OBSERVATIONS OF THE PERFORMANCE OF A SELF PROPELLED WINDROWER *

by

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INTRODUCTION

Preliminary studies, conducted at Swift Current with pull-type, end-delivery windrowers, showed that the formation of a good windrow was related to both the forward speed of the machine and the speed of the table canvas. The best windrow was made at a combination of these when the ratio of forward speed to canvas speed was 0.7 : 1. It was observed, in later work with self propelled windrowers, that machines with a horizontal table produced a compact windrow, while those with inclined tables made a wide windrow with the heads of grain criss-crossed in the centre and the straw at an angle to the direction of machine travel. Reports of these observations and information are part of unpublished data at this Research Station.

These findings prompted further studies on the performance of a self-propelled windrower. The object was to observe the effect of forward speed of travel, table canvas speed and table angle on the formation of a windrow, to note its shape and how well it was supported on the stubble.

EQUIPMENT AND PROCEDURE

A production model of a self-propelled windrower was remodelled so the table canvas speed could be varied and the angle of the table adjusted.

The main frame, which also supported the cutter bar, was widened from front to rear to accommodate the drive for the table canvas and the table tilting mechanism. The canvas roller framework was also rebuilt to fit inside the main frame. In this position, the cutter bar operated one inch below the plane of the upper side of the table canvas. The inner roller, on each half of the table, was adjustable to allow for either a 37-inch or 48-inch gap. The table framework was hinged at the front end and was supported at the rear by tubular members which formed the tilting mechanism. The table could be adjusted to angles of 15°, 20°, 26°, 31°, 37°, 42° and 48° to the horizontal (figure 1).

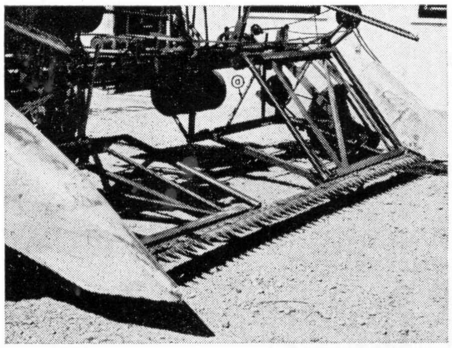

Figure 1. The table frame was widened to accommodate the tubular members of the tilting mechanism at a.

The speed of the table canvas was controlled by using a Maureymatic variable speed unit. Power was supplied to the driven side of this unit from the main power shaft of the windrower. The driving side of the unit transferred power to a cross-shaft from which each half of the table canvas was driven. Corner tighteners were used to adjust the length of the belt drives to the canvases as the table was raised or lowered (figure 2). The Maureymatic drive was replaced by step pulleys for the 1966 tests because of the difficulties met when setting the control to the same canvas speeds for various test runs. The assembled windrower, without the reel, is shown in figure 3.

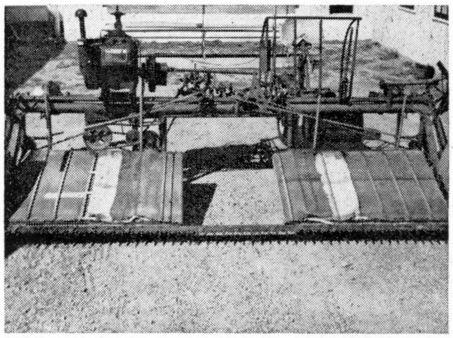

Figure 3. The remodelled windrower with the table set at the lowest angle. The reel has yet to be mounted.

Changes in forward speed of travel were made by using three positions on

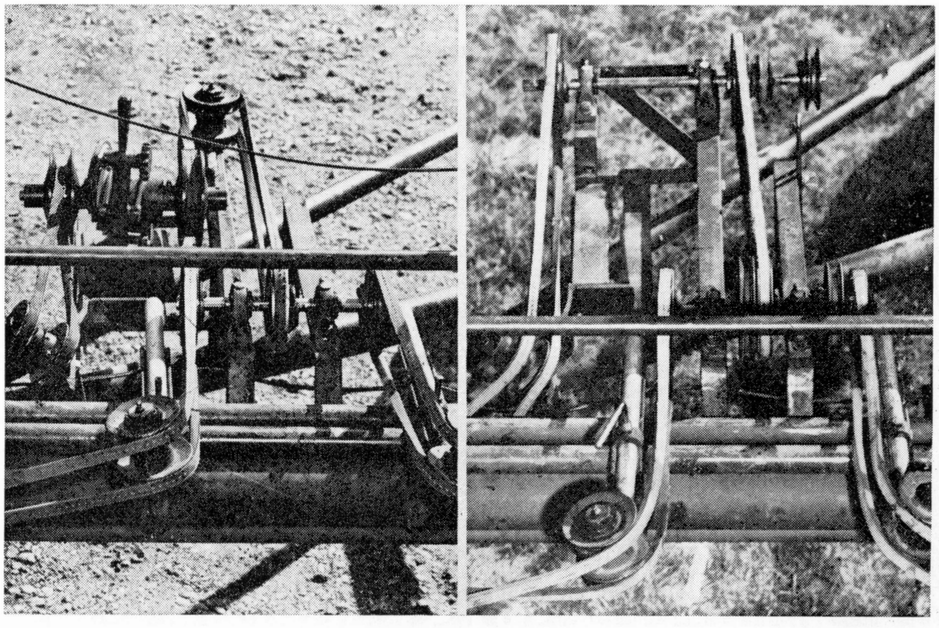

Figure 2. The Maureymatic variable speed drive used in 1963 and 1964 is shown at the left. The pulley arrangement, at the right was used in 1966 for table canvas speed variation.

the foot-operated, variable speed drive. Forward speed was calculated in feet per second by timing each run over a measured distance of machine travel.

The table canvases were placed in all seven positions for the 1963 tests, but only four positions, 15°, 26°, 37° and 48° were used in 1964 and 1966. The first tests, in 1963, showed that the 48-inch gap between the canvases was too large causing a double windrow to be formed at most combinations of machine adjustment. Therefore, only the 37-inch gap was used for the 1964 and 1966 tests. The windrower was operated at canvas speeds of 3.9, 5.6, 7.2 and 8.4 fps, and at forward speeds of 3.0, 3.5 and 4.2 mph (4.3, 5.2 and 6.2 fps).

The windrows made by each combination of forward speed of travel, table angle and canvas speed were examined and classified according to the following coding: A—evenly cut stubble, a—raggedly cut stubble; B—cut material clears guards and knife, b—cut material piles on guards and knife; C—butts and heads of cut material in line with the direction of travel, c—butts at an angle to machine travel and heads criss-crossed; D—windrow full, d—windrow hollow, d′—double windrow, d″—windrow twisted; and x—canvases jammed with straw. An acceptable windrow would be one between the coded limits of ABCD, which was well bound and full with the butts and heads in line, and ABcD, which was well bound and full, with the butts out and the heads criss-crossed (figure 4). Tests were made by windrowing wheat, oats and barley.

Figure 4. The windrow classifications shown above are an ABCD on the left and an ABcD on the right.

RESULTS AND DISCUSSION

The conformation of a windrow and its placement on the stubble are important if damage from weather is to be minimized. A good windrow should be firmly supported on the stubble, be capable of shedding water, allow a free passage of air for drying following rain or snow, and be in a condition for easy recovery by the combine pick-up.

Figure 5. Wide windrows settle in the centre and are subject to wind damage.

It was observed, generally, when windrowing any of the crops, that the classification changed rapidly as the angle of the table was raised. The degree of crisscrossing of the cut material in the windrow increased until, at the steepest angle, the windrows were just within the acceptable classification, in most cases. The windrow, when placed on the stubble at an extreme angle to the direction of machine travel, settled in the centre because of the weight of the heads. This caused the butts to become elevated and the windrow was spread and damaged by winds (figure 5). The centre troughing in the windrow can force the heads to the ground where moisture may be picked up. Drying following rain or snow may be delayed.

The tests in 1963 and 1964 were carried out in a light stand of wheat yielding 16.0 bushels per acre. Under these crop conditions, the better windrows were made when the machine was operated at a forward speed of 3.5 mph, a canvas speed of 1.2 fps and at the lower table angles to avoid hollowness and the formation of two light windrows. The oat yields in 1963 and 1964 were 41 and 28 bushels per acre, respectively. The higher yielding crop was windrowed most satisfactorily at a forward speed of 3.5 mph, a canvas speed of 5.6 fps and at a low table angle, while the lighter crop was handled satisfactorily at all combinations of machine operation. The barley crop for these two years, yielding 32 bushels per acre, was successfully windrowed at the slower forward speeds of travel, at the lower table angles, and at a canvas speed of 7.2 fps.

The windrows made when cutting wheat at canvas speeds of 3.9, 5.6 and 7.2 fps, at all forward speeds and at all table angles, were within the acceptable classification in the 1966 tests (table I). When the canvas speed was increased to 8.4 fps, the windrow formed was hollow when the forward speed was 3.0 mph, acceptable at 3.5 mph and twisted at 4.2 mph. Hollowness, or in some cases, a double windrow was caused by a small quantity of grain cut at a slow forward speed falling on a fast moving canvas. The twisting of the windrow was caused by the inability of the machine to handle the large quantity of material cut at a fast speed which was dropped, rather than placed, on the stubble. It would appear that the angle of the table had little effect on the shape of the windrow when cutting wheat. However, at the steeper angles, the degree of crisscross-

TABLE 1. CLASSIFICATION OF WINDROWS MADE BY DIFFERENT COMBINATIONS OF CANVAS SPEEDS, FORWARD SPEEDS OF TRAVEL AND TABLE ANGLES, 1966

Table angle	Canvas speed 3.9 fps			Canvas speed 5.6 fps			Canvas speed 7.2 fps			Canvas speed 8.4 fps		
	Forward speed			Forward speed			Forward speed			Forward speed		
	3.0 mph	3.5 mph	4.2 mph	3.0 mph	3.5 mph	4.2 mph	3.0 mph	3.5 mph	4.2 mph	3.0 mph	3.5 mph	4.2 mph
	Wheat—		Stubble 7 inches		Straw 27 inches		Yield 27 bu/ac			Grain/straw ratio 1 : 1.51		
15°	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCd	ABCD	ABcd″
26°	ABCD	ABCD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABCd	ABcD	ABcd″
37°	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcd	ABcD	ABcd″
48°	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcd	ABcD	ABcd″
	Oats—		Stubble 7 inches		Straw 26 inches		Yield 52 bu/ac			Grain/straw ratio 1 : 0.82		
15°	ABCD	ABCD	ABCd	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABcD	ABCD	ABCD
26°	ABcD	ABcD	ABcd	ABcD	ABcD	ABcd	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD
37°	ABcD	ABcD	ABcd	ABcd	ABcd	ABcd	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD
48°	ABcD	ABcD	aBcd	ABcd	ABcd	aBcd	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD
	Barley—		Stubble 7 inches		Straw 33 inches		Yield 44 bu/ac			Grain/straw ratio 1 : 0.88		
15°	ABCD	ABCD	ABCd	ABCD	ABCD	ABCD	ABCD	ABCD	ABCD	ABCd	ABCd	ABCD
26°	ABcD	ABcD	ABcd	ABcD	ABcD	ABcD	ABcD	ABcD	ABcD	ABcd	ABCd	abcD
37°	ABcD	ABcD	ABcdx	ABcD	ABcD	ABcD	ABcD	ABcD	abcDx	ABcd	ABCd	abcDx
48°	ABcd	ABcd	ABcdx	ABcDx	ABcDx	abcDx	ABcD	ABcD	abcDx	ABcd	ABCd	abcDx

Classification coding

A—evenly cut stubble
a—raggedly cut stubble

B—cut material clears knife
b—cut material piles on knife

C—butts and heads in line
c—butts out—heads criss-crossed

D—windrow full
d—windrow hollow
d′—double windrow
d″—windrow twisted
x—canvases jammed with straw

Note—Windrows classified ABCD or ABcD are acceptable. All others are defective.

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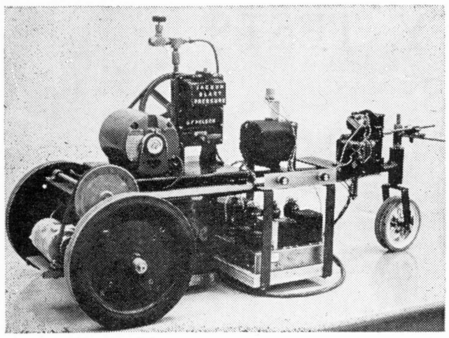

Figure 12. Model tractor with automatic steering mechanism.

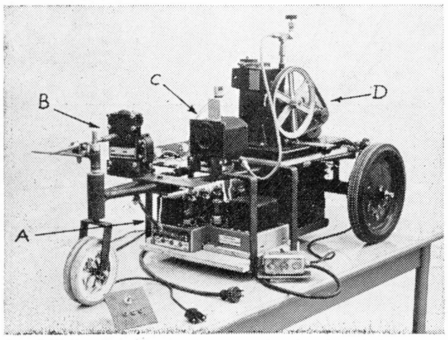

Figure 13. Elements of control circuit. A.) Servo-amplifier; B.) Servomotor, gear train and follower potentiometer; C.) Directional gyro and control potentiometer; D.) Vacuum pump used to power gyro.

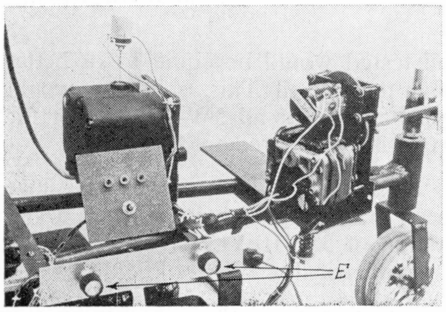

Figure 14. Close-up view of control circuit elements including rheostats (E) for setting of fixed right and left turning angles.

laboratory. The battery powered tractor served as a vehicle to carry its own steering servomechanism, a gyrocompass for detecting angular position, and the vacuum pump and motor required to drive the gyrocompass. It may be observed that the steering servomechanism is a potentiometer controlled electrical servo with a vacuum tube servo-amplifier. The control potentiometer is connected to the gyrocompass while the follower pot is driven by the steering servo motor. The fixed-angle steering signals were incorporated by adding fixed resistors to the potentiometer bridge as shown in figure 15. For testing, the tractor position was "detected" by a man observing the position of the tractor. He provided the HI, =, and LO signals by means of the 3 position switch shown in figure 15.

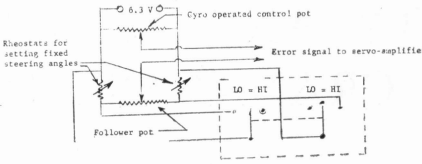

Figure 15. Input to Servo-amplifier.

The model worked satisfactorily, producing paths similar to that shown in figure 11 when subjected to disturbing influences such as picking the front of the model up off the floor and setting it down at an angle to the original direction of travel. No attempt was made to plot a frequency response curve as there was, of course, no intention of packaging this particular system of hardware for production.

CONCLUSIONS

The amount of positional information needed to keep a tratcor on a path approaching a straight line need be no more than HI, = or LO for the control system that has been described here. The hardware required for the control system is all conventional and with the possible exception of the gyrocompass, need not be expensive. The practicability, as with many automatic systems, depends upon the ability to readly measure the actual position of the tractor. The infra red detection system described in the introduction to this paper is presently under investigation by the Department of Agricultural Engineering, University of Alberta to determine its practicability for positional determination.

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ing had reached the maximum acceptable level. Windrows made with the stems at these angles tended to settle in the centre. The wheat crop in 1966 yielded 27 bushels per acre, and the grain to straw ratio of the cut material was 1 : 1.51.

The most satisfactory windrows, when cutting oats in 1966 were made at canvas speeds of 7.2 and 8.4 fps. The slower canvas speeds, 3.9 and 5.6 fps, formed windrows that were either hollow in the centre or double, particularly at the steeper table angles. This was caused by the heavy weight of the grain (yield, 52 bushels per acre; grain to straw ratio, 1 : 0.82). Forward speed of travel appeared to be more critical at the slow canvas speeds than at the faster canvas speeds.

Barley proved to be a most difficult crop to handle. Cutting at the fast forward speed of 4.2 mph was not satisfactory at any of the canvas speeds because this forward motion reduced the efficiency of the knife to cut the soft, pliable barley straw. The cut material also failed to clear the knife and jammed between the reel and canvases at the steeper table angles. The result was a loose, fluffy windrow that settled to the ground almost immediately. The best windrows were made at canvas speeds of 5.6 and 7.2 fps when the table was placed at the lower angles. The yield of barley for this test year was 44 bushels per acre and the grain to straw ratio was 1 : 0.88.

It has been observed, also, that crops cut at an early stage of maturity may be formed into a well bound windrow that remains supported on the stubble, while crops cut when ripe fall into a loose, scattered windrow. This may be caused by the additional weight of the moisture in both the grain and straw of the less mature crop. The possibility of making a slack windrow when cutting ripe grain increases if there has been wind or insect damage in the standing crop.

CONCLUSIONS

The successful operation of the windrower and the formation of a well bound and supported windrow are closely related to the type of cereal grain to be cut, the stand and yield of the crop and the stage of maturity at which this operation is done.

The results of these tests show that all operational factors, forward speed of travel, table canvas speed and table angle, had an effect on the type of windrow. The windrowing of wheat seemed to be the least affected by forward speed and table angle. A fast canvas speed should not be used. The oat windrows were more satisfactory when made at high canvas speeds, low table angles, and at all forward speeds. Barley should be windrowed at slow to moderate forward speeds, a medium canvas speed and at low table angles.

The forward speed of machine travel can be controlled by the operator. However, it would be desirable if the speed of the table canvases could be varied to suit crop conditions. The present construction of the windrower does not lend itself to the adjustment of the slope of the table, but, for a general purpose machine, it is suggested that the maximum angle should not exceed 30° to the horizontal.

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