the farming community, where resource is scarce and needs wise utilization and tight control.

The Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR) has taken the initiative and put a substantial effort in the preparation of the first document. Various related organizations, through their delegates at the technical meetings, have dealt with it thoroughly to give the document its present shape. However, this document is just a beginning, which means it may undergo periodic updating. IAR appreciates this pioneer effort and encourages the initiators to develop more test procedures for equipment that are not included in this volume.

Tadesse Gebremedhin (PhD)
General Manager, IAR
INTRODUCTION

The sound functional suitability, efficiency, and longevity of any equipment should be assessed before it is distributed for use. Such assessments need standard test procedures that can be interpreted wherever the test is to take place.

Taking the above into account, and based on the mandate given to the Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR), to test all sorts of agricultural equipment, the first draft of test procedures was prepared and attuned on-station by AIRIC staff. Then, it was presented to the Technical Committee’s first meeting held in Addis Abeba at IAR on 3–6 September 1990. The draft was then thoroughly analyzed and all the necessary amendments were incorporated into this final document.

The test procedures were intended for use in technical, laboratory and field performance evaluation of both tractor- and animal-drawn moldboard plows.

SCOPE

This document recommends the methods and procedures for testing moldboard plows with regard to performance in field operation and soundness of construction. The test procedures can be used for both tractor- and animal-drawn plows.

TERMINOLOGY

The following definitions are given for terms used in this manual.

Angle of penetration: is the angle of inclination of a share in the direction of travel when placed on a flat surface and in a working position.

Edge clearance: is the maximum clearance between the cutting edge, the line-joining point, and the wing of share.

Horizontal suction: is the horizontal clearance that a straight edge makes with the line joining the share and heel of the landside.

Size: is the perpendicular distance from the wing of share to the line-joining point of the share and the heel of landside when the share is fixed on working position.

Soil inversion: is the process through which the furrow slice is inverted during plowing.
Throat clearance: is the vertical distance from the underside of the share to the bottom of beam.

Vertical suction: is the vertical distance the share makes with the ground when the tip of the share and the heel of the landside touch the ground.

Unit draft: is the value obtained by dividing the draft by the cross-sectional area of the furrow made by the plow.

**TECHNICAL INVESTIGATION**

The technical investigation of the plow will be conducted to see if there are some visual damages, poor workmanship, availability of safety devices and compatibility of the equipment with the available power unit. This will be judged by using a form (Appendix 1).

**LABORATORY TEST**

The objectives of conducting laboratory tests are:

- To test and verify the specification of the plow as claimed by the manufacturer
- To determine the quality standards of the materials used to make the plow

**SPECIFICATION PARAMETERS**

- Name of test organization
- Name and address of manufacturer
- Name and address of distributor
- Name and address of test applicant
- Types of sample
  (a) prototype
  (b) random sample
- Number of plow bottoms
- Source of power
  (a) tractor type, model and horse power
  (b) animal type and hitching height
- Type of share
- Type of moldboard
- Landside
  (a) is it part of the frog or separate?
  (b) is it the heel part of the landside or is it detachable?
  (c) size (thickness, length, width)
- Standard
  (a) type (shape, material)
  (b) location
- Beam
a. tractor-drawn
   - size (height, width, length)
   - shape
   - material
b. animal-drawn
   - size (height, width, length)
   - shape
   - material

- Handle (animal-drawn)
  a. number
  b. material
  c. grip height (range)
  d. size and shape
  e. grip diameter

- Clevis
  a. vertical
  b. horizontal

- Type of hitching
  a. mounted
  b. trailed
  c. semi-mounted

- Hitching pin
  a. pin diameter
     - top link
     - lower link
  b. pin length
  c. material

- Cross shaft
  - cross-sectional shape and dimension

- Attachments provided
  a. gauge wheel
  b. coulter
  c. jointer
  d. braces
  e. hook
  f. others

- Rear furrow wheel
- Front furrow wheel
- Size of plow and its width of cut

- Suction
  a. vertical suction
  b. horizontal suction

- Adjustment provided for:
  a. depth and range of adjustment
  b. width and range of adjustment

- Throat clearance on working position
Angle of penetration
Size of different bolts, nuts and bearings
Total weight
Overall size (length, width, height)
- working position
- transport position
Ground clearance
  (a) transport position
  (b) trash clearance
Number of greasing points

While recording the laboratory test/data, any deviations from the manufacturer's claim must also be recorded and reported along with the specifications of the manufacturer.

CONSTRUCTION MATERIALS AND THEIR HARDNESS/STRENGTH

The hardness of the following components of the moldboard plow can be determined using the Rockwell Hardness Tester. Uniformity of hardness should be analyzed and then will be compared to the recommended value.

Share: The hardness of the cutting edge (bevelled part) of the share will be measured along the cutting width at least at five evenly spaced points; the hardness of the body of the share will also be measured at five randomly selected points.

Moldboard: Hardness measurements of the moldboard will be taken at five randomly selected points over the moldboard body.

Landside: The hardness of the landside will be measured by taking measurements at five randomly selected points on the landside.

Frog: The hardness of the frog should be measured at five randomly selected points on the frog.

All hardness measurements should be recorded on a specially prepared sheet (Appendix 2).

DIMENSIONAL ANALYSIS OF PARTS SUBJECTED TO WEAR AND TEAR

Weight of share: Weight of share should be measured before field tests are conducted and after durability is assessed in field tests using standard weight tests.

Alignment of parts: The details should be checked whether:

a. distance between two consecutive share points are equal
b. distance between two consecutive heels of landside are equal
c. all share points are in the same horizontal plane and lie in one straight line
d. beam of plow bottom are in the same horizontal plane  
e. all bearing points of each plow bottom are in one horizontal plane  
f. the landsides of a plow bottom are in one horizontal plane

**RUNNING IN**

A preliminary test should be conducted for at least 8 hr to see that the moving parts are in proper functional order and are convenient to polish the machine and to make the necessary adjustments before the machine is subjected to a field test.

**FIELD TESTING**

The field testing should be conducted with respect to the objective of assessing the performance of the machine and in line with the objective it is designed for—its technical suitability and its ease of manipulation. The data on this are recorded using the field data form given in Appendix 5.

**Site selection**

The test should be conducted on at least two types of soil—light and heavy soils. The field size should be 40 m x 10 m for the animal-drawn and 40 m x 200 m for the tractor-drawn equipment (Fig. 1.1). Data should be taken before testing, during testing, and after testing.

**Test condition**

The conditions under which the test is conducted have to be clearly defined. These include field condition, implement condition, power source condition, and operator’s condition. Field condition and subsequent operational measurements should be taken, as far as possible, at the same place in the testplot. Three samples in case of animal-drawn plows and five samples in case of tractor-drawn plows should be taken in a testplot.

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Figure 1.1. Field layout for tractor- and animal-drawn implements
The following field conditions should be checked, measured and reported.

a. plot size  
b. type of soil  
c. last crop grown  
d. date of harvest of last crop  
e. date and details of preceding tillage after last harvest  
f. topography of the field and its slope  
g. soil moisture percentage  
h. bulk density  
i. cone index  
j. shear strength  
k. weed condition (type, density, size, etc.)

Soil property measurement

(a) Soil moisture content

Core samples should be taken at 5-cm interval up to the plow depth. Three and five core samples for the animal-drawn and tractor-drawn plows respectively, at evenly distributed places in the test plot, should be taken for moisture content determination. In the laboratory each sample should be taken out of the core sample and be thoroughly mixed. From the mixed sample, a smaller sample of 25–35 g should be taken for determining soil moisture content by standard oven-drying method (i.e. drying the soil at 103°C). Soil moisture content on dry weight basis is calculated using the following formula.

\[
\text{Soil moisture, dry basis (\%)} = \frac{\text{wt. of wet - wt. of dry soil}}{\text{wt. of dry soil}} \times 100
\]

Bulk density

Cylindrical core samples (or any defined volume) should be taken from the test plot; if the samples taken for soil moisture determination are taken using a sample of defined volume, the bulk density would be calculated from the moisture samples. The bulk density is calculated as follows.

\[
\text{Bulk density, dry basis (g/cm}^3\text{)} = \frac{M}{V}
\]

where \(M\) = mass of dried soil; \(V\) = volume of core sample

For cylindrical core sample, the following formula is used to calculate bulk density.

\[
\text{Bulk density, dry basis (g/cm}^3\text{)} = \frac{4M}{\pi D^2 L}
\]

where \(M\) = mass of dried soil; \(D\) = internal diameter of core sample; \(L\) = length of core sample
Cone penetrometer reading

A cone of 30° included angle, with the larger diameter being 20.3 mm giving a cross-sectional area of 3.22 mm² or any other standard cone, can be used. The value of resistance to penetration can be obtained using a calibration chart or can be calculated from the readings. The field measurements should be taken by reading. The reading instruments and the subsequent calculation should be done in the office. Cone penetrometer readings will be taken vertically to the depth of plowing. In case of sandy soils, the measurement can be taken by pushing the cone vertically into the soil up to its base only. Cone penetrograph can also be used to measure the depth in a form of graph.

It must be noted that for a meticulous assessment of the penetration resistance to the measuring instruments the instructions given on the operation manual, accompanying the instruments, should be followed.

Soil shear strength

Commercially available soil shear meter should be used to measure soil shear strength. The measurements should be taken following the instruction manual of the instrument.

Weed condition

The condition of weeds in the testplot has to be described in terms of size, species and density. Where applicable, the weed count can be done by using a wooden or angular iron form of square shape 1 m sidedivided into four equal parts (Fig. 1.2). The biomass of the weed or the trash in the field can also be measured by taking samples using this frame. The data will be taken before and after the test.

Figure 1.2. Weed sampling frame
Working width

A width meter is used to determine the working width. About 3 m is measured from the end of the plowed strip to the unplowed land and a peg is placed on the unplowed strip. After the tractor passes that line, the unplowed strip is subtracted from the previously measured strip. This is repeated over the whole sample. The average will give the working width. Uniformity will be measured by calculating the coefficient of variation.

Working depth

A width meter is used to determine the working depth as well. The profile meter contains a horizontally drilled bar with 20 holes for letting through pins that are used to measure the depth of furrow configuration. The equipment has a water level to keep it horizontal. Once the apparatus is in place, the equipment is placed on the furrow that is first marked before the land is plowed. The plowed soil is removed from the furrow until a clean furrow bottom appears making sure that the plowed land is not excavated. The equipment with the pins is placed on the plowed land checking the level so that it is put perfectly horizontal. The length of pins above the bar is measured. The difference between the length of the pin at the corresponding measured distance above the bar gives the furrow depth. The maximum depth recorded is taken as the maximum depth. Uniformity will be assessed by calculating coefficient of variation.

Furrow profile

The depth of the furrow is plotted against the corresponding horizontal distance starting from zero at one end using a square paper.

The area of the furrow profile is determined by counting the number of squares or by using planimeter if available. The area of the furrow is divided by the width to determine the average depth.

Evenness

Plowing evenness is calculated by dividing the average depth of plowing by the standard deviation.

Speed

Two sets of poles, AA and BB, are put in the test plot as shown in Fig. 1.3. The time taken by the plow to cover the marked distance between the two lines AA and BB is noted five times with the help of a stopwatch. Arithmetic average of the five readings is used to calculate the speed in m s\(^{-1}\).

Power requirement

a. Trailed plow

Insert a dynamometer in the hitch to measure the draft. If the line of pull is not horizontal, the angle of pull should be measured and the draft will be calculated as follows.
Draft = pull \times \cos \theta

For field measurement of draft, a 100 m (or other defined length) distance should be marked in the middle of the long row using two pegs.

The plow should be operated over the defined row length and draft measurement should be taken. At the same time, the time taken to traverse this defined row length should be noted to determine the speed of travel. The draft measurements, as far as possible, should be taken around the points where field condition measurements and furrow shape and size measurements are taken.

b. Mounted tractor-drawn plow

Over the defined row length, another auxiliary tractor should be used to pull the implement-mounted tractor. The later tractor should be in neutral gear with the implement in operating position. Two draft measurements, one when the plow is in operating position and the next when the plow is lifted off the ground, should be taken in the same row. The draft requirement of the plow can be calculated by subtracting the draft measured while the plow is lifted off the ground from the draft measured while the plow is operating.

Slip

The slip of tractor will be measured by making a mark on the drive wheel of the tractor (Fig. 1.4) and the distance the tractor traveled in 10 revolutions of the drive wheel with no load (A) and with load (B). The slip will be calculated by using the following formula.

\[ Slip(\%) = \frac{A-B}{A} \times 100 \]
Unit draft

The unit draft will be calculated by dividing the draft by the cross-sectional area of the furrow (N/cm²).

Qualitative assessment of work and operation

A subjective assessment should be made on inversion and pulverization of soil, evenness of plowed land, condition of tractor, etc. during and after field test.

Ease of operation

This should include:

a. stability of implement
b. ease of turning, control and adjustment
c. safety

Soundness of construction

During the entire period of testing, complete record of defects and breakdowns should be recorded to indicate the soundness of construction.

Operator's assessment

The operator should be asked to give his opinion about the operation of the plow.
Labor requirement

This must include:

a. total man-hour of operator at test and per hectare
b. total man-hour of unskilled labor at test and per hectare

ENERGY REQUIREMENT

Specific energy

The specific energy is expressed as the energy per volume of soil worked. The sample average draft is multiplied by 1 m and the average sample profile area is multiplied by 1 m. Multiplying both the numerator and the denominator will give energy in the numerator and volume in the denominator. This will give energy per volume worked.

Fuel consumption

The power unit is filled with fuel before the test starts and after it is completed. The amount required to fill the tank after the operation is recorded as fuel consumed during operation. Based on the specification of the engine (liters/kWh), the equivalent fuel energy consumed (kWh) is calculated.

Soil inversion

The soil inversion shall be measured using the following methods.

a. Virgin (fallow land). For virgin or fallow land, the soil inversion will be determined by giving the percentage of the inverted furrow slice.

b. Animal-drawn plow. For a plot plow using animals, the soil inversion will be determined by giving percentage furrow slice inversion and by measuring the unplowed land in the testplot.

c. In the case of sandy soils and places where it is difficult to determine inversion, using the former two methods described in (a) and (b), the biomass method will be employed; i.e. measuring the weight of weeds or trash in the testplot before and after plowing and putting these in percentage.

\[
\text{Inversion(\%)} = \frac{\text{wt. before plowing} - \text{wt. after plowing}}{\text{wt. before plowing}} \times 100
\]

DETERMINATION OF FIELD CAPACITIES OF MACHINES

The machines are grouped into two: tractor-drawn and animal-drawn.
Tractor-drawn implements (machines)

The actual field capacity (AFC) of a machine or an implement is defined as follows:

\[ AFC = Wa \times Sa \times Te \]

where \( Wa \) = working width; \( Sa \) = working speed; \( Te \) = time efficiency

Working width (Wa)

The working width will be determined by taking successive measurements during field test, as shown in Fig. 1.5.

As shown in Fig. 1.5, the distances of the consecutive furrow walls from three reference points that are located at the end of the field and along its length will be successively measured using a tape. The algebraic difference between each pair of the consecutive readings will be taken as the working width of a single pass. The number of such passes should be at least 10. Overlaps and unworked areas might occur, though the chances of the latter are very rare in tractor-drawn implements or machines. To determine whether there are overlaps or unworked areas in the field the different working widths should be checked against a single figure of the working width measured in the absence of overlap and unworked area. This figure will be determined from the furrow profile plotted during the test for soil cutting efficiency. Any figure greater than this will have to be discarded as it indicates the presence of unworked area. Moreover, the number of such figures and their magnitude have to be separately reported as an indication of the quality of work. Thus the average of the remaining figure gives the working width (Wa).

Figure 1.5. Measurement of working width
Working speed

The best gear at which the tractor works comfortably has to be selected prior to the commencement of the test. The net working time between engagement and disengagement of the implement or the machine in work will be recorded. The distance traveled in each case will be recorded and divided by the corresponding net time. The average of this figure will be the working speed (Sa).

Time efficiency

During field test, the various components of working and stoppage times (as listed below) will be recorded. Then, the time efficiency will be calculated using the following formula.

\[ Te = \frac{\text{net working time (no.4)}}{\text{total time with the range 4 - 9}} \times 100\% \]

The following list describes the time elements that involve labor that are associated with typical field operations and that should be included when computing the capacities or costs of machinery related to the various farm enterprises.

1. Machine preparation time at the farmstead (includes removal from and preparation for storage, and shop work)
2. Travel time to and from the field
3. Machine preparation time in the field both before and after operation (includes daily servicing, preparation for towing, etc.)
4. Theoretical field time (the time the machine is operating in the crop at an optimum forward speed and performing over its full width of action)
5. Turning time and time crossing grass water-ways (machine mechanisms are operating)
6. Time to load or unload the machine if not done on-the-go
7. Machine adjustment time if not done on-the-go (includes unplowing)
8. Maintenance time (includes refuelling, lubrication, chain tightening, etc., if not done on-the-go does not include daily servicing)
9. Repair time (the time spent in the field to replace or renew parts that have become inoperative)
10. Operator's operating time

Animal-drawn implements or machines

The actual field capacity (AFC) of the implement or machine is calculated as follows.

\[ AFC = \frac{\text{total area} - \text{unworked part}}{\text{total time} - \text{stoppages}} \times S.F. \]

where \( S.F. = \text{speed} \)

Total area

The total area to be worked should be 10 m x 40 m.
Unworked part

Unlike tractors, animals cannot be controlled wholly during operation and there may occur unplowed land (unworked parts) in the field. To calculate the actual area covered, such parts have to be deducted by plotting profiles of samples in the field. This is done by taking elevation readings of points at 5 cm intervals over a 2 m length from reference line both before and after testing. There should be four such locations in the testplot.

Total time and stoppage

The total time of operation will be measured by recording the time over 20 m distance at the middle of the testplot. The normal speed at which a pair of Ethiopian oxen with a weight of about 600 kg can walk comfortably can be calculated from the draft requirement of the implements and, hence, the speed factor (S.F.) is defined as follows:

\[
S.F. = \frac{NS}{WS}
\]

where \( WS \) = the average speed measured during the test; and \( NS \) = the normal speed calculated for a pair of average Ethiopian oxen

**DURABILITY TEST**

The durability test will be conducted to assess the long-term use of the plow. The daily performance, defect and breakdown should be recorded. The performance test should be conducted by the user with frequent supervision of the test engineer, with the following parameters being recorded. A minimum of 250 ha should be plowed before a conclusion is made regarding the machine.

a. area plowed
b. total time of plowing
c. type of tractor
d. fuel consumption
e. breakdowns and defects
f. ease of operation
g. other problems
h. observations by the user

The data will be filled using the format in Appendix 7.
Appendix 1. Technical Investigation

1. Packing:  
good □ medium □ poor □

2. Visible damage:  
undamaged □ partially damaged □ damaged □

3. Weld:  
good □ medium □ poor □

4. Paint:  
good □ medium □ poor □

5. Guards of moving parts:  
adequate □ partially adequate □ none □

6. Protruded objects:  
safe □ medium □ unsafe □

7. Safety precautions:  
available □ medium □ not available □

8. Spare parts:  
adequate □ partially adequate □ none □

9. Hand tools:  
adequate □ partially adequate □ none □

10. Measuring instruments:  
adequate □ partially adequate □ none □

11. Time to assemble:  
short □ medium □ long □

12. Skill required to assemble:  
low □ medium □ high □

13. Quality of manual:  
   a. instruction  
good □ fair □ poor □
   b. operational  
good □ fair □ poor □
   c. service  
good □ fair □ poor □

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14. Provision for loading and unloading:
   available □  not available □

15. Coupling:
   convenient □  inconvenient □

16. Tightness of bolts, nuts and other fasteners:
   tight □  loose □

17. Adequacy of lubrication of bearings and other moving parts:
   adequate □  inadequate □

18. Provision for transportation:
   available □  not available □

19. Provision for adjustment:
   available □  not available □

20. Adequacy of hydraulic system:
   good □  fair □  poor □  not applicable □

Appendix 2. Data Sheet for Recording Hardness

<table>
<thead>
<tr>
<th>Name of part</th>
<th>Hardness sample</th>
<th>Uniformity</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moldboard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frog</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Instruments

All the equipment used for laboratory and field test should be listed as follows.

**Testing apparatus required**

**Laboratory**

- Calliper
- Oven
- Desiccator
- Weighing balance
- Hardness tester
- Vibrating sieves (set)

**Field**

- Sample tubes for soil moisture
- Tapes
- Sampler for clod size
- Bags and rigid containers for taking soil sample
- Stopwatches
- Pegs
- Pocket meter and ruler
- Dynamometer/dynamograph
- Paper, colored pencils, sticky tape, ballpoint pen, clip board, etc.
- Hammer
- Spanners (open and socket type)
- Mallet
- Counter
- Engineer’s level
- Ranging rod
## Appendix 4: Data Sheet for Dimensional Analysis

<table>
<thead>
<tr>
<th>Part</th>
<th>Measurement</th>
<th>Before test</th>
<th>After test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share</td>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance between two consecutive share points</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance between share points from the ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landside</td>
<td>Distance between two consecutive heels of landside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam</td>
<td>Distance of beam from the ground at plow points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td>Distance of bearings from the ground</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5. Laboratory and Field Test Data Form for Primary Tillage Implements

LABORATORY TEST

Implement:__________________ Date of test:__________________
Power source:__________________ Place of test:__________________

1. Bulk density of soil

<table>
<thead>
<tr>
<th>Bag no.</th>
<th>Wt. of core sampler, bag &amp; soil (g)</th>
<th>Wt. of core sampler &amp; bag (g)</th>
<th>Wt. of wet soil (g)</th>
<th>Wt. of dry soil (corrected)</th>
<th>Bulk density, wet base (g/cm)</th>
<th>Bulk density, dry base (g/cm)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Moisture content of soil

<table>
<thead>
<tr>
<th>Can no.</th>
<th>Wt. of empty can</th>
<th>Wt. of can &amp; wet soil (g)</th>
<th>Wt. of can &amp; dry soil (g)</th>
<th>Wt. of wet soil (g)</th>
<th>Wt. of dry soil (g)</th>
<th>Moisture content, dry base (%)</th>
<th>Moisture content, wet base (%)</th>
<th>Remarks</th>
</tr>
</thead>
</table>

**FIELD TEST DATA FORM**

Plot no.: ____________________________
Date of test: _______________________
Place of test: _______________________
Implement: ___________________________
Power source: _______________________ 
Description of topography and soil: __________
Condition of field and previous cultivation: ________________
Plot size: ___m length x ___m width
Gradient in direction: _____________________
Gradient: _____________________________
<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed in 1 m² area before operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confined (vertical) cone penetrometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Soil shear strength</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Bulk density sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Soil moisture sample</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Condition of tractor: ____________________________
Time of start of test: __________________________

<table>
<thead>
<tr>
<th>Time for __m work length (sec.)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>B Dynamometer readings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Plow in nonworking position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii) Plow in working position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C Angle of dynamometer link (°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ S \text{ Working speed (m/sec)} = \frac{\text{dist.}}{\text{time}} \]

Time for stoppage

<table>
<thead>
<tr>
<th>Sample</th>
<th>From</th>
<th>To</th>
<th>Total time</th>
<th>Reasons/remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

21
### Working width

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Furrow depths

<table>
<thead>
<tr>
<th>No</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fuel consumption: 

Time of test completion: 

Total number of furrow passes in the plot width: 

Weeds not destroyed after operation (in 1 m² area): 

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6 A: Data Collecting Form for Field Capacity of Tractor-drawn Plow

1.A. **Working Width with No Overlaps**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
</tbody>
</table>

1.B. **Working Width Related to Operational Pass (WA)**

<table>
<thead>
<tr>
<th>Reference points</th>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>Average (Wa)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Net Time Between Engagement and Disengagement of the Plow (Sa)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net time</td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>Distance travelled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Timetable**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical field time (net time)</td>
<td></td>
</tr>
<tr>
<td>Turning time and crossing waterways</td>
<td></td>
</tr>
<tr>
<td>Loading and unloading time of the machine</td>
<td></td>
</tr>
<tr>
<td>Machine adjustment time</td>
<td></td>
</tr>
<tr>
<td>Maintenance time</td>
<td></td>
</tr>
<tr>
<td>Repair time</td>
<td></td>
</tr>
<tr>
<td>Operator's operating time</td>
<td></td>
</tr>
<tr>
<td>Total time</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Time efficiency} = \frac{\text{net time}}{\text{total}} \times 100
\]

\[
\text{Field capacity} = Wa \times Sa \times Te
\]
Appendix 7. User Survey Form

Implement ________________________ Date ________________

1. GENERAL DESCRIPTION OF THE MACHINE

► Type: __________________________________________
► Prime mover: ____________________________________
► Supplier: ______________________________________
► Manufacturer's address: __________________________
► Date of supply of the machine: ____________________

2. CONVENIENCE OF OPERATION

► Transportation: _________________________________
► Control, turning, etc.: __________________________
► Ease of adjustment: _____________________________
► Quality of work: ______________________________
► Output (compared with others): __________________
► Required skill of operation: _____________________
► Compatibility: ________________________________

3. PROBLEMS ENCOUNTERED

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Problem</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

25
4. Breakdowns

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Part broken</th>
<th>Reasons for breakdown</th>
<th>Consequences</th>
</tr>
</thead>
</table>

5. Repairs

- Availability of spare parts
  - local
  - imported

- Place of repair
  - local
  - external (specify the distance)
  - skill required
  - specialization
  - experience
  - fair knowledge
6. Unused Machines

<table>
<thead>
<tr>
<th>Reason</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>No use in the season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of repairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of spare parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of prime mover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of other better-performing machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty to operate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Operated Hours (Estimated)

8. Acceptability

- Estimate the price
- What group do you recommend it for?
  - a. individual farmers (small scale)
  - b. large scale

9. Improvements

- suggest the necessary modifications in detail

10. Remarks
INTRODUCTION

The functional suitability and soundness of construction of any equipment should be assessed before it is distributed to the user. Such assessments need a standard test procedure that can be interpreted wherever the test is conducted.

Taking the above into account, and based on the mandate given to the Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR) to test all sorts of agricultural equipment, the first draft test procedures was prepared and attuned on-station by AIRIC staff. Then it was presented to the Technical Committee’s first meeting held in Addis Abeba at IAR, 3-6 September 1990. The draft was then thoroughly discussed and all the necessary amendments were incorporated into this final document.

The test procedures were intended for technical, laboratory and field performance evaluation of both animal- and tractor-drawn disk plows.

SCOPE

This test procedure recommends the methods and procedures for testing disk plows. The procedure encompasses methods of assessing soundness of construction and laboratory and field performance of the equipment.

TERMINOLOGY

Vertical angle: the angle measured counter-clockwise from the vertical to the position of the disk.

Horizontal angle: the angle which the horizontal diameter of the disk makes with the direction of travel.

Concavity: the radius of the hollow sphere that the disk is a section of.

Unit draft: the draft per unit cross-sectional area of the furrow.

TECHNICAL INVESTIGATION

The technical investigation of the plow will be conducted to see whether there is any visual damage—poor workmanship, availability of safety devices, and incompatibility of the equipment with the available power unit. This will be judged using the form in Appendix 1.
LABORATORY TEST

The objectives of laboratory test are:

a. To study and verify the specification of the plow as claimed by the manufacturer
b. To determine the standard of the materials of construction of the plow

Specifications

- Name of test organization
- Name and address of manufacturer
- Name and address of distributor
- Name and address of test applicant
- Types of samples
  a) prototype
  b) random sample
- Plow weight and dimension
- Clearance
  a) transport height
  b) trash clearance
- Source of power
  a. tractor type
  b. animal type
- Disks
  a. diameter of disks
  b. number of disks and fixing holes
  c. disk angle
    i. vertical
    ii. horizontal
- Description of frame
- Disk support
- Scrapers
- Furrow wheel
- Plow support
- Photograph or sketch of equipment be attached

MATERIAL OF CONSTRUCTION AND HARDNESS

Hardness of the ground engaging parts should be determined. The parts here will be the hardness of the disk and the scraper.

Disk: Five concentric circles should be made on the surface of the disk at 30 mm interval. Then the hardness will be measured at five places on each circle and on the same radial lines using the Rockwell Hardness Tester. The data will be recorded using the form in Appendix 2. The uniformity on each circle and the variation along the radial lines will be analyzed.
Scraper: The hardness on the scraper will be determined by taking at least five points on the first 40 mm of the cutting edge using the Rockwell Hardness Tester.

**DIMENSIONAL ANALYSIS OF PARTS SUBJECTED TO WEAR AND TEAR**

These details should be taken before the machine is ready for field operation and after the durability test is completed using the form in Appendix 4.

Details to be checked

*Disk*: The weight, diameter and thickness of the disk should be measured using a standard weight, a measuring tape and a calliper respectively.

*Measurement of concavity of the disk*: The disk is placed on a level surface and four cord points are marked at 45° to one another on the disk ends. Placing a straight rule on the cord points, 8–12 points are marked on the disk surface at 5-cm interval. Then, starting from one edge the distance of these points from the plane of the rule to the disk surface is determined. The procedure is then repeated for the other three cords. After taking the data, the distance of these points from the ruler’s plane is plotted against the horizontal distance and a tangent is drawn at any two points. The radius of the curves will be averaged for the four plots to obtain the concavity of the disk.

*Scraper*: The weight and thickness of the scraper’s cutting edge will be measured using a standard weight and a calliper.

*Disk support*: This will be inspected to determine the characteristics of the bearing, shafts and housing alignments. The plow is placed on a horizontal surface, the distance between the point of contact of each disk and the lower face of the frame is measured using a measuring rule. The distance between the mid point of each disk and the lower face of the frame will be measured using the same method. The distance between the rear extreme of the plow and the hitch linkage should be measured.

*Horizontal angle disk*: The operator is asked to make a line using the furrow wheel that indicates the direction of travel. A horizontal bar is placed across the center of the disk, and plumb bob lines are dropped from the edges of the disk to locate two points. The disk is then lifted from the ground. A line is drawn using the two points crossing the line made by the furrow wheel. Then the angle between the line and the one made by the furrow wheel is measured (Fig. 2.1). This gives the horizontal angle.

*Vertical angle disk*: A horizontal steel rule with a sliding vertical arm is placed on the disk. The sliding arm is moved until it touches the lower part of the disk that rests on the ground. The vertical and horizontal distances are read from the rule (Fig. 2.2). The vertical angle is determined using the tangent relation.
Figure 2.1. Horizontal disk angle measurement

Figure 2.2. Vertical disk angle measurement
RUNNING IN

A preliminary test is conducted for at least eight hours to see that the moving parts are in proper functional order, to polish the machine, and to make the necessary adjustment before the machine is taken out for field test.

FIELD TESTING

The field testing will be conducted with the objective of assessing the performance of the machine in line with the aim it is designed for—its technical suitability and its ease of manipulation. The data will then be complete.

Site selection

The test should generally be conducted on at least two types of soil—light soil and heavy soil. The field size should be 40 m x 10 m for animal-drawn equipment and 40 m x 200 m for tractor-drawn equipment (Fig. 2.3). Data will be taken before and after testing.

![Field sizes for both tractor- and animal-drawn equipment](image)

Test condition

The conditions under which the test is conducted have to be clearly defined. These include field conditions, implement condition, power source condition and operator’s condition. Field condition and subsequent operational measurements should be taken, as far as possible, at the same place in the testplot. Three samples for the animal-drawn plow and five samples for the tractor-drawn plow should be used in the testplot.

The following field conditions shall be checked, measured and reported.

- a. size of plot
- b. type of soil
- c. last crop grown
- d. date of harvest of last crop
- e. date and details of preceding tillage after last harvest
f. topography of the field and slope
g. soil moisture percentage
h. bulk density
i. cone index
j. shear strength
k. weed condition (type, density, size etc.)

Soil property measurement

a. Soil moisture content. Core sample should be taken at 5 cm interval up to the plow depth. Three core samples for the animal-drawn and five for the tractor-drawn plows (at evenly distributed places in the testplot) should be taken for moisture content determination. In the laboratory, each sample should be taken out of the core sampler and thoroughly mixed. From the mixed sample a smaller sample of 25–30 g should be taken for soil moisture content determination by standard oven-drying method (i.e. drying the soil at 103°C).

Soil moisture content on dry weight basis is calculated using the following formula.

\[
\text{Soil moisture, dry basis (\%)} = \frac{\text{wt. of wet soil} \ - \ \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100
\]

b. Bulk density. Cylindrical core samples (or any defined volume) should be taken from the testplot (if the samples taken for soil moisture determination are taken using a sample of defined volume, the bulk density could be calculated from the moisture samples).

The bulk density is calculated as follows.

\[
\text{Bulk density, dry basis (g/cm}^3\) = \frac{M}{V}
\]

where \(M\) = mass of dried soil; \(V\) = volume of core sample

For cylindrical core sample the following formula is used to calculate bulk density.

\[
\text{Bulk density, dry basis (g/cm}^3\) = \frac{4M}{\pi D^2 L}
\]

where \(M\) = mass of dried soil; \(D\) = internal diameter of core sample; \(L\) = length of core sample

C. Cone penetrometer reading. Cone of 30° included angle with the larger diameter being 0.798 in (20.3 mm), giving a cross-sectional area of 0.5 square inch (3.226 mm\(^2\)) or any other standard cone, can be used. The value of the resistance to penetration can be obtained using a calibration chart or can be calculated from the reading. The reading instruments and subsequent calculations should be done in the office. Cone penetrometer readings will be taken vertically at about the depth of plowing. In case of sandy soils, the measurement can be taken by pushing the cone vertically into the soil up to its base only. Also, cone penetrograph can be used to measure the depth in a form of graph.
It must be noted that for a detailed operation of penetration-resistance measuring instruments the instructions given on the operation manual, accompanying the instrument, should be followed.

D. Soil shear strength. Commercially available soil shear meter should be used to measure soil shear strength. Measurements should be taken following the instruction manual of the instrument.

Weed condition

The condition of the weed in the testplot has to be described in terms of size, species and density. Where applicable, the weed count can be done by using a wooden or angle iron form of square shape, 1 m sidedivided into four equal parts (Fig. 2.4). The biomass of the weed or the trash in the field can also be measured by taking samples using this frame. The data will be taken after the test is completed.

Working width

To determine the working width, a width meter is used. About 3 m is measured from the end of the plowed strip to the unplowed land and a peg is placed on the unplowed strip. After the tractor passes that line, the unplowed strip is subtracted from the previously measured strip. This is repeated over the whole sample. The average will give the working width. Uniformity will be measured by calculating the coefficient of variation.

Working depth

A width meter is used to determine the working depth as well. The profile meter contains a horizontally drilled bar with 20 holes for letting through pins that are used to measure the depth of furrow configuration.

The equipment has a water level to keep it horizontal once the apparatus is in place. The equipment is placed on the furrow that is marked before the land is plowed. The plowed soil is removed from the furrow till a clean furrow bottom appears, making sure not to excavate the plowed land. The equipment with the pins is placed on the plowed land checking the level so that it is put perfectly horizontal. The length of pins above the bar is measured. The difference between the length of the pin at the corresponding measured distance above the bar gives the furrow depth. The maximum depth recorded is taken as the maximum depth. Uniformity will be assessed by calculating coefficient of variation.

![Figure 2.4. Square frame for taking weed sample](image)
Furrow profile

The depth of the furrow is plotted against the corresponding horizontal distance starting from zero at one end using a square paper.

The area of the furrow profile is determined by counting the number of squares or by using planimeter, if available. The area of the furrow is divided by the width to determine the average depth.

Evenness

The evenness of plowing is calculated by dividing the average depth of plowing by the standard deviation.

Speed

Two sets of poles AA and BB are put in the testplot as shown in Fig. 2.5. The time taken by the plow to cover the marked distance between the two lines AA and BB is noted five times with the help of a stopwatch. Arithmetic average of the five readings is used to calculate the speed in meters per second.

Power requirement

a. For trailed plow

Insert a dynamometer in the hitch to measure the draft. If the line of pull is not horizontal the angle of pull should be measured and the draft will be calculated as follows.

\[
\text{Draft} = \text{pull} \times \cos \theta
\]

For field measurement of draft, a 100 m or other defined length distance, should be marked in the middle of long row using two pegs.

The plow should be operated over the defined row length and draft measurement should be taken. At
the same time, the time taken to traverse this defined row length should be noted to determine the speed of travel. The draft measurements, as far as possible, should be taken around the points where field condition measurements and furrow shape and size measurements are taken.

b. For mounted tractor-drawn plow

Over the defined row length, another auxiliary tractor should be used to pull the implement-mounted tractor. The latter tractor should be in neutral gear with the implement in operating position. Two draft measurements, the plow being in operating position, and next the plow being lifted off the ground, should be taken in the same row. The draft requirement of the plow can be calculated by subtracting the draft measured while the plow is lifted off the ground from the draft measured while the plow was operating.

Slip

The slip of tractor wheels is determined by making a mark on the drive wheel of the tractor and the distance the tractor travelled in 10 revolutions of the drive wheel with no load (A) and with load (B) (Fig. 2.6). The slip will be calculated by using the following formula.

\[
\text{Slip} (%) = \left(1 - \frac{B}{A}\right) \times 100
\]

Unit draft

The unit draft will be calculated by dividing the draft by the cross-sectional area of the furrow (N/cm²).

Qualitative assessment of work quality and operation

Subjective assessment should be made on inversion of soil, pulverization of soil, evenness of plowed land, condition of tractor, etc. during and after field test.

Figure 2.6. Measuring slip of tractor wheels
Ease of operation

This should include:
   a. stability of implement
   b. ease of turning, control and adjustment
   c. safety

Soundness of construction

During the entire period of testing complete records of defects and breakdowns should be kept to indicate the soundness of construction.

Operator's assessment

The operator should be asked to give his/her opinion about the operation of the plow.

Labor requirement

This must include:
   a. total man-hour of operator at test and per hectare
   b. total man-hour of unskilled labor at test and per hectare

Energy requirement

Specific energy

The specific energy is expressed as the energy per volume of soil worked. The sample average draft is multiplied by 1 m and the average sample profile area is multiplied by 1 m. Multiplying both the numerator and denominator will give energy on the numerator and volume in the denominator. This will give energy per volume worked.

Fuel consumption

The power unit is filled with fuel before the test starts and after the test is completed. The amount required to fill the tank after the operation is recorded as fuel consumed during operation. Based on the specification of the engine (liters/kWh) the fuel consumed energy equivalent (kWh) is calculated.

Soil inversion

The soil inversion shall be measured using the following methods.

a. Virgin (fallow land): For virgin or fallow land the soil inversion will be determined by giving the percentage of the inverted furrow slice.

b. Animal-drawn plow: For a plot plowed using animals the soil inversion will be determined by giving percentage furrow slice inversion and by measuring the unplowed land in the testplot.
Any figure greater than this will have to be discarded as it indicates the presence of unworked area. Moreover, the number of such figures and their magnitude have to be separately reported as indicative of the quality of work. Thus the average of the remaining figure gives the working width (Wa).

**Working speed**

The best gear at which the tractor works comfortably has to be selected prior to commencing the test. The net working time between engagement and disengagement of the implement or the machine in work will be recorded. The distance traveled in each case will be recorded and divided by the corresponding net time. The average of such figure will be the working speed (Sa).

**Time efficiency**

During field test the various components of working and stoppage times (as listed below) will be recorded. Finally the time efficiency will be calculated using the following formula.

\[
Te = \frac{\text{net working time (no. 4)} \times 100}{\text{total time with the range 4-9}}
\]

The following list describes the time elements that involve labor, which are associated with typical field operations, and that should be included when computing the capacities or costs of a machinery related to various farm enterprises.

1. machine preparation time at the farmstead (includes removal from and preparation for storage, and shop work)
2. travel time to and from the field
3. machine preparation time in the field both before and after operation, which includes daily servicing, preparation for towing, etc.
4. theoretical field time (the time the machine is operating in the crop at an optimum forward speed and performing over its full width of action)
5. turning time and time required for crossing grass water-ways (while machine mechanisms are operating)
6. time to load or unload the machine, if not done on-the-go
7. machine adjustment time, if not done on-the-go (includes unplow)
8. maintenance time, which includes refuelling, lubrication, chain tightening, etc. (if not done on-the-go, this does not include daily servicing)
9. repair time (the time spent in the field to replace or renew parts that have become inoperative)
10. operator’s working time

**Animal-drawn Implements or Machines**

The actual field capacity (AFC) of the implement or machine is calculated as follows:

\[
AFC = \frac{\text{total area - unworked part}}{\text{total time - stoppages}} \times S.F.
\]

where S.F. = the speed
Total area

The total area to be worked should be 10 m x 40 m.

Unworked part

Unlike tractors, animals cannot be well controlled during operation and there could be unplowed land (unworked part) in the field. To calculate the actual area covered, such parts have to be deducted by plotting profiles of samples in the field. This is done by taking elevation readings of points at 5-cm intervals over a 2-m length from reference line both before and after testing. There should be four such locations in the testplot.

Total time and stoppages

The total time of operation will be measured by recording the time over a 20-m distance at the middle of the testplot. Then normal speed at which a pair of Ethiopian oxen, weighing about 600 kg, can walk comfortably shall be calculated from the draft requirement of the implement and hence the speed factor (S.F.) is defined as follows:

\[
S.F. = \frac{NS}{WS}
\]

where \( WS = \) the average speed measured during the test;
\( NS = \) the normal speed calculated for a pair of average Ethiopian oxen

**Durability Test**

A durability test will be conducted to assess the long-term use of the plow. The daily performance, defect and breakdown should be recorded. The performance test shall be conducted by the user with a frequent supervision by the test engineer. A minimum of 250 ha will be plowed before reaching a conclusion about the machine. The following parameters should be recorded.

a. area plowed  
   b. total time of plowing  
   c. type of tractor  
   d. fuel consumption  
   e. breakdowns and defects  
   f. ease of operation  
   g. other problems  
   h. observations by the user

The data will be filled using the format in Appendix 7.
# Appendix 1. Technical Investigation

1. Packing:
   - good □
   - medium □
   - poor □

2. Visible damage:
   - damaged □
   - partially damaged □
   - undamaged □

3. Weld:
   - good □
   - medium □
   - poor □

4. Paint:
   - good □
   - medium □
   - poor □

5. Guards of moving parts:
   - adequate □
   - partially adequate □
   - none □

6. Protruded objects:
   - safe □
   - medium □
   - unsafe □

7. Safety precautions:
   - available □
   - medium □
   - not available □

8. Spare parts:
   - adequate □
   - partially adequate □
   - none □

9. Hand tools:
   - adequate □
   - partially adequate □
   - none □

10. Measuring instruments:
    - adequate □
    - partially adequate □
    - none □

11. Time to assemble:
    - short □
    - medium □
    - long □

12. Skill required to assemble:
    - low □
    - medium □
    - high □

13. Quality of manual:
   - *instruction:*
     - good □
     - fair □
     - poor □
   - *operational:*
     - good □
     - fair □
     - poor □
   - *service:*
     - good □
     - fair □
     - poor □
14. Provision for loading and unloading:
   available □  unavailable □

15. Coupling:
   convenient □  inconvenient □

16. Tightness of bolts, nuts and other fasteners:
   tight □  loose □

17. Adequacy of lubrication of bearings and other moving parts:
   adequate □  inadequate □

18. Provision for transportation:
   available □  not available □

19. Provision for adjustment:
   available □  not available □

20. Adequacy of hydraulic system:
   good □  fair □  poor □  not applicable □

Appendix 2: Data Sheet for Recording Hardness

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>Material</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Uniformity</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Radial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Circular</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scraper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Instruments

All the equipment used for laboratory and field tests should be listed. Some of the common equipment are listed below.

**TESTING APPARATUS REQUIRED**

**Laboratory**

- Calliper
- Oven
- Desiccator
- Weighing balance
- Hardness tester
- Vibrating sieves (set)

**Field**

- Sample tubes for soil moisture
- Tapes
- Sampler for clod size
- Bags and rigid container for taking soil sample
- Stopwatches
- Pegs
- Pocket meter and ruler
- Dynamometer/dynamograph
- Paper, colored pencils, sticky tape, ball-point pen, clipboard, etc.
- Hammer
- Spanners (open and socket type)
- Mallet
- Counter
- Engineer’s level
- Ranging rod
Appendix 4: Data Sheet for Dimensional Analysis

<table>
<thead>
<tr>
<th>Part</th>
<th>Measurement</th>
<th>Before test</th>
<th>After test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disk</td>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concavity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scraper</td>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>Height from the ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk axe</td>
<td>Height from center of disk to the ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>Rear of plow to hitching point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk Angle</td>
<td>Vertical angle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Horizontal angle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5: Laboratory and Field Test Data form for Primary Tillage Implements

**LABORATORY TEST**

Implement: ___________________________ Date of test: ___________________________
Power source: ___________________________ Place of test: ___________________________

1. Bulk density of soil

<table>
<thead>
<tr>
<th>Bag no.</th>
<th>Wt. of core sampler, bag &amp; soil (g)</th>
<th>Wt. of core sampler &amp; bag (g)</th>
<th>Wt. of wet soil (g)</th>
<th>Wt. of dry soil (corrected)</th>
<th>Bulk dry soil (g/cm³)</th>
<th>Bulk density, wet base (g/cm³)</th>
<th>Bulk density, dry base g/cm³</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Total mean
2. Moisture content of soil

<table>
<thead>
<tr>
<th>Can no.</th>
<th>Wt. of empty can with</th>
<th>Wt. of can &amp; wet soil (g)</th>
<th>Wt. of can &amp; dry soil (g)</th>
<th>Wt. of wet soil (g)</th>
<th>Wt. of dry soil (g)</th>
<th>Moisture content, dry base (%)</th>
<th>Moisture content, wet base (%)</th>
<th>Remarks</th>
</tr>
</thead>
</table>

3. Field test data form

Date of test: ________________________________________
Place of test: ________________________________________
Implement: _________________________________________
Power source: _______________________________________
Description of topography and soil: ___________________
Condition of field and previous: ______________________
Cultivation: ________________________________________
Plot size: _____ m long x _____ m wide
Gradient in direction: ______________________________
Gradient: ________________________________________

Plot no: _______
Weeds in 1 m² area before operation:
Confined (vertical) cone penetrometer:
Soil shear strength:
Bulk density sample:
Soil moisture sample:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Conditions of tractor:
Time of start of test:

<table>
<thead>
<tr>
<th>Time for ____ m work length (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B = Dynamometer readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. plow in nonworking position</td>
</tr>
<tr>
<td>ii. plow in working position</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C = Angle of dynamometer link (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S = Working speed (m/sec) = ( \frac{\text{dist}}{T} )</td>
</tr>
</tbody>
</table>

4. Time for stoppage

<table>
<thead>
<tr>
<th>Sample</th>
<th>From</th>
<th>To</th>
<th>Total time</th>
<th>Reasons/Remark</th>
</tr>
</thead>
</table>

Average
5. Working width

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Furrow depth

<table>
<thead>
<tr>
<th>No.</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fuel consumption: _____________________________
Time of test completion: _____________________
Total number of furrows or passes in the plot width: ________
Weeds not destroyed after operation: _____________________
(in 1 m² area)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6 A. Data Collecting Form for Field Capacity of Tractor-drawn Plow

1A. WORKING WIDTH WITH NO OVERLAPS

<table>
<thead>
<tr>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

1B. WORKING WIDTH RELATED TO OPERATIONAL PASS (Wa)

<table>
<thead>
<tr>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference points</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Average (Wa)</td>
</tr>
</tbody>
</table>

2. NET TIME BETWEEN ENGAGEMENT AND DISENGAGEMENT OF THE PLOW (Sa)

<table>
<thead>
<tr>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>Net time</td>
</tr>
<tr>
<td>Distance travelled</td>
</tr>
<tr>
<td>Speed</td>
</tr>
</tbody>
</table>

50
3. **Timetable**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical field time (net time)</td>
<td></td>
</tr>
<tr>
<td>Turning time and crossing waterways</td>
<td></td>
</tr>
<tr>
<td>Loading and unloading time of the machine</td>
<td></td>
</tr>
<tr>
<td>Machine adjustment time</td>
<td></td>
</tr>
<tr>
<td>Maintenance time</td>
<td></td>
</tr>
<tr>
<td>Repair time</td>
<td></td>
</tr>
<tr>
<td>Operator's personal time</td>
<td></td>
</tr>
<tr>
<td><strong>Total time</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Time efficiency* = \( \frac{\text{net time}}{\text{total}} \times 100 \)

*Field capacity* = \( Wa \times Sa \times Te \)
Appendix 6 B. Data Collecting Form for Field Capacity of Animal-drawn Plows

1. AREA
   a. Area to be plow _____________
   b. Area unplowed _____________

2. TIME
   a. Duration of test _____________
   b. Stoppage time _____________

<table>
<thead>
<tr>
<th>No.</th>
<th>From</th>
<th>To</th>
<th>Total time</th>
<th>Reason for stoppage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. SPEED OF OPERATION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 Average</td>
</tr>
<tr>
<td>Distance</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 7: User Survey Form

Implement ____________________ Date ____________

1. GENERAL DESCRIPTION OF THE MACHINE

► type
► prime mover
► supplier
► manufacturer’s address
► date of supply of the machine

2. CONVENIENCE OF OPERATION

► transportation
► control, turning, etc.
► ease of adjustment
► quality of work
► output (compared with others)
► required skill of operation
► compatibility

3. PROBLEMS ENCOUNTERED

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Problem</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. BREAKDOWNS

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Part broken</th>
<th>Reason for the breakdown</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
INTRODUCTION

The functional suitability and soundness of construction of any equipment should be assessed before it is distributed to the user. Such assessment need a standard test procedure that can be interpreted wherever the test is conducted.

Taking the above into account and based on the mandate given to the Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR) to test all sorts of agricultural equipment, the first draft test procedure was prepared and attuned on-station by AIRIC staff. Then it was presented to the Technical Committee’s second meeting held in Addis Abeba at IAR, 2–6 October 1990. The draft was then thoroughly discussed and all the necessary amendments were incorporated in this final document.

The test procedure is meant for technical, laboratory and field performance evaluation of both animal-drawn and tractor-drawn disk harrows.

SCOPE

This test procedure recommends the methods and the procedure for testing disk harrows with respect to performance of field operation and soundness of construction. The test procedure can be used for both tractor- and animal-drawn disk harrows.

TERMINOLOGY

Concavity: the radius of the hollow sphere that the disk is a section of.

Range angle: the angle between the aid of the gang and the line perpendicular to the direction of motion.

Disk spacing: the transverse distance between the adjacent disk edge. This can be obtained by adding the thickness of one disk and the length of the spool.

Ground clearance: the vertical distance between the ground and the lower edge of the disk when the harrow is supported on transport wheels.

Width of cut: the transverse distance between the top or bottom cutting edges of the end disks when the harrow is set at a gang angle of 18° (in case of offset type included angle of 36°)
TECHNICAL INVESTIGATION

The technical investigation of the disk harrow will be conducted to see whether there are some visual damage, poor workmanship, availability of safety devices and compatibility of the equipment with the available power unit. This will be judged using the form in Appendix 1.

LABORATORY TEST

The objectives of the laboratory test are:

► To study and verify the specification of the disk harrow as claimed by the manufacturer or applicants
► To determine the type and standard of materials of the components of the disk harrow

Specifications

► name of test organization
► name and address of manufacturer
► name and address of distributor
► name and address of test applicant
► types of sample
  a. prototype
  b. random sample
► number of disks
► source of power
  a. tractor type, model and horse power
  b. animal type, hitching height

Types of harrows
  a. single action
  b. double action
  c. offset
  d. Tandem

Type of hitching
  a. trailed
  b. mounted

Gangs
  a. number of gangs
  b. number of disk on each gang
  c. disk spacing
  d. gang angle ranges
<table>
<thead>
<tr>
<th>Disk Harrow</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. type (plain, notched or flat-centered)</td>
<td></td>
</tr>
<tr>
<td>b. diameter</td>
<td></td>
</tr>
<tr>
<td>c. thickness</td>
<td></td>
</tr>
<tr>
<td>d. concavity</td>
<td></td>
</tr>
<tr>
<td>e. hardmess</td>
<td></td>
</tr>
<tr>
<td>f. center hole (square or circular with key-way)</td>
<td></td>
</tr>
<tr>
<td>g. type of beveling (single, stepped)</td>
<td></td>
</tr>
<tr>
<td>- length of bevel</td>
<td></td>
</tr>
<tr>
<td>- angle of bevel</td>
<td></td>
</tr>
<tr>
<td>- bevelled from concave side</td>
<td></td>
</tr>
<tr>
<td>- bevelled from convex side</td>
<td></td>
</tr>
<tr>
<td>h. notch</td>
<td></td>
</tr>
<tr>
<td>- number</td>
<td></td>
</tr>
<tr>
<td>- width</td>
<td></td>
</tr>
<tr>
<td>- depth</td>
<td></td>
</tr>
</tbody>
</table>

Plain spool
a. length |  |
| b. end diameters |  |
| c. axle hole size |  |

Bearing spool
a. length |  |
| b. end diameters |  |
| c. axle hole size |  |
| d. method of fixing on axle |  |
| e. method of fixing to frame |  |

Axle
a. type |  |
| b. size |  |
| c. length |  |
| d. method of fixing to frame |  |

Lubrication
a. type |  |
| b. recommended lubricant and periodicity |  |

**DIMENSIONAL ANALYSIS OF PARTS SUBJECTED TO WEAR AND TEAR**

These details should be taken before the machine is ready for field operation and after the durability test is completed (see the form in Appendix 4).
Details to be checked

**Disk**: the weight, diameter and thickness of the disk should be measured using a standard weight measuring tape and a calliper respectively.

*Measurement of concavity of the disk*: measure the horizontal distance between the edge of the disk and after dividing it by two, record it as (a) measure the vertical distance at the center and record it as (b) the radius of the sphere of which the disk is a section of or its concavity is given by the following equation.

\[
\text{Concavity} = \frac{a^2 + b^2}{2b}
\]

**Scraper**: the weight and thickness of the scraper cutting edge will be measured using a standard weight and a calliper.

**Frame**: diameter, alignment

**Running In**

A preliminary test should be conducted for at least eight hours to see that the moving parts are in proper functional order, to polish the machine, and to make the necessary adjustment before the machine is taken out for field test.

**Field Testing**

The field testing will be conducted with the objective of assessing the performance of the machine in line with the objective it is designed for—its technical suitability and ease of manipulation. The data will be completed using the field data form in Appendix 5.

**Site selection**

The test should be conducted generally on at least two types of soil—light soil and heavy soil. The field size should be 40 m x 10 m for the animal-drawn equipment and 40 m x 200 m for the tractor-drawn equipment (Fig. 3.1). Data will be taken before testing, during testing and after testing.

*Figure 3.1. Field sizes for tractor- and animal-drawn implements*
Testing condition

The conditions under which the test is conducted have to be clearly defined. These include field condition, implement condition, power source condition and operator’s condition. Field condition and subsequent operational measurements should be taken, as far as possible, at the same place on the testplot. Three samples for the animal-drawn harrows and five samples for the tractor-drawn harrows should be taken in a testplot.

The following field conditions should be checked, measured and reported.

a. size of plot
b. type of soil
c. last crop grown
d. date of harvest of last crop
e. date and details of preceding tillage after last harvest
f. topography of the field and slope
g. soil moisture percentage
h. weed condition (type, density, size etc).
i. clod size

Soil property measurement

a. Soil moisture content: core samples should be taken at 5-cm interval up to the harrow’s depth. Three core samples for the animal-drawn and five samples for the tractor-drawn harrows at evenly distributed places in the testplot should be taken for moisture content determination.

In the laboratory, each sample should be taken out of the core sampler and thoroughly mixed. From the mixed sample a smaller sample of 25–35 should be taken for determination of soil moisture content by standard oven-drying method (i.e. drying the soil at 103°C).

Soil moisture content on dry weight basis is calculated using the following formula:

\[
\text{Soil moisture, dry basis (\%) } = \frac{\text{wt. of wet soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100
\]

b. Surface evenness: the surface has to be observed and noted before the test to subjectively assess the levelling efficiency of the harrow after the test.

c. Clod size: if the clods in the field are fine, then a standard sieve has to be used for assessing clod pulverization; five samples should be collected for this. If the clods are massive, the minor and major diameters of 10 clods in each location have to be measured before the test in such locations.

Weed condition

The condition of weeds in the testplot has to be described in terms of size, species and density. Where applicable, the weed count can be done by using a wooden or angle iron form of square
shape, 1 m side-divided into four equal parts (Fig 3.2). The biomass of the weed or the trash in the field can also be measured by taking samples using this frame. The data will be taken when the test is completed.

Working width

Five working widths, perpendicular to the direction of motion, should be measured using tapes.

Pulverization efficiency

If the clods in the testplot are fine, then the standard sieve method should be used. However, if the clods are massive and cannot be handled by the sieves, the ratio of the sizes of the clods before and after the test indicated in section 6 should be used to assess the clod pulverization efficiency.

Speed

Two sets of poles AA and BB are put in the testplot as shown in Fig. 3.3. The time taken by the harrow to cover the marked distance between the two lines AA and BB is noted five times with the help of a stopwatch. Arithmetic average of the five readings is used to calculate the speed in meters per second.
Power requirement

a. For trailed harrow: Insert a dynamometer in the hitch to measure the draft. If the lines of pull are not horizontal, the angle of pull should be measured and the draft will be calculated as follows.

\[ \text{Draft} = \frac{\text{pull} \times \cos \theta}{\text{width of operation}} \]

For field measurement of draft, a 100 m or other defined length distance should be marked in the middle of the long row using two pegs. The harrow should be operated over the defined row length, and draft measurement should be taken. At the same time, the time taken to traverse this defined row length should be noted to determine the speed of travel. The draft measurements, as far as possible, should be taken around the points where field condition measurements and furrow shape/size measurements are taken.

b. For mounted tractor-drawn harrows: Over the defined row length another auxiliary tractor should be used to pull the implement-mounted tractor. The latter tractor should be in neutral gear with the implement in the operating position. Two draft measurements: first the harrow in operating position and next the harrow lifted off the ground should be taken in the same row. The draft requirement of the harrow can be calculated by subtracting the draft measured while the harrow will be lifted off the ground from the draft measured while the harrow was operating.

Unit draft

The unit draft will be calculated by dividing the draft by the width of operation (N/M).

Qualitative assessment of work and operation

Subjective assessment should be made on inversion of soil, pulverization of soil, evenness of harrowed land, condition of tractor, etc. during and after field test.

Ease of operation

This should include:
   a. stability of implement
   b. ease of turning and ease of control and adjustment
   c. safety

Soundness of construction

During the entire period of testing a complete record of defects and breakdowns should be kept to indicate the soundness of construction.

Operator's assessment

The operator should be asked to give his opinion about the operation of the harrow.
Labor requirement

This must include:

a. total man-hour of operator at test and per hectare
b. total man-hour of unskilled labor at test and per hectare

Fuel consumption

The power unit is filled with fuel before the test starts and after the test is completed. The amount required to fill the tank after operation is recorded as fuel consumed during operation. The fuel-consumed energy equivalent (kWh) is calculated based on the specification of the engine (liters/kWh).

**DETERMINATION OF FIELD CAPACITIES OF MACHINES**

The machines are grouped into two — tractor-drawn and animal-drawn.

**Tractor-drawn implements (machines)**

The actual field capacity (AFC) of a machine or an implement is defined as follows.

\[ AFC = Wa \times Sa \times Te \]

where \( Wa \) = working width; \( Sa \) = working speed; and \( Te \) = time efficiency

**Working width (Wa)**

The working width is determined by taking successive measurements during field test (Fig. 3.4). As shown in Fig. 3.4., the distances of the consecutive furrow walls from three reference points that are located at the end of the field and along its length will be successively measured using a tape.
**ANIMAL-DRAWN IMPLEMENTS OR MACHINES**

The actual field capacity (AFC) of the implement or machine is calculated as follows.

\[
AFC = \frac{\text{total area} - \text{unworked part}}{\text{total time} - \text{stoppages}} \times 100
\]

where \( S.F. = \) the speed factor

**Total area**

The total area to be worked should be 10 m x 40 m.

**Unworked part**

Unlike tractors, animals cannot be well controlled during operation and there could be unharrowed land (unworked parts) in the field. To calculate the actual area covered such parts have to be deducted by plotting profiles of samples in the field. This is done by taking elevation readings of points at 5-cm intervals over a 2-m length from reference line both before and after testing. There should be four such locations in the testplot.

**Total time and stoppage**

The total time of operation will be measured by recording the time over 20 m distance at the middle of the testplot. The normal speed at which a pair of Ethiopian oxen weighing about 600 kg will walk comfortably can be calculated from the draft requirement of the implement and hence, the speed factor (S.F.) is calculated as follows.

\[
S.F. = \frac{NS}{WS}
\]

where \( WS = \) the average speed measured during the test;
and \( NS = \) the normal speed calculated for a pair of average Ethiopian oxen.

**DURABILITY TEST**

The durability test will be conducted to assess the long-term use of the harrow. The daily performance, defects and breakdowns should be recorded. The performance test should be conducted by the user with frequent supervision of the test engineer. The following parameters should be recorded. A minimum of 250 ha will be harrowed before a conclusion is made about the machine.

- area harrowed
- total time of harrowing
- type of tractor
- fuel consumption
- breakdowns and defects
- ease of operation
- other problems
- observations by the user

The data will be filled using the format in Appendix 7.
Appendix 1. Technical Investigation

1. Packing:
   good □  medium □  poor □

2. Visible damage:
   damaged □  partially damaged □  undamaged □

3. Weld:
   good □  medium □  poor □

4. Paint:
   good □  medium □  poor □

5. Guards of moving parts:
   adequate □  partially adequate □  none □

6. Protruded objects:
   safe □  medium □  unsafe □

7. Safety precautions:
   available □  medium □  not available □

8. Spare parts:
   adequate □  partially adequate □  none □

9. Hand tools:
   adequate □  partially adequate □  none □

10. Measuring instruments:
    adequate □  partially adequate □  none □

11. Time to assemble:
    short □  medium □  long □

12. Skill required to assemble:
    low □  medium □  high □

13. Quality of manual:
    a. instruction:
       good □  fair □  poor □
    b. operational:
       good □  fair □  poor □
    c. service:
       good □  fair □  poor □
14. Provision for loading and unloading:
   available □   unavailable □

15. Coupling:
   convenient □   inconvenient □

16. Tightness of bolts, nuts and other fasteners:
   tight □   loose □

17. Adequacy of lubrication of bearings and other moving parts:
   adequate □   inadequate □

18. Provision for transportation:
   available □   not available □

19. Provision for adjustment:
   available □   not available □

20. Adequacy of hydraulic system:
   good □   fair □   poor □   not applicable □
## Appendix 2. Data Sheet for Recording Hardness

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>Material</th>
<th>Hardness sample</th>
<th>Uniformity</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Frame</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spool</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gang axle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gang angling mechanisms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>wire</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Loading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>platform</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawbar/hitch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bearing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hitch pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Instruments

All the equipment used for laboratory and field test should be listed. Some of the common equipment are listed below.

TESTING APPARATUS REQUIRED

Laboratory

► Calliper
► Oven
► Desiccator
► Weighing balance
► Hardness tester
► Vibrating sieves set

Field

► Sample tubes for soil moisture
► Tapes
► Sampler for clod size
► Bags and rigid container for taking soil sample
► Stopwatches
► Pegs
► Pocket meter and ruler
► Dynamometer/dynamograph
► Paper, colored pencils, sticky tape, ballpoint pen, clip board, etc.
► Hammer
► Spanners (open and socket type)
► Mallet
► Counter
► Engineer’s level
► Ranging rod
### Appendix 5. Laboratory and Field Test Data Form for Disk Harrow

#### 1. MOISTURE CONTENT

<table>
<thead>
<tr>
<th>Can no.</th>
<th>Weight of empty can (g)</th>
<th>Weight of can &amp; wet soil (g)</th>
<th>Weight of can &amp; dry soil (g)</th>
<th>Weight of wet soil (g)</th>
<th>Weight of dry soil (g)</th>
<th>Moisture content, dry base (%)</th>
<th>Moisture content, wet base (%)</th>
<th>Remarks</th>
</tr>
</thead>
</table>

Field test data form

Date of test_______________________________
Plot No.__________________________________
Place of test:______________________________
Implement:_______________________________
Power source:_____________________________
Description of topography and soil:__________________________
Condition of field and previous:__________________________
Cultivation:______________________________

Plot size:_____ m long x _____ m width
Gradient in direction:__________________________
Gradient:__________________________
## 2. Clod Analysis Form

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Totals</th>
<th>Average size of particles retained on each sieve (mm)</th>
<th>Average size x total weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (base)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>25.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.5 (p)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average diameter of clods retained on largest sieve (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average diameter x weight (P)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Mean clod diameter} = \frac{Y}{X}
\]
Appendix 7. User Survey Form

Implement ____________________  Date________________________

1. **GENERAL DESCRIPTION OF THE MACHINE TYPE**
   - Prime mover
   - Supplier
   - Manufacturer’s address
   - Date of supply of the machine

2. **CONVENIENCE OF OPERATION**
   - Transportation
   - Control, turning, etc.
   - Ease of adjustment
   - Quality of work
   - Output (compared with others)
   - Required skill of operation
   - Compatibility

3. **PROBLEMS ENCOUNTERED**

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Problem</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **BREAKDOWNS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Part broken</th>
<th>Reason for the breakdown</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

76
5. Repairs

6. Availability of Spare Parts

- Local
- Imported

5. Place of Repair

- Local
- External (specify the distance)

5. Skill Required

- Specialization
- Experience
- Fair knowledge

6. Unused Machines

<table>
<thead>
<tr>
<th>Reason</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>No use in the season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of repairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of spare parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of prime mover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of other better-performing machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty in operating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. **Operated Hours (Estimated)**

8. **Acceptability**
   - Estimate the price
   - What group do you recommend it for?
     a. *individual farmers (small-scale)*
     b. *large-scale farms*

9. **Improvements**
   - Suggest the necessary modifications in detail

10. **Remarks**
INTRODUCTION

The functional suitability and soundness of any construction equipment should be assessed before it is distributed to the user. Such assessments need a standard test procedure that can be interpreted, wherever the test is conducted.

Taking the above into account, and based on the mandate given to the Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR) to test all sorts of agricultural equipment, the first draft test procedure was prepared and attuned on-station by AIRIC staff. Then, it was presented to the Technical Committee’s second meeting held at IAR in Addis Abeba during 2–6 October 1990. The draft was then thoroughly discussed and all the necessary amendments were incorporated in this final document.

The test procedure is meant for technical, laboratory and field performance evaluation of both animal-drawn and tractor-drawn levelers.

SCOPE

This test procedure prescribes the methods and procedures for testing levelers with respect to performance of field operation and soundness of construction. The test procedure can be used for both tractor- and animal-drawn blade-type levelers.

TERMINOLOGY

For the purpose of this test procedure, the following definitions are given.

Concavity: the radius of the curvature of the soilboard
Cutting edge: is the front edge of the blade that makes the cut in the soil
Soilboard: is the part that collects and holds the soil
Theoretical working width: the length of the leveler blade
Vertical angle of working organ: is the angle of maximum inclination of the blade measured from a horizontal plane
Horizontal angle of working organ: is the angle of turning of the blade in the vertical plane measured from the horizontal position of the blade which is perpendicular to the direction of travel of the leveler.

TECHNICAL INVESTIGATION

The technical investigation of the leveler will be conducted to see whether there are some visual
damage, poor workmanship, availability of safety devices and compatibility of the equipment with the available power unit. This will be judged using the form in Appendix 1.

LABORATORY TEST

The objectives of the laboratory test are:

► To study and verify the specification of the leveler as claimed by the manufacturer or applicants
► To determine the type and standard of materials used for the components of the leveler

Specifications

► Name of test organization
► Name and address of manufacturer
► Name and address of distributor
► Name and address of test applicant
► Types of sample
  a. prototype
  b. random sample
► Source of power
  a. tractor type
  b. animal type
► Height of blade
► Width of blade
► Thickness of blade
► Details of hitch
  • shape and construction
  • beam/frame (for animal-drawn)
    - number of handles
    - material
    - grip height range
► Type of hitching
  • mounted _________
  • trailed _________
  • semi-mounted _______
► Way and range of adjustment of working width and depth
► Angle of turning of the blade in horizontal plane
► Angle of tilting of the blade in vertical plane
► Ground clearance of the blade (maximum)
► Size of different bolts, nuts and bearings
► Number of lubrication points

Any deviations from the manufacturer’s claim should be recorded and reported along with the specification supplied by the manufacturer.
MATERIAL OF CONSTRUCTION AND HARDNESS

The hardness of the following components of the leveler will be determined using the Rockwell Hardness Tester. The uniformity of hardness will be analyzed and the hardness will be compared to that of the recommended value.

Blade: The hardness of the blade (bevelled part) will be measured along the cutting width at least at 10 evenly spaced points.

Board: Hardness measurement will be taken at 10 randomly selected points on the board.

DIMENSIONAL ANALYSIS OF PARTS SUBJECTED TO WEAR AND TEAR

Weight of blade: Weight of blade should be measured before the field test and after the durability test using a standard weight.

Measurement of angles

Vertical angle of working organ (Fig. 4.1): This is measured according to the following procedure.

► put the blade on a horizontal surface
► lift the blade and tilt it to its maximum possible range in the vertical plane while the other tip of the blade still touching the surface
► mark a point on the surface, from the center or any other point, by using a plumb bob
► measure the horizontal and vertical distances
► determine the angle by using the tangent relation

Figure 4.1. Measurement of vertical angle
Horizontal angle of working organ (Fig. 4.2): The horizontal angle is measured according to the following procedure.

- put the blade on a horizontal surface perpendicular to the direction of travel of the leveler
- mark a line along the length of the blade and mark the center on the surface
- turn the blade at the maximum possible angle and mark another line on the horizontal surface
- draw a perpendicular line to the horizontal line
- measure the distances
- determine the angle by using the tangent relation

**RUNNING IN**

A preliminary test should be conducted for at least eight hours to see that the moving parts are in proper functional order, to polish the machine and to make the necessary adjustments before the machine is taken out for field test.

**FIELD TESTING**

The field testing will be conducted with the objective of assessing the performance of the machine in line with the objective it is designed for, its technical suitability and its ease of manipulation. The data will be completed using the field data form in Appendix 5.
Site selection

The test should be conducted generally on at least two types of soils—light soil and heavy soil. The field size should be 40 m x 10 m for the animal-drawn and 40 m x 200 m for the tractor-drawn implements (Fig. 4.3). Data should be taken before testing, during testing and after testing.

Test conditions

The conditions under which the test is conducted have to be clearly defined. These include field condition, implement condition, power source condition and operator’s condition. Field condition and subsequent operational measurements should be taken, as far as possible, at the same place in the testplot. Three samples, in case of animal-drawn levelers and five sample in case of tractor-drawn levelers should be taken in the testplot.

The following field conditions shall be checked, measured and reported.

a. size of plot
b. type of soil
c. topography of the field and slope
d. soil moisture percentage
e. clod size
f. surface evenness

Soil property measurement

Soil moisture content: Core samples should be taken at 5-cm intervals up to the leveler depth. Three core samples for the animal- and five for the tractor-drawn levelers, at evenly distributed places in the testplot should be taken for moisture content determination. In the laboratory, each sample should be taken out of the core sampler and thoroughly mixed. From the mixed sample a
smaller sample of 25–35 g should be taken to determine soil moisture content by standard oven-drying method (i.e. drying the soil at 103°C).

Soil moisture content on dry weight basis is calculated using the following formula.

$$\text{Soil moisture on dry basis (\%)} = \frac{\text{wt. of wet soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100$$

Clod size

If the clods in the field are fine, then a standard sieve should be used for assessing clod size and five samples have to be collected. If the clods are massive, then the minor and major diameters of 10 clods in each location have to be measured before the test in five such locations.

Mean field level or surface evenness ratio

A suitable method for this measurement is to use four pegs by making a square of 4 m, along the working direction of the leveler (Fig. 4.4). A tape or a straight graduated beam will be placed on top of two diagonal pegs. The depth of the soil surface below the tape or beam will be measured at intervals of 5 or 10 cm with a pocket meter or a ruler. The process will be repeated in the second diagonal line between the other two pegs.

Since field level measurement will be taken before and after the levelling operation using the same pegs; the pegs should not be disturbed during the test operation.

The difference between the standard deviation from the mean value before and after levelling will be divided by the standard deviation from the mean value before levelling as shown below.

$$\frac{a_1 - a_2}{a_1}$$

where $a_1 =$ standard deviation before levelling  
$a_2 =$ standard deviation after levelling

Figure 4.4. Field level measurement
Speed

Two sets of poles AA and BB are put in the test plot as shown in Fig. 4.5. The time taken by the leveler to cover the marked distance between the two lines AA & BB is noted five times with the help of a stopwatch. Arithmetic average of the five readings is used to calculate the speed in m/s.

Figure 4.5. Speed measurement for both tractor- and animal-drawn levelers

POWER REQUIREMENT

a. For trailed leveler: Insert a dynamometer in the hitch to measure the draft. If the line of pull is not horizontal, the angle of pull should be measured and the draft will be calculated as follows.

\[ \text{Draft} = \text{pull} \times \cos \theta \]

For field measurement of draft, a 100 m or other defined length distance should be marked in the middle of the long row using two pegs. The leveler should be operated over the defined row length the draft measurement should be taken. At the same time, the time taken to traverse this defined row length should be noted to determine the speed of travel. The draft measurements, as far as possible, should be taken around the points where field condition measurements are taken.

b. For mounted tractor-drawn levelers: Over the defined row length, another auxiliary tractor should be used to pull the implement-mounted tractor. The latter tractor should be in neutral gear with the implement in operating position. Two draft measurements, first the leveler being in
operating position, and next the leveler being lifted off the ground, should be kept in the same row. The draft requirement of the leveler can be calculated by subtracting the draft measured while the leveler is lifted off the ground from the draft measured while the leveler is in operation.

**SLIP**

The slip of the tractor wheels should be determined by making a mark on the drive wheel of the tractor and the distance the tractor traveled in 10 revolutions of the drive wheel with no load (A) and with load (B) (Fig. 4.6). The slip is then calculated by using the following formula.

\[
\text{Slip}\% = \frac{A - B}{A} \times 100
\]

**UNIT DRAFT**

The unit draft will be calculated by dividing the draft by the cross-sectional area of the furrow (N/M).

**QUALITATIVE ASSESSMENT OF WORK QUALITY AND OPERATION**

A subjective assessment should be made on the evenness of the levelled land and the condition of the tractor, etc. during and after field test.
EASE OF OPERATION

This should include:
  a. stability of implement
  b. ease of turning, control and adjustment
  c. safety

SOUNDNESS OF CONSTRUCTION

During the entire period of testing a complete record of defects and breakdowns should be kept to indicate the soundness of construction.

OPERATOR’S ASSESSMENT

The operator should be asked to give his opinion about the operation of the leveler.

LABOR REQUIREMENT

This must include:
  a. total man-hour of operator at test and per hectare
  b. total man-hour of unskilled labor at test and per hectare

ENERGY REQUIREMENT

Fuel consumption

The power unit is filled with fuel before the test starts. And after the test is completed, the tank is filled with fuel. The amount required to fill the tank, after operation is recorded as fuel consumed during operation. Based on the specification of the engine (liters/kWh) the fuel consumed energy equivalent (kWh) is calculated.

ACTUAL FIELD CAPACITY

Tractor-drawn leveler

The actual field capacity (AFC) of a machine or an implement is defined as follows:

\[ AFC = W_a \times S_a \times T_e \]

where \( W_a \) = working width; \( S_a \) = working speed; and \( T_e \) = time efficiency
Working width (Wa)

The working width will be determined by taking successive measurements during field test, according to Fig. 4.7.

As shown in Fig. 4.7., the distances of the consecutive furrow walls from the three reference points located at the end of the field and along its length will be successively measured using a tape. The algebraic difference between each pair of the consecutive readings will be taken as the working width of a single pass. The number of such passes should be at least 10. Overlaps and unworked areas might occur, though the chances of the latter are very rare in tractor-drawn implements or machines. To determine whether there are overlaps or unworked areas in the field the different working widths should be checked against a single figure and will be determined from the furrow profile plotted during the test for soil-cutting efficiency. Any figure greater than this should be discarded as it indicates the presence of unworked area. Moreover, the number of such figures and their magnitude have to be separately reported as an indication of the quality of work. Thus the average of the remaining figure gives the working width (Wa).

**Working Speed**

The best gear at which the tractor works comfortably should be selected prior to the commencement of the test. The net working time between engagement and disengagement of the implement/machine in the work will be recorded. The distance traveled in each case will be recorded and divided by the corresponding net time. The average of such figure will be the working speed (Sa).
**TIME EFFICIENCY**

During field test the various components of working and stoppage times will be recorded as listed below. Finally, the time efficiency will be calculated using the following formula.

$$Te = \frac{\text{net working time (no. 4)}}{\text{total time with the range 4–9}} \times 100\%$$

The following list describes the time elements that involve labor, which are associated with typical field operations, and that should be included when computing the capacities or costs of machinery related to the various farm enterprises.

1. Machine preparation time at the farmstead (includes removal from and preparation for storage and shop work)
2. Travel time to and from the field
3. Machine preparation time in the field both before and after operation (includes daily servicing, preparation for towing, etc.)
4. Theoretical field time (the time the machine in operation in the crop at an optimum forward speed and performing over its full width of action)
5. Turning time and time crossing grass waterways (machine mechanisms are operating)
6. Time to load or unload the machine, if not done on-the-go
7. Machine adjustment time if not done on-the-go (includes unplow)
8. Maintenance time (includes refuelling, lubrication, chain tightening, etc.; if not done on-the-go, does not include daily servicing)
9. Repair time (the time spent in the field to replace or renew parts that have become inoperative)
10. Operator’s operating time

**ANIMAL-DRAWN LEVELER**

The actual field capacity (AFC) of the implement or machine is calculated as follows.

$$AFC = \frac{\text{total area} - \text{unworked part}}{\text{total time} - \text{stoppages}} \times S.F.$$  

where S.F. = speed factor

**Total area**

The total area to be worked should be 10 m x 40 m

**Unworked part**

Unlike tractors, animals cannot be well controlled during operation and therefore there might occur unlevelled land (unworked part) in the field. To calculate the actual area covered, such parts have to be deducted by plotting profiles of samples in the field. This is done by taking elevation readings of points at 5-cm intervals over a 2-m length from the reference line both before and after testing.
## Appendix 1. Technical Investigation

1. **Packing:**  
   - good □  
   - medium □  
   - poor □

2. **Visible damage:**  
   - damaged □  
   - partially damaged □  
   - undamaged □

3. **Weld:**  
   - good □  
   - medium □  
   - poor □

4. **Paint:**  
   - good □  
   - medium □  
   - poor □

5. **Guards of moving parts:**  
   - adequate □  
   - partially adequate □  
   - none □

6. **Protruded objects:**  
   - safe □  
   - medium □  
   - unsafe □

7. **Safety precautions:**  
   - available □  
   - medium □  
   - not available □

8. **Spare parts:**  
   - adequate □  
   - partially adequate □  
   - none □

9. **Hand tools:**  
   - adequate □  
   - partially adequate □  
   - none □

10. **Measuring instruments:**  
    - adequate □  
    - partially adequate □  
    - none □

11. **Time to assemble:**  
    - short □  
    - medium □  
    - long □

12. **Skill required to assemble:**  
    - low □  
    - medium □  
    - high □

13. **Quality of manual:**  
    - **a. instruction:**  
      - good □  
      - fair □  
      - poor □
    - **b. operational:**  
      - good □  
      - fair □  
      - poor □
    - **c. service:**  
      - good □  
      - fair □  
      - poor □
14. Provision for loading and unloading: 
   available □  unavailable □

15. Coupling: 
   convenient □  inconvenient □

16. Tightness of bolts, nuts and other fasteners: 
   tight □  loose □

17. Adequacy of lubrication of bearings and other moving parts: 
   adequate □  inadequate □

18. Provision for transportation: 
   available □  not available □

19. Provision for adjustment: 
   available □  not available □

20. Adequacy of hydraulic system: 
   good □  fair □  poor □  not applicable □

Appendix 2. Data sheet for recording hardness

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>Material</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Uniformity</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilboard</td>
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<td></td>
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<tr>
<td>Cutting blade</td>
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</tbody>
</table>
Appendix 3: Instruments

All the equipment used for laboratory and field test should be listed. Some of the common equipment are listed below.

**Testing Apparatus Required**

a. Laboratory

- calliper
- oven
- desiccator
- weighing balance
- hardness tester
- vibrating sieves (set)

b. Field

- sample tubes for soil moisture
- tapes
- sampler for clod size
- bags and rigid container for taking soil sample
- stopwatches
- pegs
- pocket meter and ruler
- dynamometer/dynamograph
- paper, colored pencils, sticky tape, ball point pen clipboard, etc.
- hammer
- spanners (open and socket type)
- mallet
- counter
- engineer's level
- ranging rod

Appendix 4. Data Sheet for Dimensional Analysis

<table>
<thead>
<tr>
<th>Part</th>
<th>Measurement</th>
<th>Before test</th>
<th>After test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade</td>
<td>Weight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix 5. Laboratory and Field Test Data Form for Disk Harrow

### 1. Moisture Content

<table>
<thead>
<tr>
<th>Can no.</th>
<th>Weight of empty can (g)</th>
<th>Weight of can &amp; wet soil (g)</th>
<th>Weight of can &amp; dry soil (g)</th>
<th>Weight of wet soil (g)</th>
<th>Weight of dry soil (g)</th>
<th>Moisture content, dry base (%)</th>
<th>Moisture content, wet base (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Field test data form

Date of test: ______________________________
Plot No.: ________________________________
Place of test: ___________________________
Implement: _______________________________
Power source: ____________________________
Description of topography and soil: ________
Condition of field and previous: ___________
Cultivation: _____________________________
Plot size: ____ m long × ____ m width
Gradient in direction: _____________________
Gradient: _______________________________
Adjustment of implement machine, if any

- Depth: _______________  
- Width: _______________  
- Horizontal angle: _______  
- Vertical angle: ___________  
- Added weight ___________

Gear selected at test

Weather (sunny, cloudy, rainy, hot, cold, etc.)

Gradient in direction ________

**B. FIELD PERFORMANCE**

Time of start of test

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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</thead>
<tbody>
<tr>
<td>Dynamometer readings</td>
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<tr>
<td>Working width (cm)</td>
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</tbody>
</table>

Time for stoppages

<table>
<thead>
<tr>
<th>No.</th>
<th>From</th>
<th>To</th>
<th>Total time (min. sec.)</th>
<th>Reason, Remarks</th>
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</thead>
<tbody>
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<td>Average</td>
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</tbody>
</table>

Total number of passes in the plot width

Machine movement pattern of field (circuitous pattern head land pattern from boundaries, etc.)
<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Average diameter of clods retained on largest sieve (mm)</td>
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<td>Average diameter x weight (P)</td>
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<tr>
<td>Average diameter of clods measured in the field (mm)</td>
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<tr>
<td>Average diameter x weight</td>
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</table>

Clods measured and weighed in the field

\[ MCD = \frac{\bar{Y}}{\bar{X}} \]
D. Field Level Measurement Before Test

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3. **Field Level Measurement After Test**

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### 5.a.

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### 5.b.

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</tbody>
</table>

### Wheel Slip

<table>
<thead>
<tr>
<th>Distance traveled (in 10 revolutions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No.</strong></td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
</tr>
</tbody>
</table>

### Fuel consumption

- Fuel consumption for area tested (1)
- Fuel consumption per working hour (l/hr)

### General assessment, work quality, evenness
Labor requirement

- Number and total man-hour of operator
  i. at test _________ man-hour
  ii. per ha _________ man-hour ha\(^{-1}\)
- Number and total man-hour of unskilled person
  i. at test _________ man-hour
  ii. per ha _________ man-hour ha\(^{-1}\)

Ease of operation

- stability of implement
- ease of turning
- adjustment
- safety

Breakdown, repair, replacement of parts during test

Additional information and remarks, if any

Testing Engineer (name and designation) ___________________
Appendix 6 A: Data Collecting Form for Field Capacity of Tractor-drawn Disk Harrow

1. A. **WORKING WIDTH WITH NO OVERLAPS**

<table>
<thead>
<tr>
<th>Sample</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Average</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

1. B. **WORKING WIDTH-RELATED OPERATIONAL PASS (WA)**

<table>
<thead>
<tr>
<th>Reference points</th>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average (Wa)

2. **NET TIME BETWEEN ENGAGEMENT AND DISENGAGEMENT OF THE LEVELER (SA)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8</td>
<td></td>
</tr>
<tr>
<td>Net time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance travelled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. TIMETABLE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical field time (net time)</td>
<td></td>
</tr>
<tr>
<td>Turning time and crossing water ways</td>
<td></td>
</tr>
<tr>
<td>Loading and unloading time of the machine</td>
<td></td>
</tr>
<tr>
<td>Machine adjustment time</td>
<td></td>
</tr>
<tr>
<td>Maintenance time</td>
<td></td>
</tr>
<tr>
<td>Repair time</td>
<td></td>
</tr>
<tr>
<td>Operator's personal time</td>
<td></td>
</tr>
<tr>
<td><strong>Total time</strong></td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Time efficiency} = \frac{\text{net time}}{\text{total}} \times 100
\]

\[
\text{Field capacity} = W_a \times S_a \times T_e
\]

Appendix 6 B. Data Collecting Form for Field Capacity of Animal-drawn Disk Harrow

1. AREA

a. Area to be worked________

b. Area left______________

2. TIME

a. Duration of test

b. Stoppage time

<table>
<thead>
<tr>
<th>No.</th>
<th>From</th>
<th>To</th>
<th>Total time</th>
<th>Reasons for stoppage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 3. Speed of Operation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sample</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 7. User Survey Form

Date __________

IMPLEMENT

1. General description of the machine
   ▶ Type
   ▶ Prime mover
   ▶ Supplier
   ▶ Manufacturer’s address
   ▶ Date of supply of the machine

2. Convenience of operation
   ▶ Transportation
   ▶ Control, turning, etc.
   ▶ Ease of adjustment
   ▶ Quality of work
   ▶ Output (compared with others)
   ▶ Required skill of operation
   ▶ Compatibility

3. Problems encountered

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Problem</th>
<th>Consequence</th>
</tr>
</thead>
</table>

4. Breakdowns

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Part broken</th>
<th>Reason for breakdown</th>
<th>Consequence</th>
</tr>
</thead>
</table>
5. Repairs

5.1 Availability of spare parts
► Local
► Imported

5.2 Place of repair
► Local
► External (specify the distance)

5.3 Skill required
► Specialization
► Experience
► Fair knowledge

6. Unused machines

<table>
<thead>
<tr>
<th>Reason</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of use in the season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of repairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of spare parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of prime mover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of other better-performing machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty in operating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Operated hours (estimated)

8. Acceptability

► Price estimation
► What group it is recommend
  a. individual farmers (small-scale)
  b. large scale

9. Improvements

► Suggest the necessary modifications in detail

10. Remarks
V. RIDGER
Seyoum Woldesenbet

INTRODUCTION

The functional suitability and soundness of construction of any equipment should be assessed before it is distributed to the user. Such assessments need a standard test procedure that can be interpreted wherever the test is conducted.

Taking the above into account, and based on the mandate given to the Agricultural Implements Research and Improvement Center (AIRIC) of the Institute of Agricultural Research (IAR) to test all sorts of agricultural equipment, the first draft test procedure was prepared and demonstrated on-station by AIRIC staff. Then it was presented to the technical committee’s second meeting, held in Addis Abeba at IAR 2–6 October 1990. The draft was then thoroughly discussed and all the necessary amendments were incorporated in this final document.

The test procedure is meant for technical, laboratory and field performance evaluation of both animal-drawn and tractor-drawn ridgers.

SCOPE

This test procedure recommends the methods and procedures for testing ridgers with respect to performance of field operation and soundness of construction. The test procedure can be used for both tractor- and animal-drawn ridgers.

TERMINOLOGY

For the purpose of this test procedure the following definitions are given.

Angle of cut: the angle formed by the lines joining point of the share and wings of share

Angle of penetration: the angle of inclination of the share in the direction of travel when the share is fitted in its working position

Edge clearance: the maximum clearance between the cutting edge and a line joining point and wing

Size: the horizontal distance between the outside ends of the moldboards expressed in mm

Throat clearance: the perpendicular distance between point of share and lower position of beam

Vertical suction: the maximum clearance under the sole plate with knife, if fitted, placed at minimum setting and horizontal surface when the ridger is resting on horizontal surface in the working position
Unit draft: the value obtained by dividing the draft by the cross-sectional area of the furrow made by the ridger

TECHNICAL INVESTIGATION

The technical investigation of the ridger will be conducted to see whether there are any visual damage, poor workmanship, availability of safety devices and compatibility of the equipment with the available power unit. This will be judged using the form in Appendix 1.

LABORATORY TEST

The objectives of the laboratory test are as follows.

► To study and verify the specifications of the ridger as claimed by the manufacturer or applicants
► To determine the type and standard of materials or components of the ridger

Specifications

► Name of test organization
► Name and address of manufacturer
► Name and address of distributor
► Name and address of test applicant
► Type of sample
  a. prototype
  b. random sample
► Number of bottoms
► Source of power
  a. tractor type, model and horsepower
  b. animal type, hitching height
► Beam
  a. tractor-drawn
    i. size: height, width, length
    ii. shape
    iii. material
  b. animal-drawn
    i. size: height, width, length
    ii. shape
    iii. material
► Size of ridger, bolts, nuts and bearings
► Vertical suction
► Throat clearance
► Angle of penetration on working position
► Adjustments provided for
  a. depth range
b. width range
► Number of greasing points
► Overall size
  a. at working position
    • length
    • width
    • height
  b. in transport position
    • length
    • width
    • height

Materials of construction and hardness

The hardness of the following components of the ridger will be determined using the Rockwell Hardness Tester. The uniformity of hardness will be analyzed and the hardness will be compared to the recommended value.

Share: The hardness of the cutting edge (bevelled part) of the share will be measured along the cutting width at least at five evenly spaced points and the hardness on the body of the share will be measured at five randomly selected points.

Moldboard: Hardness measurements will be taken at five randomly selected points over the moldboard body.

Sole plate knife: The hardness will be measured by taking measurements at five randomly selected points on the sole plate knife.

Frog: Hardness measurement shall be recorded on data sheet given (Appendix 2).

**DIMENSIONAL ANALYSIS OF PARTS SUBJECTED TO WEAR AND TEAR**

Weight of share: Weight of share should be measured before field test and after durability of field test using a standard weight.

Alignment of parts

The details shall be checked as follows.

► Distance between two consecutive plow bottoms
► All share points are in same horizontal plane and lie in one straight line
► Beam of plow bottom are in same horizontal plane
RUNNING IN

A preliminary test should be conducted for at least eight hours to see that the moving parts are in proper functional order, to polish the machine and to make the necessary adjustment before the machine is taken out for field test.

FIELD TESTING

The field testing will be conducted with the objective of assessing the performance of the machine in line with the objective it is designed for—its technical suitability and its ease of manipulation. The data will be recorded using the field data form in Appendix 5.

Site selection

The test should be conducted generally in at least two types of soils—light and heavy. The field size should be 10 m x 40 m for the animal-drawn equipment and 40 m x 200 m for the tractor-drawn equipment (Fig. 5.1). Data will be taken before testing, during testing and after testing.

Test condition

The conditions under which the test is conducted have to be clearly defined. These include, field condition, implement condition, power source condition and operator’s condition. Field condition and subsequent operational measurements should be taken, as far as possible, at the same place in the testplot. Three samples of animal-drawn plows and five samples of tractor-drawn plows should be taken in a testplot.

Figure 5.1. Field size measurement of both tractor- and animal-drawn implements
The following field conditions shall be checked, measured and reported.

- size of plot
- type of soil
- last crop grown
- date of harvest of last crop
- date and details of preceding tillage after last harvest
- topography of the field and slope
- soil moisture percentage
- weed condition (type, density, size, etc.)

Soil property measurement

Soil moisture content

Core sample should be taken at 5-cm interval up to the ridging depth. Three core samples for the animal-drawn and five for the tractor-drawn ridgers, at evenly distributed places in the testplot, should be taken for moisture content determination. In the laboratory each sample should be taken out of the core sampler and be mixed thoroughly. From the mixed sample a smaller sample of 25–35 g should be taken for determining soil moisture content by standard over-drying method, i.e. drying the soil at 103°C.

Soil moisture content on dry weight basis is calculated using the following formula.

\[
\text{Soil moisture content, dry basis (\%) = } \frac{\text{wt. of wet soil} - \text{wt. of dry soil}}{\text{wt. of dry soil}} \times 100
\]

Weed condition

The condition of weeds in the testplot has to be described in terms of size, species and density. Where applicable, the weed count can be done by using a wooden or angle iron form of square shape with 1 m side-divided into four equal parts. The biomass of the weed or the trash in the field can also be measured by taking samples using this frame. The data will be taken after the test is completed.

Working width

A width meter is used to determine the working width. About 3 m is measured from the end of the ridged strip to the unridged land and a peg is placed on the unridged strip. After the tractor passes that line, the unridged strip is subtracted from the previously measured strip. This is repeated over the whole sample. The average will give the working width. Uniformity will be assessed by calculating the coefficient of variation (Fig. 5.2).
Working depth

A width meter is used to determine the working depth. The profile meter contains a horizontal drilled bar with 20 holes for letting through pins that are used to measure the depth of furrow configuration. Once the apparatus is in place the equipment has a water level to keep it horizontal. The equipment is placed on the furrow that is marked first before the ridger is made. The ridged soil is removed from the furrow till a clean furrow bottom appears, making sure not to excavate the unridged land. The equipment with the pins is placed on the ridged land checking the level so that it is put perfectly horizontal. The length of pins above the bar is measured. The difference between the length of the pin at the corresponding measured distance above the bar gives the furrow depth. The maximum depth recorded is taken as the maximum depth. Uniformity will be assessed by calculating coefficient of variation.

Furrow profile

The depth of the furrow is plotted against the corresponding horizontal distance starting from zero at one end using a square paper.

The area of the furrow profile is determined by counting the number of squares or by using a planimeter, if available. The area of the furrow is divided by the width to determine the average depth.

Evenness

The evenness of ridging is calculated by dividing the average depth of ridging by the standard deviation.

Speed

Two sets of poles AA and BB are put in the testplot as shown in Fig. 5.3. The time taken by the ridger to cover the marked distance between the two lines AA and BB is noted five times with the help of a stopwatch. Arithmetic average of the five readings is used to calculate the speed in m/s.
Figure 5.3. Speed measurement of ridger

POWER REQUIREMENT

a. For trailed ridger. Insert a dynamometer in the hitch to measure the draft. If the line of pull is not horizontal, the angle of the pull should be measured and the draft will be calculated as follows.

$$\text{Draft} = \text{pull} \times \cos \theta$$

For field measurement of draft, a 100 m or other defined length distance should be marked in the middle of the long row using two pegs.

The ridger should be operated over the defined row length and draft measurement should be taken. At the same time, the time taken to traverse this defined row length should be noted to determine the speed of travel. The draft measurements, as far as possible, should be taken around the points where field condition measurements and furrow shape and size measurements are taken.

b. For mounted tractor-drawn ridger: Over the defined row length another auxiliary tractor should be used to pull the implement-mounted tractor. The latter tractor should be in neutral gear with the implement in operating position. Two draft measurements, first the ridger being in operating position and next the ridger being lifted off the ground, should be taken in the same row. The draft requirement of the ridger can be calculated by subtracting the draft measured while the ridger is lifted off the ground from the draft measured, while the ridger was operating.

SLIP

The slip of tractor wheels will be determined by making a mark on the drive wheel of the tractor and the distance the tractor travelled in 10 revolutions of the drive wheel with no load (A) and with load (B) will be measured. The slip will be calculated by using the formula.
\[ \text{Slip(\%)} = \frac{A - B}{A} \times 100 \]

**UNIT DRAFT**

The unit draft will be calculated by dividing the draft by the cross-sectional area of the furrow (N/cm²).

**QUALITATIVE ASSESSMENT OF WORK AND OPERATION**

A subjective assessment should be made on inversion of soil, pulverization of soil, evenness of ridged land, condition of tractor, etc. during and after field test.

**EASE OF OPERATION**

This should include:

- stability of implement
- ease of turning and ease of control and adjustment
- safety

**SOUNDNESS OF CONSTRUCTION**

During the entire period of testing a complete record of defects and breakdowns should be recorded to indicate the soundness of construction.

**OPERATOR’S ASSESSMENT**

The operator should be asked to give his opinion about the operation of the ridger.

**LABOR REQUIREMENT**

This must include:

a. total man-hour of operator at test and per hectare
b. total man-hour of unskilled labor at test and per hectare

**ENERGY REQUIREMENT**

Specific energy

The specific energy is expressed as the energy per volume of soil worked. The sample average draft is
multiplied by 1 m and the average sample profile area is multiplied by a meter. Multiplying both the numerator and the denominator will give energy on the numerator and volume in the denominator, which will give energy per volume worked.

Fuel consumption

The power unit is filled with fuel before the test starts. After the test is completed, the tank is filled with fuel. The amount required to fill the tank, after operation, is recorded as fuel consumed during operation. Based on the specifications of the engine (liters per kWh), the equivalent fuel consumed energy (kWh) is calculated.

**DETERMINATION OF FIELD CAPACITIES OF MACHINES**

The machines are grouped into two—tractor-drawn and animal-drawn.

Tractor-drawn Implements (Machines)

The actual field capacity (AFC) of a machine or an implement is calculated as follows:

\[ AFC = Wa \times Sa \times Te \]

where \( WA = \) working width; \( Sa = \) working speed; \( Te = \) time efficiency

Working width (Wa)

The working width will be determined by taking successive measurements during field test as shown in Fig. 5.4.

As shown in Fig. 5.4., distances of consecutive furrow walls from three reference points that are located at the end of the field and along its length will successively be measured using a tape. The algebraic difference between each pair of consecutive readings will be taken as the working width of a single pass. The number of such passes should be at least ten. Overlaps and unworked areas might occur though the chances of the latter are very rare in tractor-drawn implements or machines. To determine whether there are overlaps or unworked areas in the field the different working widths should be checked against a single figure of the working width measured in the absence of overlap and unworked area. This figure will be determined from the furrow profile plotted during the test for soil-cutting efficiency. Any figure greater than this should be discarded as it indicates the presence of unworked area. Moreover, the number of such figures and their magnitude have to be separately reported as an indication of the quality of work. Thus, the average of the remaining figure will give the working width (Wa).

Working speed

The best gear at which the tractor works comfortably has to be selected prior to the commencement of the test. The net working time between engagement and disengagement of the implement or machine in work will be recorded.
Figure 5.4. Measurement of working width

The distance traveled in each case will be recorded and divided by the corresponding net time. The average of such figure will be the working speed (Sa).

Time efficiency

During field test the various components of working and stoppage times as listed below will be recorded. Finally, the time efficiency will be calculated using the following formula.

\[
Te = \frac{\text{net working time (no. 4)}}{\text{total time with the range 4-9}} \times 100\%
\]

The following list presents the time elements that involve labor, are associated with typical field operations, and those should be included when computing the capacities or costs of machinery related to the various farm enterprises.

1. Machine preparation time, at the farmstead (includes removal from and preparation for storage, and shop work)
2. Travel time to and from the field
3. Machine preparation time in the field both before and after operation (includes daily servicing, preparation for towing, etc.)
4. Theoretical field time (the time the machine is operating in the crop at an optimum forward speed and performing over its full width of action)
5. Turning time and time for crossing grass waterways (machine mechanisms in operation)
6. Time to load or unload the machine if not done on-the-go
7. Machine adjustment time, if not done on-the-go (include unplowing)
8. Maintenance time (refuelling, lubrication, chain tightening, etc.)
9. Repair time (the time spent in the field to replace or renew parts that have become inoperative)
10. Operator’s time
Animal-drawn implements or machines

The actual field capacity (AFC) of the implement or machine is calculated as follows:

\[ AFC = \frac{\text{Total area} - \text{unworked part}}{\text{Total time} - \text{stoppages}} \times \text{S.F.} \]

where S.F. = the speed factor

Total area

The total area to be worked should be 10 m x 40 m.

Unworked part

Unlike tractors, animals cannot be well controlled during operation and there might be unplowed land (unworked parts) in the field. To calculate the actual area covered, such parts have to be deducted by plotting profiles of samples in the field. This is done by taking elevation readings of points at 5-cm intervals over a 2-m length from reference line both before and after testing. There should be four such locations in the test plot.

Total time and stoppages

The total time of operation will be measured by recording the time over 20 m distance at the middle of the test plot. From the draft requirement of the implement the normal speed at which a pair of Ethiopian oxen weighing about 600 kg will walk comfortably will be calculated and hence the speed factor (S.F.) is defined as follows.

\[ S.F. = \frac{WS}{NS} \]

where WS = the average speed measured during the test

and NS = the normal speed calculated for a pair of average Ethiopian oxen.

DURABILITY TEST

The durability test will be conducted to assess the long-term use of the plow. The daily performance, defect and breakdown should be recorded. The performance test shall be conducted by the user with frequent supervision of the test engineer. A minimum of 250 ha will be plowed before a conclusion is reached about the machine. The following parameters should be recorded.

- Area plowed
- Breakdowns and defects
- Total time of plowing
- Type of tractor
- Fuel consumption
- Ease of operation
- Observations by the user
- Other problems
### Appendix 1. Technical Investigation

1. **Packing:**
   - good □
   - medium □
   - poor □

2. **Visible damage:**
   - damaged □
   - partially damaged □
   - undamaged □

3. **Weld:**
   - good □
   - medium □
   - poor □

4. **Paint:**
   - good □
   - medium □
   - poor □

5. **Guards of moving parts:**
   - adequate □
   - partially adequate □
   - none □

6. **Protruded objects:**
   - safe □
   - medium □
   - unsafe □

7. **Safety precautions:**
   - available □
   - medium □
   - not available □

8. **Spare parts:**
   - adequate □
   - partially adequate □
   - none □

9. **Hand tools:**
   - adequate □
   - partially adequate □
   - none □

10. **Measuring instruments:**
    - adequate □
    - partially adequate □
    - none □

11. **Time to assemble:**
    - short □
    - medium □
    - long □

12. **Skill required to assemble:**
    - low □
    - medium □
    - high □

13. **Quality of manual:**
    - *a. instruction:*
      - good □
      - fair □
      - poor □
    - *b. operational:*
      - good □
      - fair □
      - poor □
    - *c. service:*
      - good □
      - fair □
      - poor □
14. Provision for loading and unloading: available □ unavailable □

15. Coupling: convenient □ inconvenient □

16. Tightness of bolts, nuts and other fasteners: tight □ loose □

17. Adequacy of lubrication of bearings and other moving parts: adequate □ inadequate □

18. Provision for transportation: available □ not available □

19. Provision for adjustment: available □ not available □

20. Adequacy of hydraulic system: good □ fair □ poor □ not applicable □

Appendix 2. Data Sheet for Recording Hardness

<table>
<thead>
<tr>
<th>Name of parts</th>
<th>Material</th>
<th>Hardness sample</th>
<th>Uniformity</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moldboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole plate knife</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frog</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Instruments

All the equipment used for laboratory and field test should be listed. Some of the common equipment are listed below.

**TESTING APPARATUS REQUIRED**

**Laboratory**

- Calliper
- Oven
- Desiccator
- Weighing balance
- Hardness tester
- Vibrating sieves set

**Field**

- Sample tubes for soil moisture
- Tapes
- Sampler for clod size
- Bags and rigid container for taking soil sample
- Stopwatches
- Pegs
- Pocket meter and ruler
- Dynamometer/dynamograph
- Paper, colored pencils, sticky tape, ballpoint pen, clip board, etc.
- Hammer
- Spanners (open and socket type)
- Mallet
- Counter
- Engineer's level
- Ranging rod
## Appendix 4. Data Sheet for Dimensional Analysis

<table>
<thead>
<tr>
<th>Part</th>
<th>Measurement</th>
<th>Before test</th>
<th>After test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share</td>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance between two consecutive share points</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance of share from the ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plow bottom</td>
<td>Distance of plow bottom from the ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam</td>
<td>Beam of plow bottom from the ground</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5. Laboratory and Field Test Data Form for Ridger

MOISTURE CONTENT OF SOIL

<table>
<thead>
<tr>
<th>Can no.</th>
<th>Wt. of empty can</th>
<th>Wt. of can and wet soil (g)</th>
<th>Wt. of can and dry soil (g)</th>
<th>Wt. of wet soil (g)</th>
<th>Wt. of dry soil (g)</th>
<th>Moisture content, dry base (%)</th>
<th>Moisture content, wet base (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FIELD TEST DATA FORM

Date of test: ___________________________
Plot no.________________________________
Place of test: ___________________________
Implement: ______________________________
Power source: ___________________________
Description of topography and soil: _______
Condition of field and previous cultivation: _______
Plot size: _______m long x _______m wide
Gradient in direction: _____________________
Gradient: ________________________________

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**FIELD DATA FORM**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furrow cross-section (width)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furrow depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth of cut</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ridge spacing</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Soil moisture sample</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Conditions of tractor: ______
Time of start of test: ______

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>T Time for ______m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>work length (sec.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B Dynamometer readings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i) Ridger in non-working</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>position</td>
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<td></td>
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<td></td>
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<tr>
<td>ii) Ridger in working position</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>C Angle of dynamometer link (*)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

\[ S = \text{Working speed (m/sec)} = \frac{\text{dist.}}{T} \]

**TIME FOR STOPPAGE**

<table>
<thead>
<tr>
<th>Sample</th>
<th>From</th>
<th>To</th>
<th>Total time</th>
<th>Reasons, Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

125
WORKING WIDTH

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fuel consumption: ________________________
Time of test completion: ________________________
Total number of furrows or passes in the plot width: _____

TIMETABLE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical field time (net time)</td>
<td></td>
</tr>
<tr>
<td>Turning time and crossing water ways</td>
<td></td>
</tr>
<tr>
<td>Loading and unloading time of the machine</td>
<td></td>
</tr>
<tr>
<td>Machine adjustment time</td>
<td></td>
</tr>
<tr>
<td>Maintenance time</td>
<td></td>
</tr>
<tr>
<td>Repair time</td>
<td></td>
</tr>
<tr>
<td>Operator's time</td>
<td></td>
</tr>
<tr>
<td>Total time</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Time efficiency} = \left( \frac{\text{net time}}{\text{total time}} \right) \times 100
\]

\[
\text{Field capacity} = W_a \times S_a \times T_e.
\]

Appendix 6 A. Data collecting form for field capacity of animal-drawn disc-harrow

1. AREA
   
   a. Area to be worked: ________________________
   b. Area left: ________________________
5. REPAIRS

► Availability of spare parts
  Local: _____________________
  Imported: __________________

► Place of repair
  Local: _____________________
  External (specify the distance): ___________

► Skill required
  Specialization: ______________
  Experience: ________________
  Fair knowledge: ____________

6. UNUSED MACHINES

<table>
<thead>
<tr>
<th>Reason</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>No use in the season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of repairs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of spare parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of prime mover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor quality of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of other better-performing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty in operating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. OPERATED HOURS (ESTIMATED)

8. ACCEPTABILITY

► Estimate the price
► What group do you recommend it for?
  a. individual farmers (small-scale)
  b. large scale

9. IMPROVEMENTS

Suggest the necessary modifications in detail.

10. REMARKS


130
Members of the Technical Committee

Chairpersons

Betemariam Ayehu  AETSC
Demessew Hailu  AETSC

Secretary

Seyoum Woldesenbet  AIRIC

Members

Alemayehu Tessema  AETSC
Solomon Belachew  NMWC
Degufu Zerfu  NMWC
Endeshaw Belay  NMWC
Getachew Yesuf  NMWC
Abebe Belayneh  RTPD
Mohammednur Hussien  Wenji Sugar Estate
Zeratsion Tsehaye  ESI
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Friew Keiemu  AIRIC
Araya Kebede  AIRIC
Demekke Bekele  AIRIC
Melesse Temesgen  AIRIC
Dereje Adugna  AIRIC
Adugna Kebede  AIRIC
Mulukun Tilahun  AIRIC
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Zelalem Bekele  AIRIC
Mengistu Geza  AIRIC