INTRODUCTION

The problem of stones entering combines is well known by those farming in stoney areas where crops are windrowed. Considerable damage can occur to the combine, and in addition the grain is contaminated. From data supplied by the Board of Grain Commissioners for Canada (2) stones present in wheat when delivered to the lakehead resulted in one car out of 825 cars being graded rejected (3) on account stones during the crops years 1960-61 and 1961-62. For the same years one car in 145 cars of barley was graded rejected and one car in 915 cars of oats was graded rejected. Fewer numbers of cars of all grains were rejected during crop years 1962-65. In all years a considerably higher percentage of cars of barley was rejected on account of stones than for the other grains.

Some data, of a comparative nature, in regard to pickups and stones has been published in the form of test reports on individual pickups by the Agricultural Machinery Administration. These data are brought together to evaluate the effect of some pickup characteristics on their performance with regard to stones. Other pickup characteristics which probably affect the picking up of stones and the possibility of evaluating their effect through the use of the test procedure are discussed.

EXPERIMENTAL PROCEDURE

The experimental procedure used in obtaining the data reported in the test reports (3) involved a laboratory technique for purposes of comparison rather than measurements under actual field conditions. The procedure used is contained in the Appendix of test reports under discussion, but is presented below to assist in the interpretation of the results.

Measurement of a pickup’s ability to throw stones into windrows or to “pick up” stones is difficult under actual field conditions. Even more difficult is the task of measuring the effect of changes in pickup characteristics or specifications thought to be responsible for “picking up” stones. Field conditions are extremely variable and make it difficult to replicate results in the field. Not only does the stone population vary greatly, but soil and crop conditions also vary. In addition, the uneveness of the field prevents operating the pickup at precisely the same level for each trial.

It has been recognized that seldom do pickups literally “pick up” stones, but only toss the stones into the windrow. The windrow carries the stones into the combine. The test procedure outlined is based on the premise that the amount of stones actually picked up and delivered to the combine should be proportional to the amount tossed into the windrow. The test procedure is a method to measure the ability of a pickup to toss stones into the windrow.

Three beds of stones arbitrarily graded to size were laid out, each 40 feet in length and 10 feet in width. Three sizes of stones classed as small, medium and large were determined by retaining on and passing through different-sized screens. The small stones passed through a ¾-inch mesh screen. The medium-sized stones passed through a 2-inch mesh screen but were retained on a ¾-inch mesh screen. The large-sized stones passed through a 6-inch mesh screen but were retained on a 2-inch mesh screen.

A level strip of ground was chosen and the stones were worked into the loose topsoil (dry condition) so that the stones were partially embedded into the soil. Trial runs were made to determine a suitable height for the pickup to operate over the bed of stones so that an adequate sample could be collected in the receiving hopper. The hopper was located an arbitrary distance ahead of the pickup and above the ground surface. Once a suitable height had been determined the pickup carrier (figure 1) was moved to a level concrete area and the distance between the teeth and the concrete surface was measured. The distance was then applied in setting the pickup height of all pickups tested. The hopper was set 8½ inches above the concrete surface and 18 inches ahead of the pickup. A forward speed of 3½ mph was chosen for the test. Additional runs were made with the rotational speed of each pickup increased by 25 per cent, as well as with pickup height above the ground increased one-half inch.

The samples were collected from each bed of stones using the same settings to permit the use of analysis of variance for determining if the differences noted between pickups and other settings were significant. The stones collected were returned to the bed and each bed of stones hand raked after each run to prevent the stones from segregating and to maintain the bed as nearly identical as possible for each run.

TEST RESULTS AND DISCUSSION

Four pickups were used in these tests; figures 1 and 2 show these pickups. Pickup T1460 (figure 2a) is an apron type with the teeth fastened to rods mounted on the apron. T1560 (figure 2b) is a chain and bar type. T1660 (figure 2c) is also a chain and bar type with narrow belts running between the teeth to act as strippers. A.M.S. 4 (figure 1) is a cylinder type with the teeth mounted on cam controlled bars.

The test results of the above pickups indicated statistically significant differences existed between the various pickups. These differences were shown by the laboratory tests but were not confirmed by actual measurements in the field.
The reasons for the differences shown between pickups are not readily apparent. Many factors appear to contribute to a pickup's ability to toss or throw stones into the windrow. The factors known to contribute in this regard, are discussed below as well as others which also appear to contribute.

**TABLE I. EFFECT OF PICKUP ROTATIONAL SPEED ON QUANTITY OF STONES GATHERED**

<table>
<thead>
<tr>
<th>Pickup</th>
<th>Standard Speed</th>
<th>1.25 x Standard Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stones</td>
<td>Stones</td>
</tr>
<tr>
<td></td>
<td>K*</td>
<td>Large</td>
</tr>
<tr>
<td>T1460</td>
<td>0.9</td>
<td>3.0</td>
</tr>
<tr>
<td>T1560</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>T1660</td>
<td>1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>AMS4</td>
<td>1.25</td>
<td>109.5</td>
</tr>
</tbody>
</table>

*Spring Constant K measured parallel to direction of travel.

**TABLE II. EFFECT OF PICKUP HEIGHT ON QUANTITY OF STONES GATHERED**

<table>
<thead>
<tr>
<th>Pickup</th>
<th>Teeth Raised ½ inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stones</td>
</tr>
<tr>
<td></td>
<td>Teeth at Ground Line</td>
</tr>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>T1460</td>
<td>0.0</td>
</tr>
<tr>
<td>T1560</td>
<td>0.5</td>
</tr>
<tr>
<td>T1660</td>
<td>0.4</td>
</tr>
<tr>
<td>AMS4</td>
<td>109.5</td>
</tr>
</tbody>
</table>

**Factors in Pickup Design and Operation**

Considering first those factors reported on it is readily seen that for all the pickups the rotational speed and pickup height are important.

**Rotationai Speed:** The rotational speed of a pickup determines the velocity of the tooth. As shown in table I increasing the rotational speed 25% increased the amount of stones picked up in nearly all cases. Tooth velocity may be partly responsible for the differences in the stones picked up by the various pickups. The tooth velocity, (at the point of picking up) given in the specifications for the pickups does not, however, verify this in every case. Other factors must also contribute.

The tooth velocity, while controlled by the rotational speed, also varies as the tooth travels around the cam of a pickup. To avoid picking up stones a low velocity is desired, but unfortunately some pickups have the highest tooth velocity at or near the point where the tooth may touch the ground when the pickup is lowered.

**Pickup Height:** The height of the pickup teeth above the ground was a very important factor as shown in table II.
Some of the pickups, after raised ½ inch did not pick up any stones and the AMS-4 pickup picked up only about 1/20 as many stones.

These results establish that when the windrow is supported on the stubble, the pickup should not be allowed to contact the ground. This practice will keep stone pickup to a minimum with most pickups. However, when windrows are settled to the ground the pickup must be set low enough to contact the crop material and inevitably will contact the ground. For this reason other design factors become important.

Other Factors for Consideration

Spring Constant: Although the values of the spring constant for the teeth of the pickups are given (Table 1) the effect of changing the value has not been evaluated. The results between pickups do not permit any conclusions to be drawn in this regard even though there are differences in value of spring constant K. A pickup tooth with a high spring constant will, however, be more liable to toss stones than one with a lower spring constant which may deflect enough to pass over the stone before putting it in motion.

The spring constant in a lateral direction is even greater in importance. If there is no lateral deflection the tooth will have to move the stone it strikes or be deflected back until it will pass over it instead of deflecting sideways and around the stone. Measurements of the lateral spring constant were not taken although this value was known to vary considerably between pickups. Frequently pickup teeth deflect more easily in the direction of travel; this is true of those pickups having the coil spring portion of the tooth fitted closely over a pipe. The close fit prevents the coil from opening and thus effectively shortens the active length of the tooth in the lateral direction.

Tooth Spacing and Arrangement: Teeth mounted in pairs and close together pick up stones more readily than other types, particularly if the lateral spring constant is high. A pair of teeth can act together on a single stone to move it, much more easily than a single tooth. If the rows of teeth are staggered there is not the same opportunity for two teeth to contact a stone together. The specifications for the pickups show considerable differences in tooth spacing and arrangement.

Tooth Shape: The shape of the teeth will be a factor since this will determine the angle of attack of the tooth on a stone as the tooth is deflected. Teeth with a forward curve or bend have a better chance to move a stone. Only one of the pickups was reported to have teeth which were curved.

Tooth Mass: The mass of a tooth at a given velocity will put a stone in motion with little tooth deflection if the stone is not too large. With the velocities and teeth used on most pickups stones passing through a ¾ inch screen can probably be put in motion in this manner. Data as to the differences in this regard between pickups is not given.

Number of Teeth: The number of teeth of pickup contribute to the number of stones tossed ahead. The more hits or passes per unit area of ground may assist in picking up the windrow but also increased the chances for stones to be picked up. Large differences in this specification for the various pickups are reported.

CONCLUSIONS

The results from the test reports indicate that both pickup operating height and rotational speed of combine pickups are important in regard to the number of stones picked up. A pickup operated in contact with the ground and at a high rotational speed will pick up more stones.

The importance of other pickup characteristics such as the tooth spring constant, tooth spacing and arrangement, tooth shape and mass, and the number of teeth has not been determined. The use of the test procedure outlined should enable the measurement of the effect of these factors on the ability of a combine pickup to pick up stones. With this information, characteristics could be chosen for the design of a pickup which would pick up a minimum of stones.

REFERENCES

1. Agricultural Machinery Administration Test Reports, Numbers T-1460, T-1560 and T-1660, Saskatchewan Department of Agriculture.

2. Data from Board of Grain Commissioners for Canada. Winnipeg, Man.


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Agricultural Engineering Department, University of Saskatchewan, Undergraduate Thesis.


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