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# Combine Harvester Investigations

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# COMBINE HARVESTER INVESTIGATIONS

G. W. McCUEN AND E. A. SILVER

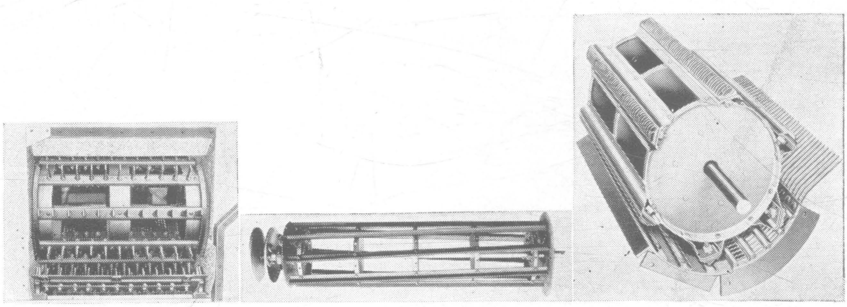
## INTRODUCTION

From 1926, when the combine was first demonstrated in Ohio, through 1934, farmers in the State bought an average of 38 combines a year. In 1935, the small, lightweight combine came on the market. This new design met an enthusiastic response, as indicated by the tremendous increase in sales of combines during subsequent years.

Previous to production of the small design, combines generally had a cut of 9 to 16 feet. These large machines were costly to operate, especially on smaller farms, heavy and difficult to transport from one field to another, and not adapted to harvest all crops raised in Ohio.

The small, one-man combines have many advantages. They are so designed that they can be pulled through any ordinary farm gate without being dismantled. They can be operated at much higher rates of ground travel and, if properly adjusted and equipped with the correct attachments, will successfully harvest the majority of farm crops grown in Ohio, including flax. The small machines are much easier to store, requiring little space. In addition, practically all small combines are designed to incorporate the straight-through principle, by which the crop passes through the machine in the most direct manner, a desirable feature in any machine, because trouble usually lurks at every corner or turn the material is compelled to take.

Because of the diversity of crops grown in Ohio and the different ripening times for these crops, use of the combine is not definitely seasonal. The combine can be used a great number of hours per year and thus yield a good return on the original investment.



**Spike-tooth** **Bar** **Rasp**

**Fig. 1.—Types of cylinders used in combines**

A change in the type of cylinder has come with the development of the small combine. Many times a companion crop, such as sweet clover or some other legume, is grown with wheat, oats, or barley. The green material present in these companion crops makes harvesting difficult. As a result, use of the spike-tooth type of cylinder has been almost discontinued, and the rasp and bar types have taken its place. These cylinders have been found well adapted to combine harvesting, particularly where foreign material exists.

The average rate of travel of the small combine harvester mounted on rubber tires has been found to be 3.53 miles per hour. The larger machines mounted on steel traveled an average of 2.51 miles per hour. With these two rates of travel as a maximum and minimum, table 1 gives the acres per hour that can be harvested with different widths of cut.

**TABLE 1.—Acreage table for different widths of cut**

| Width of cut, feet | Rate of travel, miles per hour | Acres per hour | Acres per day of the following number of hours | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7 | 8 | 9 | 10 | 11 | 12 |
| 5 | 3.53 | 1.81 | 12.6 | 14.5 | 16.3 | 18.1 | 19.9 | 21.7 |
| 6 | 3 53 | 2.18 | 15.3 | 17 4 | 19.6 | 21.8 | 23.9 | 26 2 |
| 10 | 2.51 | 2.58 | 18 1 | 20.6 | 23.2 | 25.8 | 28 4 | 30.9 |
| 12 | 2.51 | 3.53 | 24.7 | 28.2 | 31.8 | 35.3 | 38.8 | 42.4 |

Table 1 takes into consideration time lost unloading the grain tank, failure to cut full width of swath at all times, time lost for adjustments, and stops due to field conditions. The figures are based on good operating conditions. Harvesting soybeans where conditions are bad may reduce these acreages as much as 25 per cent, depending upon crop and field conditions.

## SOURCES OF GRAIN LOSSES

There are four separate, distinct areas of the combine at which grain can be lost: the cutter bar, cylinder, rear of the straw rack, and rear of the sieves. Losses at these areas are now usually known as the cutter bar, cylinder, rack, and shoe losses.

The cutter bar loss includes loose or full heads of grain which have been shelled or pitched off by an improperly adjusted reel and heads of grain which have been cut off by the knife and dropped to the ground before reaching the elevating mechanism.

Shattering losses should not be confused with cutter bar loss, and it is, therefore, advisable to make a check of losses due to shattering before the grain is cut. Tests have indicated that oats shatter much more readily than wheat. Even with prolonged standing and severe storms, the natural shattering of wheat is very small. Birds cause much shattering.

The cylinder loss includes unshelled grain left in the heads and carried to the rear of the machine by the straw rack. It does not include any loose kernels of grain. This source of loss is probably the most significant, not from the standpoint of extent, but because of the effect of the action of the cylinder upon the other sources of loss.

Rack loss includes shelled or loose grain carried over the rear of the straw rack with the straw. Depending upon the cylinder adjustment and rate of threshing, this loss may be one of the heaviest; yet it is usually the hardest to detect. The grain loss at this source is greatly affected by the nature, condition, and volume of material passing over the rack. It is the key loss and in the majority of cases is the criterion as to what is happening at the other sources of loss.

The shoe loss includes loose grain carried over the rear of the sieves with the chaff. It can be detected more readily than the loss at the straw rack. This loss, like the rack loss, is dependent to a great extent upon the condition of the straw traveling over the straw rack. If the straw is cut up badly, small pieces will sift through the straw racks and overload the sieves, making separation very difficult. In order to relieve this heavy mat of material on the sieves, the average operator usually increases the wind blast, with the result that much loose grain is carried over the rear of the sieves with the chaff.

All four sources of loss must be considered in the efficiency of combining. Furthermore, it is important that they balance each other as much as possible. It is not efficient harvesting to have one loss low, another high, as will happen if an effort is made to get all kernels out of the heads with little consideration to the other sources of loss.

The four sources of loss are used to figure the over-all efficiency and are indicative of the efficiency of harvesting. The cylinder, rack, and shoe losses are used as the basis for determining machine efficiency.

## COMBINE TESTS

With the rapid increase of combine sales in 1935, many machines were in the hands of inexperienced operators. Consequently, numerous mechanical breakages occurred. Grain losses were high, and much grain spoiled in storage. The change from stationary to combine threshing brought about new problems which could not be solved by principles established for the binder-thresher method.

For several years the Department of Agricultural Engineering of the Ohio Agricultural Experiment Station, in cooperation with the manufacturers, has studied the adaptability and efficiency of the combine under Ohio conditions. Objectives of the work have been: (1) to determine the sources, extent, and relationship of all grain losses in harvesting various kinds and conditions of crops with the combine and (2) to foster improved design and correct adjustments to overcome these grain losses.

The first part of the project consisted of an organized series of tests on the farm, with combines operated either by the farmer himself or by a custom operator. A test was made on each machine as adjusted by the farmer or custom operator. When the combine was found to be wasting grain, it was adjusted, and check tests were run to determine the result. It was necessary to make two or three check tests on many combines to reach a point where the machine was operating at its highest efficiency. How long it took to reach this point depended largely upon the condition of the crop and the nature and number of adjustments necessary. Upon completion of this series of tests, a more detailed study was made to determine the extent and relationship of the various adjustments provided for on the functional units of the machine. These tests were run under controlled conditions as much as possible.

## TECHNIQUE EMPLOYED

In order to determine the grain loss at each of the four areas, a definite plot 1/100 acre in area was established. The length of the plot was determined by dividing the area (435.6 square feet) by the full width of cut of the machine to be tested. The width of the area was maintained by operating the machine at full cut. The length of the plot was indicated by placing two range poles at each end of the plot about 10 feet out from the standing wheat.

The machine was started approximately 150 feet back from the first pole in order that all functional units would have ample time to become fully loaded. The inner grain divider was operated slightly into the standing grain to make sure of cutting a full swath.

As soon as a marked point on the combine came in line with the first two range poles, a signal was given and the test was started. A container was placed under the grain spout in the grain bin, and two canvases were pulled up under the rear of the combine, one to collect the threshed straw and the other to collect the chaff. As soon as the combine reached the two poles at the end of the test area, a signal was given, and the canvases and grain container were removed. A record was kept of the elapsed time. All the material collected during the test was representative of 1/100 acre.

The grain in the straw and chaff collected in the two canvases constituted the machine loss. The top canvas contained the cylinder (grain in heads) and rack (loose grain) losses. The lower canvas contained the shoe loss.

**Fig. 2.—Collecting straw and chaff during a test**

In order to separate these losses, it was necessary to construct special equipment, consisting of three functional units, an elevator, a shaker, and a rethresher. All material collected from the combine was first weighed and recorded. The material collected on the top canvas was then fed through the machine. The loose grain was shaken out by the shaker and collected in a box; it constituted the rack loss. The straw passed over the shaker and entered the rethresher. This unit removed any kernels of grain still in the heads, which constituted the cylinder loss. The material on the lower canvas (shoe loss) was then run through the rethresher to remove the chaff. All samples of grain were cleaned in a small fanning mill. The sum of the grain collected at the grain elevator and that reclaimed by the rethresher represented the total grain delivered to the machine at the cutter bar. The percentage loss at each area was then determined by dividing the weight of each sample (cylinder, rack, and shoe) by the total weight of grain through the machine.

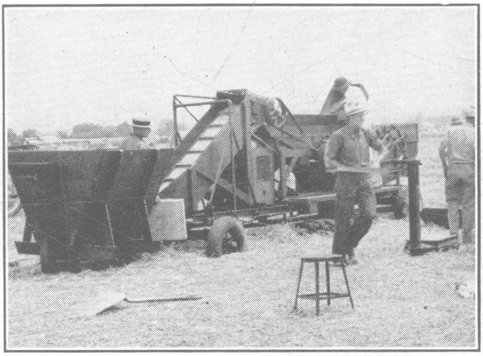


**Fig. 3.—Equipment for separating and cleaning grain losses**

The cutter bar losses were secured by placing a small square frame over the stubble immediately behind the cutter bar at various locations within the test area. All loose grain and heads of grain were picked up within the frame, threshed, cleaned, weighed, and recorded.

**Fig. 4.—Collecting cutter bar losses**

The frame represented an area of 4.356 square feet. Ten samples were taken over the area just harvested. The sum of these 10 samples multiplied by 10 represented the average cutter bar loss over the whole test area. The base used in figuring the percentage loss at the cutter bar was the sum of the machine and cutter bar losses plus the grain collected in the grain tank.

The over-all efficiency, which is indicative of the method of harvesting, was calculated by dividing the weight of the grain caught at the grain elevator by the sum of the grain collected at the elevator and all losses.

The machine efficiency was calculated by dividing the weight of the grain collected at the elevator by the sum of the machine losses (cylinder, rack, and shoe) and the grain collected at the grain elevator.

## FIELD TESTS ON FARMER- AND CUSTOM-OPERATED MACHINES

A study of combines as they were operated in the field revealed many interesting facts which formed a basis for further investigations.

Many farmers had made the mistake of purchasing a machine too small for the acreage to be harvested. This mistake was aggravated by lack of experience of the operators.

During a wet year, the crops were weedy, down, and tangled, and in many fields, second growth had appeared. Most of the small machines were driven by means of the power-take-off, which gave some trouble because of lack of an ample and steady flow of power, resulting from extra power required to pull combine over the soft ground. Although much grain harvested with the combine harvester spoiled that year, as much harvested by the binder-thresher method spoiled, and much of this grain could not be salvaged.

During a dry year, most crops were in excellent condition. They were standing up well and contained little green material. Grain losses were, therefore, much less, and adjustments on the machine were more effective. The power-take-off machines functioned more effectively this year.

Ninety-six tests were made over the 2-year period, 91 on wheat and 5 on oats. This number includes all repeat tests which were necessary to check adjustments for most efficient operation. At the time these tests were made, most farmers were skeptical about harvesting oats with a combine. Eighty-six per cent of the tests were made on the small combine and 14 per cent on the 12-foot or larger size. The first test was made with no changes on the machine. Only on retests were adjustments made or recommended.

**TABLE 2.—Number of machines tested**

| | Number of machines tested | Number of machines requiring single tests only | Number of machines requiring two or more repeat tests | Average machine grain loss per acre before any adjustments were made, pounds |
|---|---|---|---|---|
| Dry year | 28 | 14 | 14 | 34.4 |
| Wet year | 30 | 14 | 16 | 106.5 |

A few more repeat tests were made in the wet year than in the dry one because of the weedy condition of most crops. Fifty per cent or more of the machines required repeat tests to put them in good adjustment.

Table 3 gives the results of a few of the most significant tests made in the field. The data are representative of how the machines were being operated. It is evident that many machines were wasting much grain, some as high as 388 pounds per acre (machine loss), and a number of these high losses were found where crop conditions were good. Grain losses rated in the following

**TABLE 3.—Effect of machine adjustments on grain losses**

(A, B, and C indicate repeat tests on same machine)

| Condition of crop | Source of greatest loss | Test | Grain losses, pounds per acre | | | | | Machine setting |
|---|---|---|---|---|---|---|---|---|
| | | | Cylinder | Rack | Shoe | Total machine | Cutter bar | |
| Standing up well, weedy in spots | Rack | 1 | 5.5 | 241.0 | 37.0 | 283.5 | 20 | *Machine as found in operation* |
| | | 1-A | 6.0 | 54.0 | 21.0 | 81.0 | 90 | Raised cylinder to nearly maximum clearance; opened top sieve one notch; raised cutter bar |
| | | 1-B | 6.0 | 5.5 | 13.5 | 25.0 | 60 | Increased cylinder speed; lowered rack speed from 315 to 220 r.p.m. |
| | | 1-C | 5.5 | 3.8 | 4.9 | 14.2 | 60 | Raised rear end of sieves and straw rack |
| Very weedy and lodged | Rack and shoe | 1 | 7.5 | 195.0 | 185.5 | 388.0 | 10 | *Machine as found in operation* |
| | | 1-A | 9.2 | 63.0 | 5.4 | 77.6 | 55 | Lowered concaves to two notches of maximum; opened both screens two notches; raised cutter bar |
| Clean and standing up well | Cylinder | 1 | 42.0 | 5.0 | 2.0 | 49.0 | 60 | *Machine as found in operation* |
| | | 1-A | 8.0 | 2.0 | 1.0 | 11.0 | 60 | Increased cylinder speed from 925 to 1,000 r.p.m. |
| Very heavy crop and weedy | Rack | 1 | 7.5 | 200.0 | 35.1 | 242.6 | 40 | *Machine as found in operation; tractor in second gear* |
| | | 1-A | 6.5 | 84.0 | 13.0 | 103.5 | 45 | Tractor operated in low gear |
| Medium heavy crop, very clean and standing up well | Rack (very light) | 1 | 1.0 | 11.0 | .4 | 12.4 | 50 | *Machine as found in operation* |
| | | 1-A | 4.0 | 2.0 | .1 | 6.1 | 50 | Rack speed reduced from 225 to 200 r.p.m. |
| Light crop, clean | Rack (very light) | 1 | .8 | 11.5 | 3.0 | 15.3 | 60 | *Machine as found in operation; tractor third gear* |
| | | 1-A | .5 | 8.2 | 1.0 | 9.7 | 60 | Tractor operated in second gear |
| | | 1-B | .5 | 8.0 | 1.0 | 9.3 | 60 | Tractor operated in first gear |
| Weedy | Rack and shoe | 1 | 1.8 | 53.2 | 84.0 | 139.0 | 13 | *Machine as found in operation* |
| | | 1-A | 4.5 | 17.2 | 12.0 | 33.7 | 22.5 | Raised cutter bar one notch; lowered concaves three notches |
| Weedy | Rack and shoe | 1 | 9 | 31.0 | 72.0 | 103.9 | 30 | *Machine as found in operation* |
| | | 1-A | 2.2 | 11.0 | 3.0 | 16.2 | 60 | Raised cylinder for more clearance; opened lower sieve two notches; opened upper screen one notch; raised cutter bar |
| Medium heavy crop, clean | None | 1 | None | .5 | 1.5 | 2.0 | 15 | *No adjustments necessary; operated very efficiently* |

descending order: rack, shoe, and cylinder. These losses, particularly the rack and shoe, were greatly reduced by proper adjustment, although most adjustments increased the cylinder loss.

Practically all operators were very careful about getting all the kernels out of the heads. In fact, this accomplishment was the "measuring stick" for efficiency of combining in many cases, apparently a carry-over from the stationary thresher method of harvesting, in which a good deal of attention is paid to the shelling of the grain and little to the loose or shelled grain which goes out through the wind stacker. Little attention was given to the loose grain coming over the rear of the straw rack and sieves; only two operators observed this loss critically. Subsequent investigations indicated, however, that this loss has a very important effect on machine efficiency under all crop conditions.

**TABLE 4.—Percentage distribution of total machine losses**

| | Cylinder | Rack | Shoe |
|---|---|---|---|
| Dry year | 14.2 | 43.3 | 42.5 |
| Wet year | 9.8 | 58.0 | 32.2 |

The extent of the grain losses rated in the following descending order: rack, shoe, and cylinder. There was a better balance between the rack and shoe losses in the dry year than in the wet year. The ratio of cylinder loss to the other losses was slightly greater during the dry year, indicating that less attention was given to the shelling process during the dry year and that greater clearance between the cylinder and concaves was provided. As a result, the losses were more evenly distributed over the three areas. During the wet year, when conditions were bad, it seemed to be common practice to reduce the clearance between the cylinder and concaves in order to get all grains out of the heads. As a result, the rack losses were increased out of proportion to the other losses, and the cylinder losses were small in comparison with either the rack or shoe losses.

One of the most common practices was to overload the machine. This tendency was more pronounced during the wet year; nevertheless, it occurred all too frequently during the dry one. The custom operator paid less attention to overloading than the farmer operator.

Practically every adjustment possible to make on combines was made at some time during the tests. Most common adjustment was the clearance between the cylinder and concaves, and this adjustment usually was made to decrease rather than increase the amount of clearance. Increasing this clearance had an apparent effect upon losses at the other areas, as was proved by tests on machines in which rack losses were 241 pounds per acre in one case and 195 pounds per acre in another. Providing greater clearance between the cylinder and concave only reduced these losses to 54 and 63 pounds per acre. Other minor adjustments brought the loss of 54 pounds down to 3.8 pounds per acre.

In the past, particularly on the stationary threshing machine, it has been the custom to examine the heads of the threshed grain to determine whether or not a good job was being done. In fact, this has been to most operators the standard for efficient threshing. Little or no attention has been paid to grain losses at the other areas. Many times, therefore, overthreshing has occurred at the cylinder, and this condition has usually resulted in high losses at the other areas. This method of judging efficiency was carried over to combines operated by farmers and custom operators. The machine was usually set for a good job of shelling by adjusting the concaves close to the cylinder. As a result, the straw was broken up badly by the cylinder, and effective separation of the grain from the straw and chaff was made very difficult. Sufficient concave-cylinder clearance was found to be the most important factor in high machine efficiency; yet it was the most neglected. (See discussion of cylinder-concave clearance.)

Most operators were careful about holding the cylinder speed at the rated r. p. m., although few possessed a speed counter for checking it. The hum of the cylinder seemed to be the basis for determining the speed for experienced threshermen and often seemed to be an effective guide. High or low cylinder speeds did not influence cylinder loss to any great extent. However, when the r. p. m. of the rack was directly related to the speed of the cylinder, high rack losses usually resulted. An overspeeded rack will keep the straw up and not allow it to settle down sufficiently to be fully caught by the next upward movement. A rack which is under speed will not pitch the straw sufficiently to allow for effective and thorough separation. The speed of the rack is a critical adjustment and should be checked, as the straw rack is usually the first functional unit to become overloaded. It may become overloaded by either one or both of two conditions, amount of material passing over in a unit of time and the condition of material, such as the degree to which it has been broken up or the amount of green material incorporated within it. A typical example of improper rack speed is illustrated in table 3. A machine was found to be wasting grain at the rate of 283.5 pounds per acre. This machine had been adjusted for soybeans, and because of lack of combine knowledge, the operator was unable to get even one functional unit properly adjusted for wheat. The overspeeded rack contributed much to these high losses.

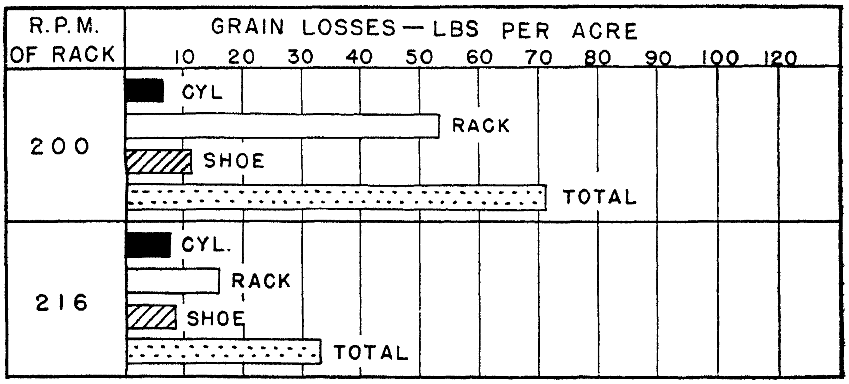



**Fig. 5.—Effect of rack speed on grain losses**

High shoe losses were usually found to be associated with high rack losses. If the rack is loaded with finely broken straw, much broken straw sifts through the rack openings and falls to the sieves, overloading them. In order to maintain a fair degree of separation, most operators resorted to applying maximum wind blast, which resulted in much grain being blown over the rear of the sieves. Changing the direction of the wind blast was seldom practiced, but this adjustment was later found to be much more effective than increasing the wind blast to maximum, because it tends to break up the heavy mat of material at the front end of the sieves and allow the grain to sift through. Opening the sieves was resorted to in some cases, but this practice leads only to poorly cleaned grain.

In a few cases, the rate of travel was found to be high, and the machine was overloaded. The effect of such operation was more serious during the wet year, because weeds and green material loaded up the sieves and straw rack and made separation difficult.

Although many machines required retests for proper adjustment, others were operating efficiently. One machine was found operating at 99.8 per cent of machine efficiency. The operator was familiar with most combine adjustments, as indicated by the following losses: cylinder, none; rack, 0.5 pound per acre; shoe, 1.5 pounds per acre—a total machine loss of only 2.0 pounds per acre.

## EFFECT OF VARIOUS MACHINE ADJUSTMENTS ON EFFICIENCY OF COMBINING

Results of the tests on farmer-operated machines indicated a need for further, more detailed study. It was planned, therefore, to make separate investigations on the major adjustments in order to determine their effect on and relationship to efficiency of combining as a whole. In previous tests, these adjustments had had the same effect on every machine, regardless of the type of cylinder or straw rack. Some machines were more easily overloaded than others, however, largely because of limited rack capacity, which affected the extent of grain losses considerably.

### CYLINDER-CONCAVE CLEARANCE

The study of cylinder and concave clearance as it affects efficiency of combining was made by varying the distance between the cylinder and concaves. The following clearances were established: ¼ inch, ½ inch, ¾ inch, and 1 inch. All other machine adjustments were held constant throughout the tests, and the speed of all functional units of the machine was held normal. Only one machine, having a rasp-type cylinder, was used, and it was operated at the same rate of travel and at the same height of cut throughout all tests. Grain losses at the cylinder, rack, and shoe were recorded. Throughout the tests, the cutter bar of the combine was set to cut a 15-inch stubble, or approximately 28 inches of straw threshed. The rate of travel averaged 2.7 miles per hour. Under these conditions, the combine was never overloaded. The crop was of even height, free from weeds, and only slightly straw-broken.

Figure 6 indicates higher grain losses at the small cylinder-concave clearance. Although the difference seems to be inconsequential, the losses would have been much more pronounced had the machine been operated close to or beyond its limit of capacity.

The cylinder loss at the ¼-inch clearance was very small. The rack and shoe losses, however, were much greater. Providing more clearance increased the cylinder loss but apparently lowered the rack and shoe losses, and to a much greater degree than the cylinder loss was increased. This adjustment naturally reduced the total machine loss.

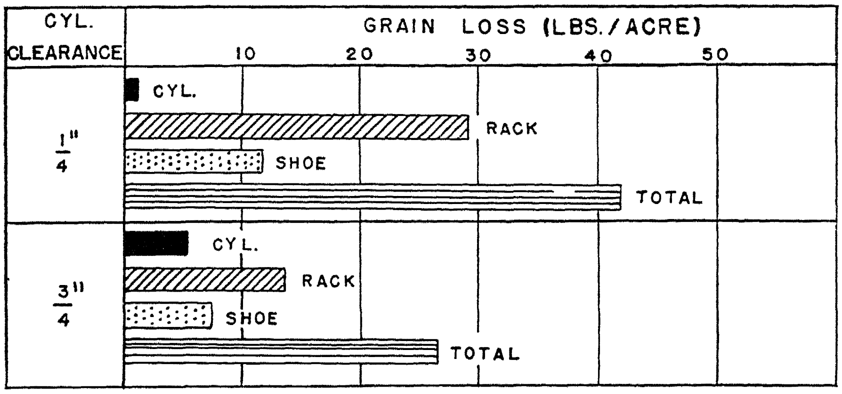



**Fig. 6.—Effect of cylinder-concave clearance on grain losses**

An effort was made to find a reason for the lowering of the rack and shoe losses at the wide cylinder-concave clearances. It was observed that the straw coming over the rack was broken up badly at the ¼-inch clearance, and this observation was substantiated by a check on the amount of straw and chaff collected during the tests. It is reasonable to expect a greater proportion of the material to be found on the shoe if the straw is broken up badly by the cylinder, because more of the short pieces sift through the rack openings. The straw on the rack is also of shorter length.

**TABLE 5.—Per cent of straw and chaff at various cylinder-concave clearances**
(Average of 12 tests)

| Cylinder—concave clearance, inches | Per cent of chaff | Per cent of straw |
|---|---|---|
| 1 | 3.6 | 96.4 |
| ¾ | 5.6 | 94.4 |
| ½ | 9.4 | 90.6 |
| ¼ | 8.7 | 91.3 |

Table 5 shows that there is a larger percentage of chaff or finely broken straw at the small clearances, indicating that the cylinder breaks up the straw more at the small clearances. This condition affects rapid separation of the grain, both on the straw rack and the shoe.

A few simple tests were made to determine the rate at which a standard amount of grain would sift through whole and finely ground straw (fig. 7) with the same amount of shaking. It required 13 seconds for 2 pounds of wheat to sift through the whole material. With the same time for shaking, only 0.9 pound sifted through the fine material.

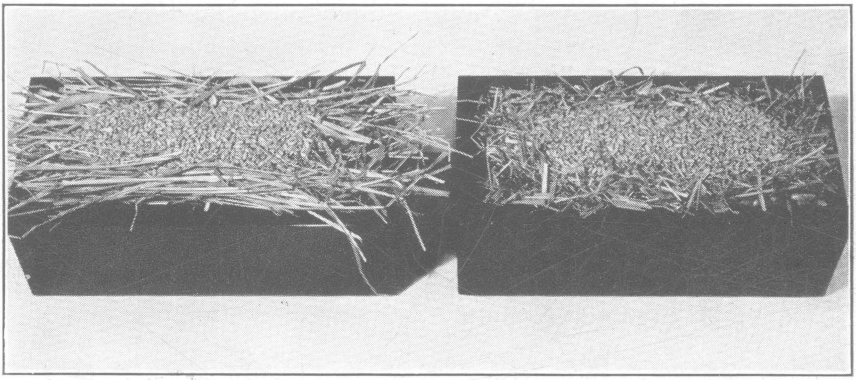


Fig. 7.—Whole material Fine material

CYLINDER SPEED

Following the cylinder-concave clearance tests, a series of tests was run on the effect of cylinder speed. It was thought that cylinder speed would probably have the same effect as the clearance between cylinder and concaves.

For this series of tests, six different cylinder speeds, varying from 1,200 to 1,700 r. p. m. at 100-r. p. m. increments, were established. All other adjustments, including the rate of travel, were held normal. In order to maintain a steady cylinder speed, the cutter bar was raised one notch above the placement in previous tests to lessen the amount of material passing through the machine. The r. p. m. of the cylinder was first set and then checked after the machine was in actual operation.

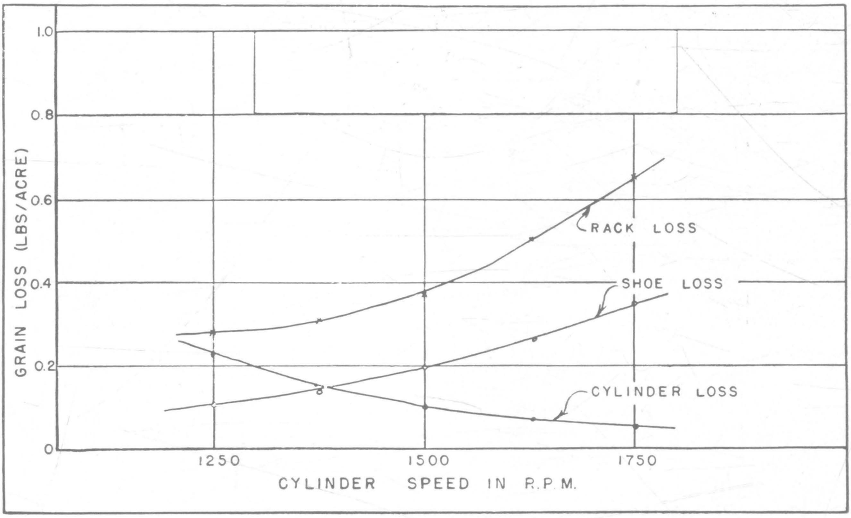



Fig. 8.—Effect of cylinder speed on grain losses

Much the same result was obtained as on cylinder-concave clearance, but not to quite the same extent. If the machine had been more fully loaded, the grain losses would have been much higher at the critical areas. Yet the same relationship existed. As the cylinder speed increased, the cylinder loss went down, and the rack and shoe losses took a consistent upward trend. This result indicates that high cylinder speeds have a tendency to break up the straw, in addition to cracking the grain, making separation of the grain slow and difficult, but certainly not to the same degree as low cylinder-concave clearance. High cylinder speeds probably have a greater effect upon cracking grain and pitching kernels back on the rack to a point where there is not sufficient time to shake them out thoroughly.

Table 6 indicates a slightly greater percentage of chaff or finely broken material at the higher cylinder speeds. This percentage is so small, however, that it is of little significance.

**TABLE 6.—Per cent of chaff and straw at various cylinder speeds**

(Average of 18 tests)

| R.p.m. of cylinder | Per cent of chaff | Per cent of straw |
|---|---|---|
| 1,200 | 3.6 | 96.4 |
| 1,300 | 4.0 | 96.0 |
| 1,400 | 4.2 | 95.8 |
| 1,500 | 4.3 | 95.7 |
| 1,600 | 4.3 | 95.7 |
| 1,700 | 5.7 | 94.3 |

#### MACHINE CAPACITY

There are two ways to vary the capacity of a combine: varying the height of cut and changing the rate of travel. The rate of travel can be varied either by changing gears or by changing the speed of the tractor engine. The speed of the tractor engine should not be changed if the combine is driven by the power-take-off, as such a change will change the operating speed of the combine. These units must be kept at the speeds recommended by the manufacturer for an efficient job. Lowering the speed of the tractor engine will also decrease the horsepower output of the engine.

The cutter bar must not be lowered to a point where excessive grain losses may exist at the rack or shoe. The cutter bar is sometimes placed too low when a maximum amount of straw is desired for bedding or other purposes. If the cutter bar must be operated low, particularly in a heavy crop, the forward travel of the machine should be decreased, in all instances by changing gears rather than by changing the speed of the tractor engine.

When the cutter bar is lowered, more material enters the machine per unit of time. The same result is accomplished by increasing the rate of travel. When the cutter bar is lowered, the increase in volume is made up largely of straw. When the rate of travel is increased, however, the increase in volume is composed of both grain and straw; in other words, the same proportion of heads of grain and straw enters the machine, but at a faster rate. It remains a question which of the two situations is the more serious, but, in either case,

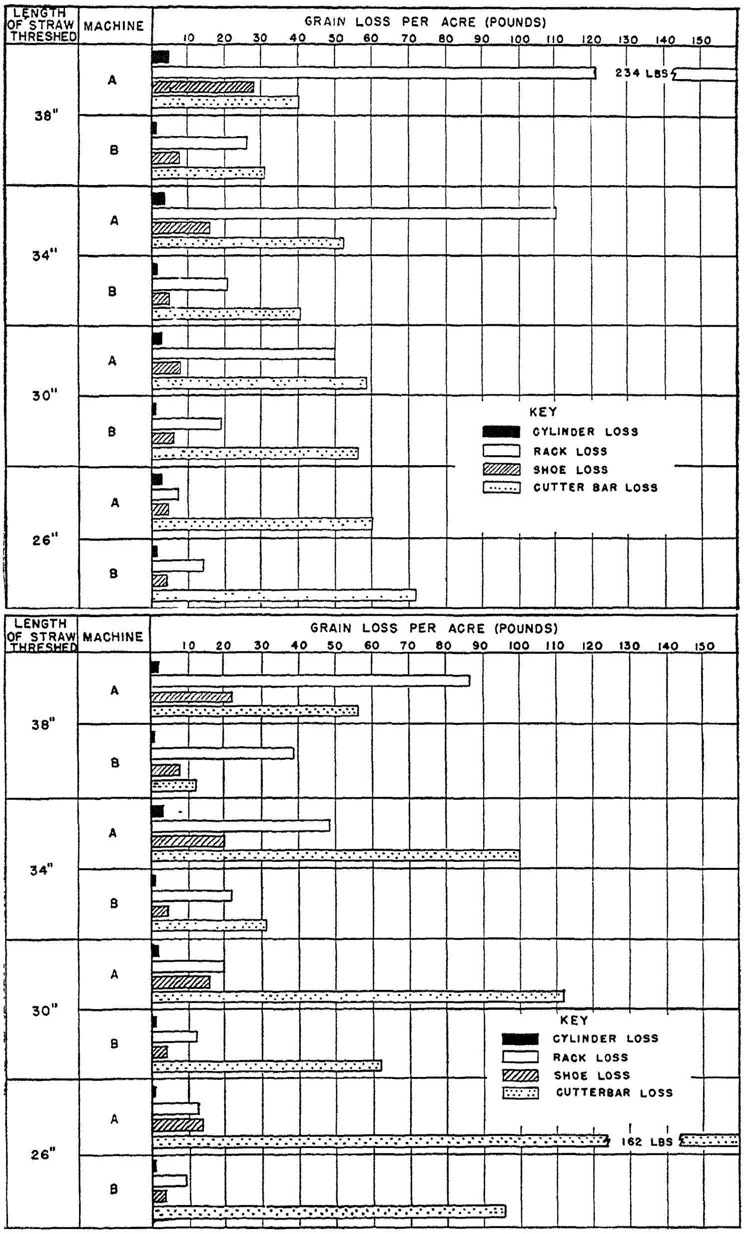



**Fig. 9.—Effect of capacity on grain losses**

**Top—Bearded wheat**
**Bottom—Beardless wheat**

enormous grain losses will result if the combine is loaded much above its limit of capacity. The capacity of the machine is influenced more by the volume of material passing through per unit of time than by any increase of weight of material at the same volume.

Field tests have indicated that no combine will waste much grain if it is operated below its limit of capacity. The limit of capacity varies with different machines of the same size or width of cut. If proper adjustments are made and maintained, however, machine efficiency can be increased greatly with a minimum of grain losses by raising the capacity of the machine per unit of time.

In order to determine the effect of volume of material passing through the combine per unit of time, a series of tests was run on two machines and on two varieties of wheat, one bearded and one beardless. Two machines with different widths of cut were used. Preliminary tests were made in order to determine the best adjustments, and the same adjustments were held throughout the series. Clearance between the cylinder and concaves was near maximum. The tractor was run in low gear. The volume of material entering the machine was varied by changing the height of the cutter bar from the ground. Both plots of wheat were of uniform height, free from weeds, and slightly straw-broken. The moisture content of the grain varied from 14 to 15 per cent.

As in all previous tests, the cylinder loss was again negligible and was influenced only slightly by the amount of material passing through the machine. The rack loss again was the highest machine loss. The cutter bar loss increased very rapidly as the cutter bar was raised. Because of the more tangled and broken condition of the beardless variety, the cutter bar loss was greater on it than on the bearded variety. It was not always possible to adjust the reel of the combine to its proper position at various heights of cut because of a limited range of adjustment. For this reason, one machine may show a higher cutter bar loss than the other because the reel picks up the cut grain and pitches it forward.

The rack loss was greatly affected by the volume of material entering the machine and was more apparent with one machine than the other, a result which seems to indicate that the straw rack on one machine had a larger capacity than that on the other. The machine losses (cylinder, rack, and shoe) were naturally low at the lower volume of material threshed. However, as these machine losses decreased, the cutter bar loss increased, depending upon the nature and condition of the crop. Total losses were lowest at the 30-inch length of straw threshed (approximately 12 inches of stubble) on one machine and at the 34-inch length of straw threshed (8 inches of stubble) on the other. One machine operated more efficiently at a lower stubble because it had greater capacity.

Figure 10 indicates the grain losses resulting from operating the tractor in second and in low gears. The cylinder loss was approximately the same in both gears, and this loss was so small that it was of little significance. The rack loss, however, was 200 pounds per acre, resulting in a total grain loss of 282 pounds per acre with the tractor operating in second gear. With the tractor operating in low gear, the rack loss was reduced from 200 to 84 pounds per acre, and the shoe loss from 36 to 12 pounds per acre, a reduction in total machine loss of 135 pounds per acre, or 47.9 per cent. Of importance, also, is the fact that the straw rack was the first functional unit to become overloaded.

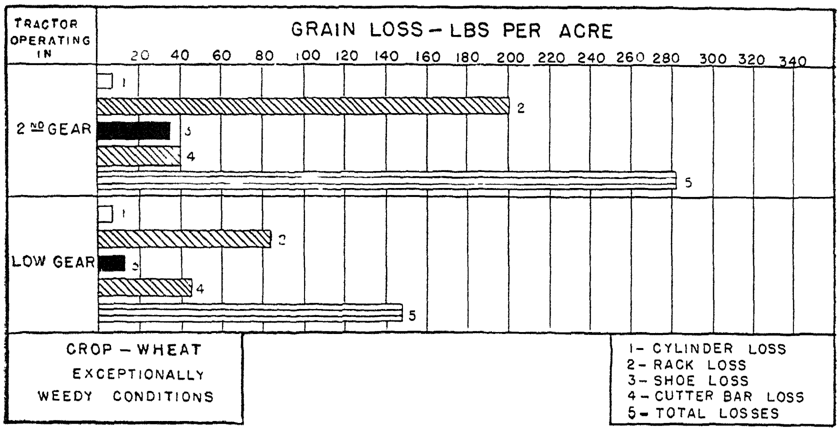



**Fig. 10.—Grain losses as affected by rate of travel**

## WHEN TO START COMBINING

The problem of when to start combining requires careful consideration. New owners of combines usually become over anxious and begin harvesting too early, with the result that the threshed grain is of low quality and will not keep in storage.

In most instances, the moisture content of the grain should be 15 per cent or less, and if the crop contains weeds or other green material, the moisture of the standing grain should be below 15 per cent, because the shelled grain picks up moisture from the broken green material as it passes through the machine. For this reason, breaking up of the material by the cylinder should be avoided as much as possible.

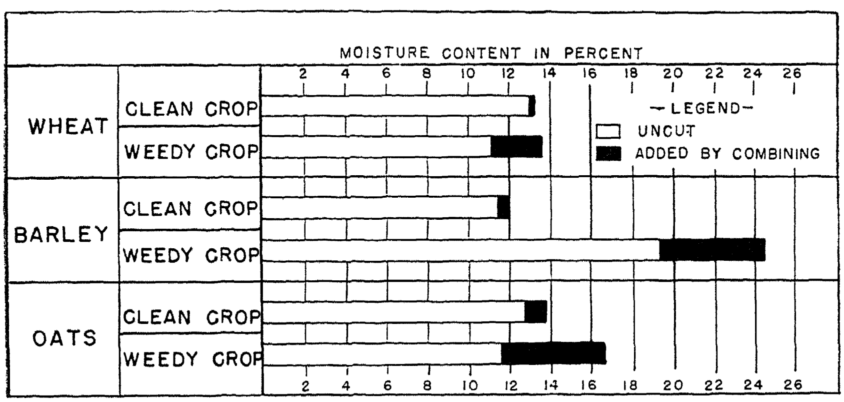



**Fig. 11.—Moisture of grain before and after combining**

Where a crop is badly infested with weeds or the grain is subject to shattering, it is sometimes desirable to harvest before the grain is down to 15 per cent moisture, particularly oats and most clover crops. Under such conditions, it is usually advisable to spread the grain or seed on a dry floor for drying and then run it through the combine again or through a fanning mill to take out the foreign material.

Under extremely weedy conditions, it is advisable to raise the cutter bar to avoid taking a large volume of green material into the machine. The increase in cutter bar loss will not be as great as the increase in rack and shoe losses when the machine becomes overloaded with weeds or other green material. The threshed grain will also be of higher quality. Windrowing the crop previous to combining is sometimes desirable, particularly with clovers. This method prolongs the harvest season in many cases, however, and increases the costs of harvesting.

The only accurate method for determining the moisture content of grain is to take a sample to the local elevator and have it determined. A number of moisture testers are now appearing on the market and can be bought for a very small sum. If showers are encountered, it is well to have a sample tested after the unthreshed grain appears to have dried out thoroughly. Tests show that kernels of grain may retain moisture for a long period after a rain even though the crop has been exposed to a subsequent period of good drying weather.

## EFFECT OF WEEDS ON GRAIN LOSSES

A heavy growth of weeds in grain crops will cause higher grain losses in combining than any other one thing. Unless exceptional care is exercised in the operation of the combine, weeds, in addition to taxing the various functional units of the combine, usually put the crop in a bad condition for harvesting by causing uneven ripening and lodging of the crop. A lodged crop usually involves high cutter bar losses.

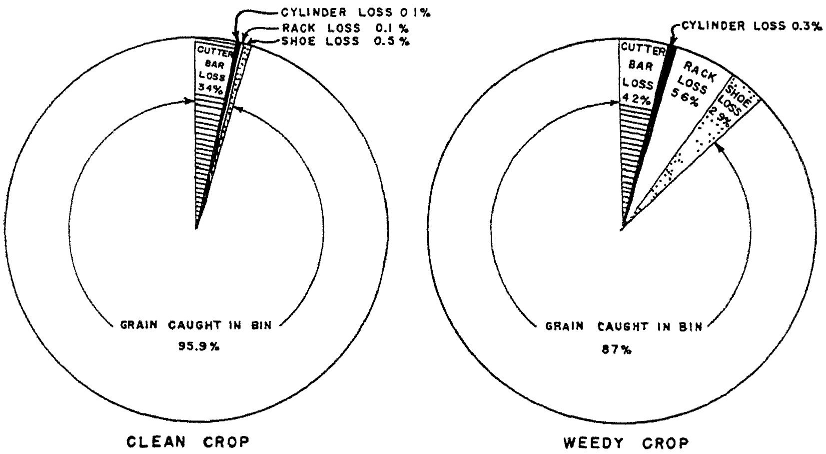



Fig. 12.—Effect of weeds on grain losses

Many varieties of weeds contain much moisture at the time of harvesting. This moisture is released by the breaking up of the material by the cylinder, and some of it is picked up by the shelled kernels of grain. Weeds also cause uneven cylinder speeds, even to the point of "slugging," which is very detrimental to efficient threshing. Separation of the grain by the straw rack and the sieves is made difficult by the formation of a tightly packed mass of material on these units. Effective separation becomes more difficult as this material is ground to a finer degree.

Figure 12 illustrates the effect of weeds on grain losses. Both tests were run in the same field, one in a clean section and one in a weedy section. Previous to the tests, the combine was adjusted for best operation, and no other adjustments were made in going from the clean to the weedy section of the crop. The combine was operated at the same rate of travel, and the cutter bar was set for the same height. The crop was standing up well in both sections.

It is evident from figure 12 that the total grain losses were considerably higher when the combine operated under weedy conditions. All four sources of loss showed an increase, although the increase at the cylinder and cutter bar was very small. The large increase at the rack and shoe is indicative of poor separation at these units caused by the weeds.

## SUMMARY AND CONCLUSIONS

The efficiency of operation of any machine is usually in direct proportion to the efficiency of the operator. The combine, like many other machines, will do a very satisfactory job if it is kept in good running order and properly adjusted for various kinds and conditions of crops. Loss of a few hours' time during harvest because of breakages due to faulty adjustments is costly. In order to keep the combine working at its highest efficiency, operators should avail themselves of all reliable information on proper and accurate adjustments. Examining the heads of grain for kernels still fast in the heads is not the proper procedure for determining grain losses.

The cylinder loss is usually the lowest loss, but the adjustment at the cylinder has a decided effect upon the losses at the rack and shoe. In order to reduce total machine losses, it is desirable to balance the losses at each of the areas as much as possible. It is not efficient threshing to have a high loss at one source and a low one at another.

Crop conditions will usually determine what adjustments should be made. If the crop is lodged and badly straw-broken, it will be necessary to operate the cutter bar low. Care must be exercised, however, not to load the combine to a point where the losses at the other sources of loss will exceed the cutter bar loss. The cutter bar loss is usually one of the highest losses. When a crop is badly straw-broken, the heads of grain are cut off and dropped to the ground. An improperly adjusted reel will also pick up and pitch to the ground many heads of grain. If the cutter bar is lowered to any great extent so that a large amount of material passes through the machine per hour, it is well to reduce the rate of travel in order to avoid overloading. No machine will waste grain until it reaches its limit of capacity. This limit can be very low, however, if proper and accurate adjustments are not made and good judgment practiced in the operation of the machine.

Next in extent of loss to the cutter bar is the rack loss. It is the key loss in many instances, because so many adjustments at the other areas have a distinct bearing upon the extent of the rack loss. Evidence also indicates that the straw rack is usually the first functional unit to become overloaded, and overloading results in high rack losses.

In order to shell every kernel of grain from the heads, it is necessary to reduce the clearance between the cylinder and concaves to a minimum, and such adjustment has the detrimental effect of breaking up the straw and possibly cracking the grain, as well as raising the power requirements. Plugging of the cylinder will also occur if feeding is more or less irregular or green weeds are encountered.

A high shoe loss is usually associated with high rack losses due to finely broken straw. A large amount of the fine material will be worked through the rack openings and fall to the sieves below. This material forms a heavy mat on the sieves and requires a heavy wind blast to lift it. The result is that much grain is blown over the rear of the sieves. Rather than resort to maximum wind blast, it is much better to change the direction of the wind blast upward at the front part of the sieves. This adjustment will also lessen the amount of grain, or tailings, taken back to the cylinder by the tailings elevator and thereby reduce cracking of the grain.

The rack and shoe losses, therefore, are dependent to a large extent upon the adjustment at the cylinder. Since the cylinder loss is usually the lowest, it is not necessary to reduce the clearance between the cylinder and concaves to a minimum. It is much better to provide full, rather than little, clearance in order to reduce total grain losses, at least to start with nearly full clearance and reduce it as the occasion demands. Such an adjustment will save grain and fuel, lessen wear on the rubbing parts of the cylinder and concave, and reduce cracking of grain, as well as raise the capacity of the combine.

Grain losses at the rack should always be checked separately if possible. The extent of these losses may be an indicator of faulty adjustment somewhere, probably at the cylinder.

Cylinder speed is not so important a factor as the clearance between the cylinder and concaves. Nevertheless, high cylinder speeds have a tendency to break up the straw and create high rack and shoe losses. If a cylinder is not running at its rated speed, the rack and shoe may also be affected. This effect may prove serious, as these units will waste much grain if they are run even slightly above or below their rated r. p. m.

A combine will handle only a certain volume of material efficiently, and the limit of capacity will vary with different machines and the condition of the crop. On crops of heavy or lodged straw, it is advisable to reduce the rate of travel, if possible, to avoid overloading the straw rack. In weedy conditions, the clearance between the cylinder and concaves should be about maximum. This adjustment prevents the grinding up of the weeds by the cylinder and thereby facilitates better separation of the grain from the straw and chaff. It also reduces the amount of exposed moisture from the green weeds which is later picked up by the loose kernels of grain as they pass over the separating and cleaning units of the combine.

## COMMON COMBINE TROUBLES, THEIR CAUSES, AND REMEDIES

| GRAIN LOSS | PROBABLE CAUSES | REMEDIES |
|---|---|---|
| Excessive cylinder losses | Low cylinder speed | Increase cylinder speed |
| | Too much clearance between cylinder and concaves | Reduce clearance between cylinder and concaves slightly |
| | Lateral spacing of concave provides too much space between teeth of cylinder and teeth of concave | Check the other probable causes before reducing the clearance |
| | Badly worn teeth or worn shelling bars | Replace |
| High rack loss | Cylinder breaking up straw too much | Increase cylinder and concave clearance (set for nearly maximum clearance) |
| | Overloaded machine | Reduce rate of travel or raise cutter bar slightly |
| | Low or high rack speed | Reduce cylinder speed, increase or reduce rack speed |
| High shoe loss | Cylinder breaking up straw too much | Reduce cylinder speed or increase clearance between cylinder and concaves |
| | Sieves closed too much | Open sieves, chaffer or grain sieve, if free grain is in tailings |
| | Too much wind blast | Reduce blast |
| | Improperly directed wind blast | Change direction of blast |
| | Sieve openings plugged | Clean sieves of obstructions |
| High cutter bar loss | | **Heads of grain** |
| | Cutter bar too high | Lower cutter bar (slightly) |
| | Reel set too low | Raise reel |
| | Reel set too far forward or backward | Set reel just ahead of cutter bar |
| | | **Loose grain** |
| | Reel running too fast for ground travel of combine | Set reel back<br>Reduce speed of reel |
| Cylinder wrapping | Grain tough or damp, extensive weed growth | Reduce rate of travel |
| | Low cylinder speed | Increase cylinder speed slightly |
| | Low beater speed | Increase beater speed slightly |
| | Machine slightly overloaded | Raise cutter bar |
| Cracked grain | Too little clearance between cylinder and concaves | Increase cylinder clearance |
| | Cylinder speed too high | Reduce cylinder speed |
| | Too much shelled grain returned to cylinder from rear of sieves | Open sieves slightly |
| | Too many concaves or rows of teeth on spike-tooth cylinder machine | Remove concaves to one row of teeth in some cases |
| Poorly cleaned grain | Excessive breaking up of straw or weedy material by cylinder | Increase cylinder clearance |
| | Sieves open too much | Close sieves slightly |
| | Insufficient wind blast | Increase wind blast |
| | Improperly directed wind blast | Direct wind blast to front part of sieves |
| | Overloaded machine | Reduce rate of travel or raise cutter bar |