A reversible rotary terracing machine

Richard Arnot Duncan
Iowa State College

Follow this and additional works at: https://lib.dr.iastate.edu/rtd

Part of the Acoustics, Dynamics, and Controls Commons, Agriculture Commons, and the Bioresource and Agricultural Engineering Commons

Recommended Citation
https://lib.dr.iastate.edu/rtd/16043

This Thesis is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
A REVERSIBLE ROTARY TERRACING MACHINE

by

Richard A. Duncan

A Thesis Submitted to the Graduate Faculty for the Degree of

MASTER OF SCIENCE

Major Subject Agricultural Engineering

Iowa State College

1938
# TABLE OF CONTENTS

| I. Introduction                                                                                       | 7 |
| II. Previous Design, Construction, and Trial                                                         | 9 |
| III. Purpose and Scope of Work this Year                                                               | 10 |
| IV. The Design and Construction                                                                      | 14 |
| A. Introduction                                                                                       | 14 |
| 1. Machine design methods and procedures                                                              | 14 |
| 2. Designing Agricultural machinery                                                                 | 16 |
| B. Units of Terracer Re-designed and Constructed                                                       | 17 |
| 1. Hydraulic pump and reservoir                                                                       | 17 |
| a. Introduction                                                                                       | 17 |
| b. Factors entering into the design                                                                   | 17 |
| c. Design, description, and operation                                                                 | 18 |
| d. Details of pump and reservoir                                                                     | 20 |
| 2. Hydraulic control block                                                                           | 25 |
| a. Introduction                                                                                       | 25 |
| b. Change in construction                                                                            | 25 |
| c. Effectiveness of change                                                                           | 25 |
| 3. Pressure increase in auxiliary ram                                                                  | 26 |
| a. Introduction                                                                                       | 26 |
| b. Change of design and construction                                                                 | 27 |
| c. Effectiveness of change                                                                           | 29 |
4. Two way plow bottom and landside 32
   a. Introduction 32
   b. Factors entering into the design 32
   c. Description and operation 33
   d. Details of plow bottom and landside 35
5. Depth Adjustment 42
   a. Introduction 42
   b. Design, construction, and operation 42
6. Auxiliary Ram Spring Mechanism 45
   a. Introduction 45
   b. Factors entering into the design 45
   c. Design, description, and operation 45
   d. Details of mechanism 52

V. Trials 55
   A. In the research room 55
   B. In the field 55

VI. The Testing 60
   A. Introduction 60
   B. Testing Objectives 60
   C. Results 64
      1. Data and information 64
      2. Discussion 87

VII. Summary 89

VIII. Conclusions 91
IX. Literature Cited  
X. Acknowledgements
<table>
<thead>
<tr>
<th>FIGURES</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reversible Terracer in Operation</td>
<td>13</td>
</tr>
<tr>
<td>1a. Reversible Rotary Terracer</td>
<td>13</td>
</tr>
<tr>
<td>2. Pump and Reservoir Installation</td>
<td>21</td>
</tr>
<tr>
<td>3. Assembly Drawing of Pump and Reservoir</td>
<td>22</td>
</tr>
<tr>
<td>4. Assembly and Detail of Pump</td>
<td>23</td>
</tr>
<tr>
<td>5. Assembly and Detail of Reservoir</td>
<td>24</td>
</tr>
<tr>
<td>6. Assembly Drawing of Cam</td>
<td>30</td>
</tr>
<tr>
<td>7. Auxiliary Ram and Torsion Spring</td>
<td>31</td>
</tr>
<tr>
<td>8. Assembly Drawing of Jig</td>
<td>36</td>
</tr>
<tr>
<td>9. Assembly Drawing of Gears</td>
<td>37</td>
</tr>
<tr>
<td>10. Marking Share for Cutting off Landside</td>
<td>38</td>
</tr>
<tr>
<td>11. Welding Frog and Landside</td>
<td>38</td>
</tr>
<tr>
<td>12. Plow Bottom Unit</td>
<td>39</td>
</tr>
<tr>
<td>13. Plow Bottom Installed</td>
<td>39</td>
</tr>
<tr>
<td>14. Assembly Drawing of Plow Bottom</td>
<td>40</td>
</tr>
<tr>
<td>15. Detail Drawing of Plow Bottom</td>
<td>41</td>
</tr>
<tr>
<td>16. Depth Adjustment - View A</td>
<td>43</td>
</tr>
<tr>
<td>17. Depth Adjustment - View B</td>
<td>43</td>
</tr>
<tr>
<td>18. Detail Drawing of Depth Adjustment</td>
<td>44</td>
</tr>
<tr>
<td>19. Selection of Spring Capacity - Graph</td>
<td>47</td>
</tr>
<tr>
<td>20. Assembly Drawing of Auxiliary Ram Spring Mechanism</td>
<td>54</td>
</tr>
<tr>
<td>21. Operating Power take-off Shaft</td>
<td>56</td>
</tr>
<tr>
<td>Number</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>22.</td>
<td>Terracer Being Reversed</td>
</tr>
<tr>
<td>23.</td>
<td>Reversing Terracer While Turning</td>
</tr>
<tr>
<td>24.</td>
<td>Operating with Rotor in Fourth Gear</td>
</tr>
<tr>
<td>25.</td>
<td>Rotor in Third Gear</td>
</tr>
<tr>
<td>26.</td>
<td>Rotor in Second Gear</td>
</tr>
<tr>
<td>27.</td>
<td>Rotor in First Gear</td>
</tr>
<tr>
<td>28.</td>
<td>Map of Terraces Built</td>
</tr>
<tr>
<td>29.</td>
<td>Terrace Profiles</td>
</tr>
<tr>
<td>30.</td>
<td>Photograph Profile of Terrace 4</td>
</tr>
<tr>
<td>31.</td>
<td>Photograph Profile of Terrace 5</td>
</tr>
<tr>
<td>32.</td>
<td>Terraces with Water in Channels</td>
</tr>
<tr>
<td>33.</td>
<td>Terraces After Water Ran Cut</td>
</tr>
<tr>
<td>34.</td>
<td>Terrace Construction Technique</td>
</tr>
<tr>
<td>35.</td>
<td>Making First Cut on First Cut</td>
</tr>
<tr>
<td>36.</td>
<td>Making Third Cut on First Cut</td>
</tr>
<tr>
<td>37.</td>
<td>Making Third Cut on First Recut</td>
</tr>
<tr>
<td>38.</td>
<td>Terracer in Operation</td>
</tr>
<tr>
<td>39.</td>
<td>Terracer in Operation</td>
</tr>
<tr>
<td>40.</td>
<td>Terracer in Operation</td>
</tr>
<tr>
<td>41.</td>
<td>Terracer in Operation</td>
</tr>
<tr>
<td>42.</td>
<td>Field Data Form</td>
</tr>
<tr>
<td>43.</td>
<td>Field Data Form</td>
</tr>
<tr>
<td>44.</td>
<td>Determination of Soil Distribution</td>
</tr>
<tr>
<td>45.</td>
<td>Soil Distribution Curve</td>
</tr>
<tr>
<td>46.</td>
<td></td>
</tr>
<tr>
<td>47.</td>
<td></td>
</tr>
</tbody>
</table>
INTRODUCTION

In 1934 the rotary, or whirlwind, terracer was developed at Iowa State College, in the Agricultural Engineering Section of the Agricultural Experiment Station, under the supervision of Professor E. V. Collins. The development of this machine introduced a new means of excavating the channel and building the terrace ridge. The soil was thrown instead of being pushed, rolled, or carried from the borrow pit, or channel, to the ridge. This new method proved to be very effective and had a number of desirable advantages. The development and operating technique has been set forth in the thesis of L. W. Johnson (4).

R. R. Drake (1) states that on a slope of seven per cent or greater it is highly advantageous to move all of the soil from the upper side of the terrace. On slopes of less than seven per cent the trend in terrace construction is to move all of the soil from the upper side of the terrace. This construction gives a uniform slope along the lower side of the terrace ridge and the possibility of a small channel developing along the lower side of the terrace is eliminated. There should be less energy consumed by this method because all of the soil is moved down the grade. When a terrace is constructed entirely from the upper side,
it is necessary to use a reversible machine, or, with a one way machine, operate at no load on the return trips.

After preliminary plans were made for a reversible rotary terracer, a two year project was approved and work was started in September 1936.
PREVIOUS DESIGN, CONSTRUCTION, AND TRIAL

The first reversible rotary terracer was designed and constructed during the school year 1936-1937. After the construction was completed one brief field trial was made on May 30, 1937. This field trial gave definite indications that the machine was fundamentally sound, and some weak points in the design and construction were observed. The first year's development of the reversible rotary terracer is covered in detail in the thesis of P. A. Whisler (10). No more work was done on the terracer until the current school year of 1937-1938.
PURPOSE AND SCOPE OF WORK THIS YEAR

This year's work is a continuation of the work started by P. A. Whisler. This thesis supplements the thesis of Mr. Whisler. The work this year consisted of making improvements in design and construction, and making conclusive trials and tests.

Changes in design and construction suggested by the first trial were:

1. Make a small pump for the hydraulic system which is more positive and trouble free.
2. Make the reversing more positive.
3. Make a two way plow bottom which would eliminate the accumulation of soil on the shank of the plow beam.
4. Eliminate the tendency of the machine to lean to the right when throwing soil to the left.

Trials were necessary to determine how well different units of the terracer and the terracer were going to perform. Trials and changes were made until we were assured that the machine would give reasonably dependable operation. It was then ready for operating tests.

Operating tests were made with the following points for observation and determination:
1. Dependability against breakdowns in the field.
2. Ability to get the job done under adverse conditions as well as favorable conditions.
3. Quality of work done.
4. Ease of operation.
5. Terrace construction time.
6. Operating and maintenance costs.
7. Simplification of design and construction.

The following objectives have been incorporated in the design of the reversible rotary terracer:

1. The fundamental principles of the whirlwind terracer are used in the design and construction of the reversible rotary terracing machine.
2. This new machine meets all of the requirements of terracing equipment, which are:
   a. The machine is coupled so that it can turn sharply at the end of terrace.
   b. It follows well on curves.
   c. It is coupled so that the depth control is independent of the variation in height of the tractor draw bar.
   d. It is easily reversible.
   e. It has rapid adjustment.
   f. It will take side thrust when on the terrace
ridge.

g. It has a reasonable construction, operating, and repair cost.
Fig. 1. Reversible Terracer in Operation

Fig. 1a. Reversible Rotary Terracer
THE DESIGN AND CONSTRUCTION

Introduction

Machine design methods and procedures (5) (6)

In general there are four considerations of prime importance in designing machines:

1. Adaptation
2. Strength and stiffness
3. Economy
4. Appearance

a. The machine shall accomplish the desired result in the most direct way possible, and with greatest convenience to the operator. This calls for simplicity in design and construction.

b. The machine parts must be made of sufficient weights and proper proportions so as not to rupture or yield enough to interfere with accuracy. By the use of modern analytical methods the dimensions of most machine parts can be accurately calculated. However, in some cases the forces are not accurately known, and it is necessary to resort to the judgment of an
experienced man. The designer must always be certain that the forces used in the calculations are the maximum forces. Not only should the maximum force condition be taken into consideration, but also internal stresses which are sometimes present in the members, such as shrinkage stresses in castings.

Some machines are the result of "machine evolution". The parts which fail are replaced by stronger parts. Two objections to this method are that it is slow and very expensive, and that any part which was originally made stronger than necessary is never changed. Thus only the parts that yield are perfected.

C. Economy may be brought about by a saving in metal, by a reduction in construction labor, or by an increase of both labor and material which increases the value of the machine.

D. A machine designer should strive for a pleasing effect. A good general rule is that simplicity and directness are always best. When the parts are combined, it is necessary sometimes to modify as to give a pleasing effect.

A generally accepted procedure in machine design is to
first make a sketch of the proposed design. The making of a satisfactory sketch is followed by a force analysis. After the force analysis has been made, calculations for dimensions and proportions are started. There is usually some point or part which lends itself best as the starting place for the calculations. When the dimensions for the parts have been worked out, the parts are put together and modifications are made. Sometimes some recalculating is necessary.

**Designing agricultural machinery.**

Agricultural machinery design and procedure are the same as for other types of machinery. However, when designing agricultural machinery there is sometimes considerable uncertainty as to the maximum loads to which the parts will be subjected.

As G. E. Fussell states (2), nobody could venture to impugn the inventiveness and skill which have been combined to produce the manifold variety of agricultural machines now in service, but the fact remains that the methods used in designing them have been largely empirical. Mr. Fussell quotes F. O. Schmitz as saying that the designer of agricultural machines has found himself for some time in a peculiar position, owing to the lack of knowledge of the actual demands made on the parts of the machines which he produces.

Efforts are now being made in many parts of the world
to fill this gap in our knowledge. Several ingenious pieces of apparatus have been designed in order to obtain quantitative measures of the tractive effort required for movement through the soil and over the ground surface, as well as to measure the internal strains on the implements while working, and also the effect of the implements on the soil.

With the aid of the soil scientist the engineer will be able to design machines and implements which will obtain the greatest possible yield of the best possible crops with the minimum expense of money and toil.

Units of Terracer Re-designed and Constructed

Hydraulic pump and reservoir.

Introduction. The first pump showed that a small reciprocating pump would furnish sufficient output and pressure, and that a small reciprocating pump could be designed which was easy to build. However, the first pump did not fill all requirements. There was trouble with air working into the cylinder. The pump block was not rigidly attached to the terracer, and it showed indications of excessive wear. The first reservoir had adequate capacity, but was isolated from the pump so that it required extra tubing.

Factors entering into the design. The objectives set up to be incorporated in the design of a new pump and reser-
voir are as follows:

1. The pump was to be installed inside the redesigned reservoir and operate submerged in oil.

2. The pump was to be operated directly from the shaft which extends 7/8 of an inch from the transmission.

3. It was to have approximately the same dimensions, bore, and stroke as the first pump.

4. Pump and reservoir must fit easily into the available space.

5. The same fundamentals were to be used in the pump design.

The size of the complete unit was closely limited by the available space. The maximum allowable outside dimensions of the reservoir were a width of 3 3/4 inches, depth of 9 inches, and length of 8 1/2 inches. The length and width could be easily held to the allowable dimensions, but since the pump was set in a vertical position, the depth of the reservoir depended on the pump design. By designing the pump as compactly as possible, the overall height was held to 7 1/2 inches.

Design, description, and operation. There were two major factors for consideration in the design of this unit -- compactness and rigidity.

The plunger drive is an eccentric of 3/4 inch width and 2 3/4 inch overall diameter. This size gives a maximum
bearing pressure of less than 200 pounds per square inch, which is a very conservative pressure. The eccentric is carburized and heat treated. The eccentric follower is heat treated mild steel. The eccentric offset is 3/16 inch so as to give a 3/8 inch stroke. The center of the bore in the pump block is directly below the center of the eccentric drive. The yoke of the plunger and the attachment to the eccentric follower are as compact as possible. The plunger pin is carburized and heat treated.

The pump block is cast iron. All passage ways were drilled out in the drill press. The plunger bore was drilled and reamed out to size. The bore was reamed out to a sliding fit for a carburized, heat treated, and ground finish pin. The valves consist of 1/4 inch steel balls held in place by light springs. The valve seats were ground in. A safety valve is built into the block, which consists of a steel ball held in place by a spring. The safety valve functions at approximately 1500 pounds per square inch pressure.

The block is attached to the bottom of the reservoir with three 1/4 inch machine screws. The pump is shut off by means of a 1/8 inch plunger which holds the suction valve open. This small plunger is operated from the auxiliary ram through a linkage.

The reservoir is arc welded in construction. The pump and reservoir are supported by bolting the front end of the
reservoir to the bearing carrier cap on the transmission. This gives a rigid support. The front end and bottoms are 1/4 inch plate. The rear end and sides are 3/16 inch plate, and the top is 1/8 inch plate. It has a volume of 69 cubic inches which is a 50 per cent increase over the volume of the old reservoir.

The pump is operated from the lower shaft in the transmission which is attached directly to the power take-off. The number of strokes of the plunger is equal to the R. P. M. of the power take-off. A motor was belted to the power take-off as soon as the pump and reservoir were installed. All indications were that the pump had sufficient pressure, capacity, and dependability. The pump and reservoir design has been satisfactory.

Details of pump and reservoir. A photograph of the installation is included as figure 2. The assembly and detail drawings are included as figures 3, 4, and 5.
Fig. 2. Pump and Reservoir Installation
Figure 3

ASSEMBLY OF OIL RESERVOIR AND HYDRAULIC PUMP FOR REVERSIBLE ROTARY TERRAC£R

OMA STATE COLLEGE, AMES, IOWA

PUMP OUTLET

OIL RETURN TUBING

SECTION OF OIL RESERVOIR

DRIVE SHAFT PASSAGE

ECLECTRIC NIPPLE OILER

40 MESH SCREEN

OIL RESECTOR
Figure 5

ASSEMBLY OF OIL RESERVOIR

DETAILS OF OIL RESERVOIR

MATERIAL:

- COPPER TUBE
- STEEL

TOP GASケット

SIDE AND ATTACHED PARTS

- TOP COVER
- OIL OUTLET CONNECTION

TOP GASCKET

ASSEMBLY OF OIL RESERVOIR

MATERIAL:

- COPPER TUBE
- STEEL
Hydraulic control block.

Introduction. After the pump and reservoir were installed the hydraulic system could be tried by operating the power take-off shaft with an electric motor. In the design of the control block the terracer was reversed by opening a valve between the lifting ram and the reversing ram. As the machine lowered into the ground the exhaust pressure from the lifting ram was to operate the reversing ram. This method of reversing was not successful because the pressure and volume of the exhausted oil were not high enough.

Change in construction. The best solution of this problem was to get all or part of the oil pressure from the auxiliary ram. By increasing the arc of the cam segment on the front or number one spool of the control block spool assembly, both the lifting and reversing rams could be thrown into the reversing ram. A new number one spool was made with a cam segment arc of 180 degrees, which was double the cam arc of the replaced spool.

New cupped leather packings were put on the cam spool assembly. A spring was put on the rear end of the cam spool assembly. This held the cams in line with the ball valves.

Effectiveness of change. The machine reversed after this change was made. However, frequently the machine lowered as it reversed. After the terracer had lowered to the ground, the auxiliary ram completed the reversing.
It would be advantageous to have the auxiliary ram pressure stepped up to a point where it would exhaust first so that the terracer could be reversed without lowering the machine. If the volume of oil available from the auxiliary ram was not sufficient, the lifting ram would exhaust enough to complete the reversing operation.

**Pressure increase in auxiliary ram.**

_Introduction._ The maximum pressure available for doing work is determined by the strength of the auxiliary ram spring. When the ram becomes filled or elongated to its allowable capacity, it shuts off the pump. Therefore, the practical way to step up the pressure in the hydraulic system was to deflect the spring more, increasing the amount of stored energy.

There were two reasons for requiring a higher pressure. The terracer would not lift satisfactorily unless the pump was operating. The stream of oil coming from the pump boosted the pressure from the auxiliary ram. The minimum pressure should be the pressure required to lift the terracer with the hitch unattached. Since this required pressure averaged about 850 pounds per square inch, the pressure available from the auxiliary ram was not high enough to meet this condition. The maximum pressure requirement was the pressure required to lift the terracer when standing still with the hitch.
attached to the tractor drawbar. This pressure ran up to a maximum of 1060 pounds per square inch. These pressures were determined by tapping a pressure gauge into the hydraulic system. Judging from the performance of the terracer on the first field trial, it would lift out of the ground when in motion with the minimum pressure of 850 pounds per square inch.

The other reason for stepping up the pressure was, as has already been mentioned, to be able to reverse the terracer without the terracer lowering.

**Change of design and construction.** In order to store more energy in the spring, the deflection must be increased. The length of moment arm, elongation of ram, and hydraulic pressure were recorded for each 10 degrees deflection of the spring, using the original cam. This information was used as a basis for designing the second cam.

The objectives which were set up to be met in the design of the new cam are as follows:

1. The working stroke of the auxiliary ram should be nine inches.
2. The overload on the spring should not be dangerously excessive.
3. The pressure in the auxiliary ram should average between 850 and 900 pounds per square inch. The area of the ram is 1.76 square inches.
4. The pressure should be nearly uniform over the entire stroke of the auxiliary ram.

5. The initial moment arm should exceed the one and one-half inches of the original cam.

The approximation for the new cam outline was about an arc of a circle. An exact solution would have involved a specialized knowledge of mathematics and cam design. The shape of the original cam was changed to the new cam outline. Arc welding was used for fabrication. With the new cam the initial deflection was 15 degrees with a moment arm of 2 1/2 inches, and the final deflection was 130 degrees with a moment arm of 8 1/2 inches.

The maximum stress was calculated using Wahl's (9) stress formula for rectangular cross section torsion springs.

\[
S_g = \frac{K_2 \cdot 6M}{bt^2}
\]

\[
K_2 = 1.1 = \text{torsion concentration factor}
\]

\[
M = 14,000 \text{ inch pounds} = \text{maximum bending moment}
\]

\[
b = 0.875 \text{ inches} = \text{axial cross section dimension}
\]

\[
t = 0.875 \text{ inches} = \text{radial cross section dimension}
\]

\[
S_g = \frac{1.1 \times 6 \times 14,000}{0.875^2} = 139,000 \text{ p.s.i.}
\]

Figure 6 shows a dimensional assembly drawing of the cam. Figure 7 shows the auxiliary ram and spring installation.

A plate was welded to the support for the fixed end of the spring. Holes were drilled and tapped on an arc so that
the initial deflection of the spring could be changed. Figure 7 shows this form.

Effectiveness of change. With the new cam installed the pressure averaged about 875 pounds per square inch. The terracer reversed without lowering and lifted readily with the hitch unattached to a tractor draw bar. The terracer lifted out of the ground when hitched and moving forward.
Figure 6

ALONG WITH GROUND ONLY CUTTING EDGES OF REVERSIBLE ROTARY TILLING CHUTE PROJ. 14-8, IOWA STATE COLLEGE
Fig. 7. Auxiliary Ram and Torsion Spring - Ram filled.

Fig. 7a. Auxiliary Ram and Torsion Spring - Guard installed - Ram exhausted.
Two way plow bottom and landside.

Introduction. The first plow built showed that the new design of a two way plow to be used on a reversible rotary terracer was practical. The first plow was made by welding two 18 inch shares together at the landside part of the share. There was a 90 degree angle between shares. The "V" shaped space between the shares was filled in with a piece of moldboard. While one share was cutting the other share was acting as the stub moldboard. The plow was reversed by tilting through 90 degrees. This plow scoured fairly well and lifted the soil to the rotor. Trouble was experienced with soil accumulating on the shank of the plow beam. There was the possibility that this would cause considerable trouble when operating under adverse conditions, so another plow bottom unit was made.

Factors entering into the design. The weights and dimensions of the parts combined to make up the complete unit were based on the parts used in the first unit, which, in turn, were based upon experience and conventional design. The field trial indicated that the first unit had sufficient strength and rigidity.

The requirements on which the design and construction were based are as follows:

1. Use parts of same weights and dimensions as used in first unit.
2. Shape the moldboard so that the soil would be carried laterally toward the rotor far enough that none would accumulate on the shank. The best solution was to reduce the angle between the shares enough to accomplish the above requirement.

3. Make the frog construction stronger.

4. Make the curves in the plow as uniform as possible so as to maintain good scouring qualities.

The amount of reduction of the angle between the plow shares was determined by calculating the reduction which would be necessary on the first plow in order to accomplish the desired result. The necessary reduction of the arc between shares and the radius of the arc were measured. \( \theta \) radians equals length of arc divided by radius of arc. \( \theta \) by calculation was 13 degrees. The angle between the new shares was 90 degrees minus 13 degrees, or 77 degrees.

**Design, construction, and operation.** It was necessary to have some means of determining where to cut the shares before welding together, some way of holding the shares relative to each other for welding, and some way of holding the landside and frog relative to each other for welding. Arc welded construction was used. These problems were solved by constructing a jig shown in figure 8.

Two 18 inch shares, one right hand and one left hand, were placed in the jig, marked and cut off with an oxy-
acetylene torch. This operation removed the landside part of the shares. The shares were placed in the jig and welded together.

To make the frog a piece was cut out of 1/4 inch boiler plate the approximate shape and size needed. The piece was cut in half the long way and each half was shaped to fit the plow by heating in a forge and hammering into shape. The two pieces were then welded together. This series of operations took less time than shaping the frog in one piece.

The landside was made from a 36 inch piece of 3 x 3 x 3/8 inch steel angle. The amount of shaping at the front end was determined by laying the plow bottom in the jig with the frog attached, and laying the angle in the "V" blocks which located it relative to the frog.

In order to have the plow landside parallel to the line of motion it was necessary that the landside make an angle of three degrees five minutes with the frame of the terracer. To secure this angle the sections of tubing which are welded to the steel angle were placed so that the center line of the pivot tube made a three degree five minute angle with each side of the steel angle. This arrangement would also cause the bottom of the plow to be inclined at an angle of three degrees five minutes with the furrow bottom; therefore, as a counter-agent, the tubing in the shank was constructed at the same angle to the horizontal in the opposite direction.
This part was copied from the first plow.

The plow with frog attached and the landside were placed in the jig. The landside was welded to the frog.

The arc through which the plow must be rotated was 90 degrees plus the 13 degrees taken from the angle between shares, or 103 degrees. In order to increase this arc it was necessary to make new the idler gear and the gear segment attached to the pivot tube. Figure 9 shows a dimensional drawing of the gear segments.

**Details of plow bottom and landside.** Figure 10 shows method of marking shares for cutting to fit together.

Figure 11 shows the relative positions of landside and frog for welding.

Figure 8 gives information necessary for duplication of jig.

Figures 10, 11, 12, 13, 14, and 15 give information necessary for duplication of plow bottom.
Fig. 10. Marking share for cutting off landside.

Fig. 11. Landside and frog in place to be welded.
Fig. 12. Plow Bottom Unit.

Fig. 13. Plow Bottom Installed.
Figure 14

PLAN VIEW SHOWING TYPICAL 2-WAY PLOW BOTTOM FOR
REVERSAL USE

AXIAL VIEW SHOWING TYPICAL 2-WAY PLOW BOTTOM

Copyright © 1954 by Iowa State College

All Rights Reserved

Figures 14-15

PHOTO, FLOP, 2.

POLYESTER RESIN

REVERSE FLOW

慢子

Figures 14-15

AERIAL VIEW SHOWING TYPICAL 2-WAY PLOW BOTTOM

Figure 14

SCALE OF DRAWING

Figure 14

LEFT HAND OR STEEL GUIDE

MIDDLE OF STEEL GUIDE
Depth adjustment.

**Introduction.** The depth of operation can be entirely adjusted by the hydraulic control. The terracer can be held at the desired depth and the depth can be readily changed by the operator. The control is operated by rotating the cam spool assembly.

This method has one inconvenience. When the terracer is lowering into the ground the operator must watch and turn the cam spool assembly back to the neutral position when the proper depth has been reached. The operator is often busy watching the tractor at this time, and is not in a position to watch the terracer closely.

**Design, construction, and operation.** A depth control and adjustment was designed. Figures 16 and 17 show it installed. Figure 18 shows the detail drawing. The shell of the control is made from a piece of two inch diameter wrought iron pipe. It works around the lifting ram plunger. The notches catch on the plunger pivot pin. The springs press against the end of the plunger, holding the depth control in position. The lifting ram cylinder comes up against the end of the control. This part worked very satisfactorily.
Fig. 16. Adjustable Stop for Maximum Depth - View A

Fig. 17. Adjustable Stop for Maximum Depth - View B
Figure 18

PLATE WELD IN END

STEEL SPRINGS 24 CIRC

DEPTH DETAIL OF ADJUSTABLE LIFT RAM FOR REVERSIBLE ROTARY TERRAC"
Auxiliary ram spring mechanism.

Introduction. Due to the desirability of having a higher pressure available in the hydraulic system, a new spring mechanism was designed. A torsion spring was not well adapted to the requirements because a torsion spring with large enough allowable load and angular deflection was too large for good design. Tension, or compression, springs were better adapted to this particular unit.

Factors entering into the design. The requirements which were set up to be incorporated in the design of the new unit are as follows:

1. The unit must fit into the available space, 28 inches in overall length, 8 inches in overall width, and 15 inches in overall height.
2. The unit must not be excessively heavy.
3. The unit must maintain a maximum pressure of at least 1050 pounds per square inch in the auxiliary ram over the entire stroke of nine inches.

Design, description and operation. These will be dealt with individually as follows:

1. Spring design
   a. Spring deflection

   The cam design could be greatly simplified by keeping equal the spring deflection and stroke of the ram. The ram stroke had been set at
nine inches which was determined by the necessary capacity. It was necessary to have the spring partially loaded. The minimum spring deflection was set at 12 inches. This gave 9 inches working deflection with a 3 inch initial deflection.

b. Required maximum spring load.

Required load on ram:

1050 pounds per square inch pressure in ram
1.76 square inches area of ram
84 per cent assumed efficiency

\[ 1050 \times 1.76 \times 0.84 = 2300 \] pounds pull on ram

The maximum spring load was determined by means of the graph shown in figure 19. The maximum spring load was set at 3500 pounds at 12 inches deflection.

c. Spring design

The limiting factors in the spring design are as follows:

1. The free length cannot exceed 22 inches.
2. The outside diameter cannot exceed 7\(\frac{1}{2}\) inches.
3. The spring or springs must have an allowable load of 3500 pounds.

A tension spring could not be used because the limited overall length would not allow
Selection of spring capacity for auxiliary ram spring mechanism reversible rotary terracer.

Figure 19
for end connections.

A single compression spring with sufficient capacity and allowable deflection had a free length of 27 inches.

It was possible to get a combination of multiple compression springs which would fill all of the requirements. Because of necessary compactness the idea of using a combination of concentric springs was used.

In the design of concentric helical springs using round wire, the solid heights, deflections, and stresses can be kept equal by keeping the spring index, which is the ratio of mean coil diameter to wire diameter, the same for all coils.

This condition was not adhered to exactly. It was desirable to keep the outside spring diameter at a minimum as long as the free lengths were within the maximum limit.

The two springs used were designed by using the torsional stress and axial deflection formulas.

\[ Q = \frac{3s\pi d^3}{8D} \]
\[ \Delta = \frac{80d^5s}{d^4E_s} \]

\[ Q = \text{axial load in pounds} \]
\[ S_g = \text{allowable shearing stress} = 85,000 \text{ p.s.i.} \]
\[ d = \text{diameter of wire in inches} \]
\[ D = \text{mean coil diameter in inches} \]
\[ A = \text{total axial deflection in inches} \]
\[ n = \text{number of active coils} \]
\[ E_s = \text{shearing modulus of elasticity} = 10,500,000 \text{ p.s.i.} \]

d. Spring specifications

<table>
<thead>
<tr>
<th>Springs</th>
<th>no. 1</th>
<th>no. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>stress used ((S_g))</td>
<td>85,000</td>
<td>85,000 p.s.i.</td>
</tr>
<tr>
<td>wire size</td>
<td>3/4 in.</td>
<td>5/8 in.</td>
</tr>
<tr>
<td>mean coil diameter</td>
<td>6 1/2 in.</td>
<td>5 in.</td>
</tr>
<tr>
<td>total number of coils</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>coil winding</td>
<td>right hand</td>
<td>left hand</td>
</tr>
<tr>
<td>finish</td>
<td>plain</td>
<td>plain</td>
</tr>
<tr>
<td>end finish</td>
<td>squared and</td>
<td>squared and</td>
</tr>
<tr>
<td></td>
<td>ground</td>
<td>ground</td>
</tr>
<tr>
<td>free length</td>
<td>20(\frac{1}{2}) in.</td>
<td>22 in.</td>
</tr>
<tr>
<td>maximum load</td>
<td>2170 lbs.</td>
<td>1630 lbs.</td>
</tr>
<tr>
<td>total deflection</td>
<td>12.9 in.</td>
<td>13.25 in.</td>
</tr>
</tbody>
</table>

e. Check on spring design using Wahl's formulas.

After these springs were designed and ordered there was made available the work of A. M. Wahl (7) (8) on the design of mechanical springs. He has determined that the maximum stresses run higher than the torsional stress
formula indicates. In addition to the torsional stress there is a direct shear stress and a stress concentration at the inner diameter of the coil.

Wahl's total stress formula:

\[ S_s = \frac{S_D D}{d^3} \]

\[ K = \frac{4c - 1 + 0.615}{4c - 4} \]

\[ c = \frac{D}{d} \text{ spring index} \]

Wahl's total deflection formula:

\[ A = c_2 \frac{S_{ah}}{10,000} \]

\[ c_2 = \text{deflection factor based on coil and wire diameters.} \]

\[ n = \text{number of active coils} \]

The maximum working stress in the two springs for this unit can be determined by means of the total deflection formula.

Spring no. 1:

\[ l_2 = \frac{.15 (S_{ax} 9)}{10,000} \]

\[ S_s = 89,000 \text{ p.s.i.} \]

Spring no. 2:

\[ l_2 = \frac{.10 (S_{ax} 13)}{10,000} \]

\[ S_s = 92,250 \text{ p.s.i.} \]
Although these stresses are higher than the original design allowed, they are slightly under the limiting stresses as found by Zimmerli (7, p. 41) in fatigue tests.

The springs will be adjusted relative to each other so that the eccentricity of one spring will oppose that of the other. The center of load should fall approximately on the axial line of the springs.

The critical buckling loads are larger, by a safe margin, than the maximum working loads.

(2) Sketching proposed design.

Several sketches were made of proposed designs. The final sketch was similar to the assembly drawing, figure 20. This design gave a compact and self contained unit.

(3) Force analysis.

Before the dimensions of the parts could be calculated it was necessary to know the loads at the maximum condition. A force analysis was made with the spring compressed 13\(\frac{1}{2}\) inches, which gave the maximum load condition.
(4) Design calculations.

Calculations for dimensions of parts were based on an allowable shearing stress of 5,000 p.s.i., and an allowable tensile stress of 10,000 p.s.i.

(5) Cam design

A set of cams were necessary in order to maintain a constant pull on the ram while the spring load varied from a minimum to a maximum.

Two sets of cams were used in order to set the ram closer to the spring axis, making a more compact and efficient unit. Each cam consists of two segments welded together. One segment is a half circle upon which the spring cable wraps. The other segment has a changing radii, changing the moment arm so that there is an unvarying pull on the ram. This cam design was approximated by calculation and completed by trial and error.

Details of mechanism. Figure 20 shows an assembly drawing of the unit. Construction of this unit is not entirely complete. The terracer was tested with the original
torsion spring using the new cam designed for it. The field testing of the terracer indicated that this new unit would have several advantages: (a) increase of pressure, (b) more compact, (c) self contained unit, and (d) less accident hazard.
TRIALS

In the Research Room

The only unit of the terracer which could be tried without putting the machine into actual operation was the hydraulic system. By applying rotary power to the power take-off, the pump, the lifting and the reversing mechanisms could be tried. The adequacy of the pressure available from the auxiliary ram could be checked, and the system could be checked for leaky valves and connections. Figure 21 shows the set-up used for the inside trial.

In the Field

1. First Field Trial - March 24, 1938.

   A field trial was made on the Agricultural Engineering Experimental Field. There was sufficient trash on the ground to indicate favorable performance of the terracer in trashy conditions. Moisture condition of the soil was good except for some wet spots. The terracer was operated with a Graham-Bradley, two plow, general purpose tractor. Indications were that a tractor with more power would be more satisfactory.

   After three hours of operation at a moderate speed and depth the plow was scouring satisfactorily. The plow lifted
Fig. 21. Set-up for Operating Power Take-off Shaft and Hydraulic Control.
the soil to the rotor satisfactorily. This reversible machine threw the soil as effectively as the whirlwind machines, and lifted and reversed without failure. The depth adjustment proved to be effective and satisfactory. The plow cut 18 inches while operating either way with the terracer hitched to the center of the tractor draw bar. The rear tread of the tractor was 56 inches. The rolling coulter cut directly above the landside. Although there would be some advantage in having the rolling coulter cut a fraction of an inch beyond the landside, this change could not be conveniently made.

The field trial showed up several weak points of design and construction. Improvements of these parts were worked out.

a. When the rotor was operating at a slow speed, throwing considerable soil to the left, the terracer tended to lean to the right. This was caused by the torque of the power take-off which rotates clockwise.

An automatic lock was devised which would lock the left wheel in the furrow position. This lock consisted of a link pivoted on the furrow wheel stop. A notch was made on the left end and a cam shape on the right end (link mounted on machine). When the left wheel was the furrow wheel, the link
locked the wheel in position. When the terracer rises, the land wheel rises first. As the right or land wheel rises, a stop works on the cam shape of the link and unlocks the furrow or left wheel. When the furrow wheel stop is rocked over so that it acts as a stop for the right wheel, the link is swung up to where it does not catch.

b. There was a slight back wash of soil from the rotor. Some of this soil accumulated on the faces of the lower gear segments. When the terracer was reversed this soil packed in the gear teeth causing considerable radial force.

Shields were attached to the lower gear segments which shielded the dirt from the gear faces.

c. Soil and trash accumulated between the gear segment attached to the plow pivot tube and the rear side of the plow beam shank. Most of the accumulation was from the land side or furrow wall. This condition was corrected by bolting a box type shield to the shank, which filled in the space between the shank and gear segment.

d. Occasionally the pump was slow filling the auxiliary ram. It is desirable that the auxiliary ram fill up fairly rapidly, because, at the end of the terrace some pressure is needed immediately after the ter-
racer is raised to help reverse the terracer.

The reservoir and pump were partially dismantled. One outlet connection from the pump was loose. Also, a stronger spring was needed to give a positive release of the pump cut-off.

2. Second Field Trial - April 14, 1938.

The terracer was tried again on the Agricultural Engineering Experimental Field. The soil was a little drier than at the first trial, but other conditions were the same. The same tractor was used.

The terracer performed very satisfactorily. No trouble was experienced and it did a good job.

Minor changes were made when it was returned to the shop. The excess material was removed from the lower reversing gear segment guard. A short section of pipe in the hydraulic system was increased in length by one inch so that the high pressure tubing on the lifting ram would not rub. There had been some trouble with leaky central valves caused by minute pieces of leather and lint. A 40 mesh screen was added to the pump inlet.
THE TESTING.

Introduction

In the development of this reversible rotary terracer there were two basic objectives. First was the design, construction, and trial of the machine. The development and trial were continued until the performance of the machine definitely indicated that it would give continuous and reasonably efficient operation.

The second basic objective was to make operating tests which would definitely indicate its merits and faults.

This new machine must not only be made to operate satisfactorily and perform the work for which it is intended, but also it must be justified as to economic value. Field trials indicated its structural quality and soundness of design.

Testing Objectives

Factors which must be considered in arriving at a definite and comprehensive terrace construction cost are:

1. Information about the terraced field
   a. Slope in per cent
   b. Type and depth of surface soil
c. Type of subsoil
d. Moisture condition of soil
e. Weather conditions during construction
f. Vegetative cover
g. Extent of erosion on slope

2. Information and data about the terrace
   a. Terrace cross section or profile
   b. Length
c. Abruptness of curves

3. Equipment used
   a. Size, make, and cost
   b. Repair condition

4. Operating cost
   a. Fuel, oil, and grease used
   b. Wages of operators
   c. Repairs and maintenance of equipment
d. Interest on investment and depreciation of equipment.

5. Cost of engineering and supervision

6. Cost of bringing low spots in terrace up to grade

7. Cost of constructing outlet.

In testing this new machine all of the above information was not necessary. We were interested primarily in the cost of operation, construction time, quality of work done, and the dependability of the machine to give continuous service under reasonable conditions.
The terraces built on the tests were the drainage-type terrace. (3) This type terrace is constructed entirely from the upper side, and, as the name implies, acts primarily as a drainage channel to conduct excess rainfall from the fields at nonerosive velocities. Since low-velocity surface drainage is required, the channel and not the ridge is of primary importance. The excavated earth is used to bring the lower side of the channel to a height sufficient to provide necessary capacity. A high ridge is not desirable since it seriously interferes with tillage operations, increases construction costs, and frequently requires for its formation a large part of the topsoil scraped from the field. In the drainage-type terrace the ridge should be considered as supplemental to the channel, and should blend gradually into the surface slopes to afford a minimum of interference with machinery operations.

The operating field tests were carried on at the Soil Conservation Service, Camp No. 7, Eldora, Iowa. Very effective assistance and cooperation were given us by the Soil Conservation Service. The first work was done on an 18 per cent slope under adverse conditions of soil and weather. This work was not very satisfactory. A change needed to be made in the lifting linkage of the terracer in order to operate satisfactorily on steep slopes. The design of the knee action lifting linkage should be changed so that the furrow
wheel is forced to lower into the lowered position first and is locked into position. On moderate slopes the furrow wheel lowers first, but some trouble was experienced on the steep slope. On lifting it is better to have the land wheel lift first. This part gave no trouble.

Most of the terracing was done on one field where conditions were satisfactory. Data and information were collected on this part of the testing.
Results

Data and information.

1. Operation of terracer

Most of the construction work was done using an Oliver "70" Standard Tractor, with a 17-27 H.P. Rating. The work was finished up using an Oliver "80" Standard Tractor, with a slightly higher rating. Both tractors handled the terraces very satisfactorily.

The terracer was hitched to the center of the tractor drawbar. The drawbar was adjusted to approximately 14 inches above the ground. The steering mechanism on the terracer was set to steer the terracer straight ahead. The satisfaction given by this adjustment suggested that the steering mechanism could be eliminated.

The hydraulic control is operated by means of the small telescoping shaft which is attached to the tractor. One complete turn of the control in a counter-clockwise direction raises, reverses, and lowers the terracer and returns the control to the neutral position. The control is operated by quarter turns with a short time interval between each quarter turn.

The terracer was reversed while turning at the ends of the terrace. Figures 22 and 23 show the reversing.

The adjustable stop for maximum depth was usually
set one notch shallower when the recuts were started. On the shallow finishing cuts the depth was controlled with the hydraulic control.

There is a specially built four speed transmission on the terracer which gives the rotor four speeds. Figures 24, 25, 26, and 27 show the terracer operating at the four different rotor speeds. The best technique for building terraces with this reversible terracer required the fourth rotor gear for all cuts. This suggested that the transmission could be eliminated.
Fig. 22. Terracer Being Reversed.

Fig. 23. Reversing Terracer While Turning at End of Terrace.
Fig. 24. Rotor in Fourth Gear - 930 R.P.M.  
Tractor Speed - 4 M.P.H.

Fig. 25. Rotor in Third Gear - 675 R.P.M.  
Tractor Speed - 4 M.P.H.
Fig. 26. Rotor in Second Gear - 500 R.P.M.
Tractor Speed - 4 M.P.H.

Fig. 27. Rotor in First Gear - 320 R.P.M.
Tractor Speed - 4 M.P.H.
3. Construction of Terraces

This part of the operating tests can be most effectively presented by means of photographs and illustrations. Figure 28 is a map showing the terraces built. Two short terraces were partially constructed on an 18 per cent slope. However, no data of value were accumulated on that part of the testing. Figure 29 shows the profiles of the terraces constructed. Figures 30 and 31 show two profiles by means of photographs. A white rope was laid across the terrace and another rope was held level.

Immediately following the construction of these terraces a 1.16 inch rain fell. Figure 32 shows two of the terraces before all of the water had run out at the outlet. Figure 33 shows three of the terraces after the water had run out.

The most successful technique developed is shown in figure 34. Terraces 4, 5, and 6 were constructed using this technique. Figures 35, 36 and 37 show the terracer operating on terrace 3. The first cuts were made with the rotor in third gear. If a smaller terrace is to be built, some of the cuts on the inside of the channel and the last series of recuts could be left out.

The effectiveness of the machine in getting the job done is indicated by the performance in figures 38, 39, 40, and 1.
Figure 28

ROY FINSTER FARM
2 1/2 MILES NE ELDORA, IOWA
TOTAL LENGTH OF TERRACES - 6125 ft
- 1.8 M

SCALE OF FEET

TERRACE NO. 1 2 3 4 5
ROAD

850'
1050'
1250'
1300'
800'
1700'

R.A.D.
Fig. 30. Photograph Profile of Terrace 4

Fig. 31. Photograph Profile of Terrace 5
Fig. 32. Terraces with Water in Channels
Fig. 33. Terraces After Water Ran Out
TECHNIQUE FOLLOWED IN CONSTRUCTING TERRACE WITH REVERSIBLE ROTARY TERRACER

TERREZ ACER OPERATED AT DEPTH OF 7 1/2 INCHES
ALL CUTS THROW DOWN GRADE
SPEED OF TRACTOR, 3.5 TO 4.2 M.P.H.
ALL CUTS MADE USING HIGH ROTOR CLEAR - R.P.M. OF ROTOR, 320 TO 385
NUMBERS INDICATE SEQUENCE OF CUTS

ORIGINAL SURFACE

TERRACE PROFILE

13 3/4′,

38′,

15′,

15′,

10′
Fig. 35. Making First Cut on Series of First Cuts

Fig. 36. Making Third Cut on Series of First Cuts

Fig. 37. Making Third Cut on Series of First Recuts
Fig. 38. Terracer Cutting on Series of First Cuts - Terrace 6. Rotor Speed - 920 R.P.M. Tractor Speed - 4 M.P.H.

Fig. 39. Terracer Cutting on Series of Second Recuts - Terrace 6. Rotor Speed - 985 R.P.M. Tractor Speed - 4 M.P.H.
Fig. 40. Terracer Operating on Series of Second Recuts - Terrace 6.
Rotor Speed - 985 R.P.M.
Tractor Speed - 3.22 M.P.H.

Fig. 41. Terracer Operating on Series of Second Recuts - Terrace 6.
Rotor Speed - 985 R.P.M.
Tractor Speed - 3.22 M.P.H.
3. Data

The field data were kept on forms which were made up before starting the operating tests. Sample copies with field data are included as figures 43 and 43.

Data for terraces 4, 5, and 6 were summarized and have been compared in table form, table I, with similar data on the experimental whirlwind terracer. An attempt was made to secure similar data on other types of terracing equipment; however, none was available which was complete enough to be of comparable value.

With this type of machine the distribution of the stream of soil thrown by the rotor is of considerable importance. The method of determining this distribution is shown in figure 44. Each pan was 12 inches in length. The soil in each pan was weighed and recorded. The conditions which would affect the results, such as soil type, moisture, wind, slope, vegetation, and the number of cuts, were kept as uniform as possible. Figure 45 shows the effect of changing the angle of the rotor relative to the plow beam shank. Figure 46 shows the effect of forward speed on distribution. Figure 47 shows a comparison of the whirlwind and reversible machines.
TERRACE CONSTRUCTION COST DATA
(Terrace Field Data)

2 1/2 Mi. N.E. Eldora, Iowa

Location of Field Roy Finster Farm Date 4-25-38
Terrace No. 5 Terrace Length 800 ft.
Terrace Profile (Date on separate sheet)
Slope of land 2.32% Soil type: Surface Clinton Subsoil Loess
Depth of Surface Soil 9"
Extent of erosion on slope Sheet - small gullies
Vegetative Cover Fall plowed
Moisture condition of soil: Wet ___ Med. X Dry ___
Tilth condition of surface: Loose ___ Med. X Solid ___
Weather Clear, warm, low breeze
Number of 1st cuts: Upper side 14 Time 52 min.
Number of 1st recuts: Upper side 12 Time 47 min.
Number of 2nd recuts: Upper side 12 Time 39 min.
Number of 3rd recuts: Upper side ___ Time ___
Total number of cuts: Upper side 38 Time 2 hr., 18 min.
No Load Return Trip Distance for one way machine - 800 ft.

Figure 42
TERSACE CONSTRUCTION COST DATA
(Operating Cost Data)

Terrace No. 5
Terracer Reversible Rotary Size 18" cut
Tractor Oliver standard Size "70", 17-27

Construction Time:

Tractor Hours 2 hr. 18 min. Man Hours 2 hr. 18 min.

7 Gal. gasoline for tractor @
7 Gal. low grade fuel for tractor @
1/4 Qt. oil for tractor @
1/8 Pounds of grease for tractor @
1/8 Pounds of grease for terracer @
1/4 Pints oil for terracer @

Figure 43
Fig. 44. Twelve Inch Pans for Determination of Soil Distribution
SOIL DISTRIBUTION
DIFFERENCE CAUSED BY CHANGING ANGULARITY OF
ROTOR RELATIVE TO PLOW BEAM SHANK

SHIM ANGLE

- 0" 0° ROTOR VERTICAL
- ¼" 3°
- ½" 6°
- ¾" 9°
- 1" 12°

ROTOR SPEED - 920 R.P.M.
FORWARD SPEED - 4 M.P.H.
7" x 18" PLOW CUT

WEIGHT OF SOIL IN POUNDS
DISTANCE IN FEET

Figure 45
Soil Distribution
Effect of Changing Forward Speed

- 4.25 M.P.H.
- 3.25 M.P.H.
- 2.70 M.P.H.

Rotor Speed - 985 R.P.M.
Oliver "80" Standard Tractor

Figure 46
Figure 47

Soil Distribution

Comparison of Whirlwind & Reversible Machines

Whirlwind, Rotor Speed 1060 R.P.M.
Reversible, Rotor Speed 920 R.P.M.
Forward Speed 3 M.P.H.
Forward Speed 3.25 M.P.H.

Distance in Feet

Weight of Soil in Pounds
Table I

Summarized Terrace Construction Cost and Time Data

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Whirlwind</td>
<td>Henry, Iowa</td>
<td>Clinton</td>
<td>Moist</td>
<td>Clover</td>
<td>5.5%</td>
<td>3,055 ft.</td>
<td>10</td>
<td>5</td>
<td>17.5</td>
</tr>
<tr>
<td>Reversible</td>
<td>Hardin, Iowa</td>
<td>Clinton</td>
<td>Moist</td>
<td>Corn Stalks and 3.36%</td>
<td>3,750 ft.</td>
<td>13.6</td>
<td>13.6</td>
<td>19.15</td>
<td>19.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Ridge</td>
<td>3.94 ft. 2</td>
<td>8.35 yd. 5</td>
<td>1.636.8</td>
<td>10.95</td>
<td>$8.75</td>
<td>$5.54</td>
<td>14.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9734</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.0796</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>8.90 ft. 2</td>
<td>13.4 yd. 3</td>
<td>2,630.0</td>
<td>18.6</td>
<td>9.68</td>
<td>12.10</td>
<td>21.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.8268</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.0445</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44.5</td>
</tr>
</tbody>
</table>
Discussion

Very little mechanical trouble was experienced in the field. The two 1/4 inch cables which transmit the spring load to the auxiliary ram plunger, pulled out of the brazing in the anchor block. This was the only trouble experienced with the hydraulic unit. When operating in a high wind, earth accumulated around the furrow wheel stop and kept it from rocking easily into position. A small shield was attached to the furrow wheel stop. The furrow wheel stop needed to be held more firmly in position. This problem was solved by attaching a spring directly below the stop pivot point and attaching the upper end of the spring to a center point on the stop. After the stop rocked over center, the pull of the spring helped hold the stop in position.

A better soil distribution could be obtained by tilting the rotor out at the bottom. The rotor could be held out by putting a shim on the support rest. Several shim thicknesses were tried, but most of the terrace construction was done using a 1/2 inch shim. This held the rotor out six degrees from the vertical position.

The fuel consumption averaged .875 gallons of gasoline per 100 feet of terrace. 200 to 300 feet of terrace were constructed per hour. The quality of work done was the very best. No further work would have been necessary before
seeding over the terraces.

The ease with which this machine is operated is of considerable value. The hydraulic control eliminated all pulling and twisting in lifting and adjusting the machine. The tractor became stuck several times in wet spots. Because of the hydraulic lift the terracer could be quickly lifted and the tractor was able to proceed. Also, any depth adjustment could be made quickly and easily while in motion or while standing still.

The terracer gave dependable operation and satisfaction under adverse conditions. The plow bottom scoured satisfactorily at all times. Because of the rubber mounting of the rotor very little of the rotor vibration or shock was transmitted to the rest of the machine.

One of the most important points indicated by these tests was that the terracer could be simplified in design and construction. The transmission and steering mechanism could be eliminated. The knee action lifting linkage could be simplified. The rotor head could be simplified and made lighter. The soil distribution could be improved by directing more work on the rotor design, location of rotor relative to the plow bottom, and rotor speed. Tests should be made to determine the consumption and utilization of power.
SUMMARY

This work was confined to the improvement in design and construction of, and the making of trials and tests on a reversible rotary terracing machine.

Considerable attention was given to the improvement in design and construction. The design of this machine consisted almost entirely of new principles and new applications of old principles.

Most of the change in design and construction was done before any field trials were made.

Two field trials were made after ground and weather conditions became favorable. Some necessary changes were made following these trials.

Enough field tests were made to definitely indicate a number of the merits and faults.

The draft of the reversible terracer is almost exactly the same as the draft of the whirlwind terracer, which was available for comparison.

The soil distribution was better with the reversible terracer than with the whirlwind.

Indications were that a terrace of a certain capacity could be constructed at less expense of time and money with this new reversible terracer than with a whirlwind machine.
The terraces constructed with the reversible terracer would interfere very little with farming operations, owing to the good width and gentle slopes on the ridge and in the channel.

The design and construction of the reversible terracer could be simplified enough so that the cost of production would be approximately that of the whirlwind terracer.

The reversible terracer weighs 1,250 pounds, and the production cost should be about the same per pound of weight as the production cost of a tractor.
CONCLUSIONS

1. The reversible rotary terracing machine is practical and has definite and promising possibilities.

2. The type of terrace built with this machine would do much toward selling terraces and terracing to farmer operators.

3. This machine is operated with a two plow or larger tractor, and so is adapted to the power unit on most farms.

4. This machine could be simplified a great deal without decreasing its effectiveness.

5. Its efficiency in moving earth would compare very favorably with any other type of terracing equipment.

6. The production cost of the reversible rotary terracer should not greatly exceed the production cost of the whirlwind terracer.
LITERATURE CITED


ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Professor E. V. Collins of the Agricultural Engineering Department for his excellent supervision, assistance, and encouragement in this study.

The interest and cooperation of Dr. J. B. Davidson of the Agricultural Engineering Department is gratefully acknowledged. The useful suggestions and criticisms of other members of the Agricultural Engineering Department were appreciated.

The writer wishes to acknowledge the cooperation and valued assistance of Engineer Stanley A. Collins of the Soil Conservation Service.
IOWA STATE COLLEGE
DIVISION OF AGRICULTURE
PERSONNEL SERVICE
AMES, IOWA

RICHARD A. DUNCAN

Degree: M. S. in Agricultural Engineering, Iowa State College.
B. S. in Agricultural Engineering, University of Illinois, Urbana, Illinois.

Major Curriculum: Agricultural Engineering.

Major Interests:
College: College Teaching in Agricultural Engineering, Research or Experiment Station Work in Agricultural Engineering.
Commercial: Farm Tractor Mfg., Farm Equipment Mfg., Farm Management.

College Address: 233 Sheldon Ave., Ames, Iowa.
Home Address: R. F. D. 1, Alexis, Illinois.

Personal Data:

Educational and Social Experiences:
I was born on a farm near Gainesville, Texas. At the age of eight years I moved with my parents to a farm near Alexis, Illinois, which is still my home.
Student Branch of A. S. A. E. (2-3-4), President A. S. A. E. (3); Agricultural Council (3); Engineer Military Rifle Team (4); R. O. T. C. (3-4).
Officer's Reserve Corps.

Gainful Experiences:
Fred Duncan, (father), farm hand, 6 years (part-time), 4 years, full time.
University of Illinois, Agricultural Engineering Department, drafting, experimental work, 3 years (part-time).
J. I. Case Company for 4 months, training and general sales; 7 months, (part-time), retail sales.
Fred Duncan and Son, 11 months, farm operation.
Research Fellow, Agricultural Engineering Section, Iowa State College for 9 months.

References:
J. E. Davidson, Head, Agricultural Engineering Department, Iowa State College, Ames, Iowa.
E. V. Collins, Agricultural Engineering Section, Iowa State College, Ames, Iowa.
S. C. Turkenkoph, J. I. Case Company, Dallas Branch, Dallas, Texas.

Available for Employment: July 1, 1938.