PERFORMANCE OF CYLINDRICAL GRADERS IN RELATION TO CORN CLEANING PROBLEMS

by

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INTRODUCTION

With the storage of a large current corn crop, plus the carry-over from prior years, the farmer, elevator operator, processor, and consumer are faced with a serious problem--contamination. Rodent contamination, in the form of waste elimination, occurs chiefly while the grain is in storage or transit. Insect contamination, however, may occur while the grain is still in the field. These two sources of contamination present a serious sanitation and quality control problem to the processor. Unfortunately, more than eighty-five per cent of the entire corn crop remains on the farm thereby presenting an almost impossible enforcement problem of maintaining "clean" corn (11).

Authority has been granted to the Food and Drug Administration (6), however, to control the sanitation of this commodity in relation to its use in the wet and dry corn milling industries.

Contamination, such as insect and rodent, is not necessarily reflected in the Federal Grade (7) upon which the grain is purchased. In general, the first five United States Department of Agriculture grades are based upon factors such as moisture, cracked corn, and foreign material. Rodent excreta is a factor only when it exceeds two-tenths of one per cent by weight, and then is graded as "sample," indicating a distinctly low quality raw material. This places the processor in a most difficult position from the standpoint of procurring or maintaining a supply of "clean" corn for milling.

Various devices and principles have been tried and tested by the industry and governmental agencies in order to effect complete removal of the rodent fece contamination from corn. Some rodent pellets (fece) can be removed by screening devices, others by a combination of breaking by impact and then screening or aspirating. Still other pellets can be removed by water flotation and scouring devices. The method of washing and flotation does have an advantage, as wet scouring may remove hairs, particles of rodent fece, dirt and other deposits which are stuck to the surface of the grain. More recently the principle of electrostatics has been employed for rodent pellet removal with fair success. The main problems with these devices have been; low capacity, poor removal, loss of sound and broken corn with the contamination, and high cost of operation.

The purpose of this research was to study the effect of feed rate, cylinder speed, cylinder slope, screen type and screen opening upon the performance of cylindrical graders, to study the efficiency of cylindrical graders in removal of rodent contamination from corn and to determine the feasibility of utilizing this equipment for separating a major portion of the corn from the rodent contamination.

REVIEW OF LITERATURE

The Federal Food, Drug, and Cosmetic Act as amended (6) defines a good as adultrated, "if it consists in whole or in part of any filthy, putrid, or decomposed substance or if it is otherwise unfit for food, or if it has been prepared, packed, or held under unsanitary conditions whereby it may have been rendered injurious to health."

Harris, and others (7) reported in a survey conducted from June 1950 to June 1951 that of one thousand and eighteen samples of corn which were examined for both rodent pellets and internal insects only thirty-eight samples contained neither rodent pellets or internal insects. However, of these one thousand and eighteen samples there were two hundred and fourteen which contained no rodent pellets. The average number of rodent pellets found per peck sample was seventy-eight and one-half. It was reported that there was more insect contamination in corn from areas in the southern United States while more rodent contamination was found in corn from the northern United States. It was shown that grade had no apparent relationship to rodent contamination or insect filth, and hence cannot be used as a basis for the selection of corn with low amounts of contamination. During the period covered by this survey both insect and rodent contamination reached a maximum near the end of the crop year.

Mehltretter and Watson (8) reported on the size distribution and specific gravity of rat pellets which were obtained from the pit of a grain elevator. Two groups of pellets were obtained. It was reported that the variations in length of rat pellets were considerably greater than those of width for the two groups. There was a lack in uniformity in the specific gravity of a subgroup of pellets which were taken from the original samples. The range of the specific gravity of the pellets was 0.60 to 1.32. No correlation was found between the specific gravity and size of the rat pellets.

No references were found regarding the size distribution of yellow dent corn as used commercially.

Farrell, Milner, and Katz (5) reported on a method of separation by projection. The separations reported were on various fractions of wheat, sorghum, and corn. Good results were reported when separating wheat from gravel of approximately the same size.

Woodhead (14) reported on a method of separation by water which took advantage of the streamlined, teardrop shape of corn kernels as opposed to the rodent pellet shape which offered greater resistance to upward surging water. Surges of water carried the pellets upward and over weirs for rejection.

Wohlrabe, Pfeifer, and Dilley (13) reported on several new methods for separating rodent pellets from corn. Selective fragmentation and deformation of dry pellets resulted in removal of over ninety-five per cent of the rodent pellets. The equipment used had a capacity of approximately twenty-five bushels per hour per foot of roll length. Equipment using detection by photocells was found to have a very low capacity of approximately three bushels per hour. This equipment would remove all except the very light colored rodent pellets with a reject fraction of about two per cent of the feed. Detection of pellets by electrical conductivity and removal by an impulse actuated gate resulted in complete removal of rodent pellets with a two to three per cent loss of corn. The capacity of the equipment was twelve bushels per hour per foot of detector roll length. Wet scouring and screening was found to be most effective with all rodent pellets being removed with only a negligible loss of corn. Water consumption was about fifty gallons per bushel.

Ake (1) reported on electrostatic cleaning methods as employed for cleaning several different types of grain. For a typical corn cleaning operation, corn containing six to twelve rodent pellets per bushel was cleaned to a level of zero to one rodent pellet per bushel. Corn lost to reject amounted to about one per cent of the feed.

Cost for an electrostatic unit to serve a five hundred bushel per hour mill would be about twenty thousand dollars plus royalty payments depending upon the throughput as reported by Andrews (2). The mechanism of cleaning was also discussed. Rodent pellets, taking on a greater charge than the corn are deflected out of the falling stream into a reject hopper, leaving the corn clean and ready for the mill. Electrodes are charged with thirty thousand volts and discharge to grounded conveying rolls which carry the contaminated grain.

Several standard methods of cleaning were reported on by Dunwody (4) along with a discussion on the value of the recoverable waste.

Wichser (11) presented the many problems with which the corn miller is faced. Contamination affects the milling grade of corn but is not necessarily reflected in the Federal Grade and generally the processor is not able to successfully separate the maximum degree of contamination permitted by Federal Grade.

Whitby (10) reported that the mechanism of sieving can be divided into two distinct regions with a transition region between. Where there are many particles still on the sieve which are much less than the mesh size, region one exists. The mechanism changes as particles much less than the mesh size are removed and region two sieving begins. In region two the cumulative percentage was found to follow the log-normal law.

Brown and others (3) state that, "the capacity of a trommel (cylindrical screen) increases with increased speed up to a point where blinding occurs due to crowding through the screen." Increasing the speed of rotation to the critical speed results in the material being carried around the cylinder without cascading over its surface. The critical speed may be computed by equating the force of gravity to the centrifugal force.

$$mg = \frac{2\ mv^2}{D}$$

where m = mass (lb.)
g = acceleration due to gravity (ft./sec.^{2})
v = velocity of particle (ft./sec.)
D = diameter of cylinder (ft.)

when N = number of revolutions of the cylinder per minute

$$v = \frac{\pi DN}{60}$$

and

$$N = \frac{76.65}{\sqrt{D}}$$

The effectiveness of screens is based upon both the recovery of the product of the desired material in the feed and the exclusion or rejection from the product of the undesirable material in the feed.

MATERIALS AND METHODS

Samples supplied by member companies of the Corn Industries Research Foundation were used in the determination of corn kernel size distributions. These distributions both for kernel width and kernel thickness were determined on a weight basis. Test sieves used were standard one foot square test sieves manufactured by A. T. Ferrell and Company. The sieves were mounted on a modified Eriez Model 30 A vibratory feeder operating at sixty cps and a displacement of 0.090 inches. Approximately five hundred grams of corn were used for determination of the kernel width distributions. The corn was placed in the top sieve of a stack of round hole sieves, 26/64 to 12/64 of an inch at 1/64 of an inch intervals, and the stack was then vibrated for five minutes. Material retained on each sieve was then weighted to the nearest gram using a Toledo double platform scale. Procedure for the kernel thickness distributions was similar using a series of slotted sieves with a 3/4 inch long slot, 19/64 to 6/64 of an inch wide at 1/64 of an inch intervals, and increasing the vibration time to fifteen minutes.

Five samples of rodent pellets were obtained from farm corn cribs, size distributions were determined on each of them using the round hole test screens vibrated for a period of five minutes. The material was given a preliminary sieving through a 7/8 by 3/4 inch oval screen and over a 6/64 inch round hole screen to remove cobs, stalks, chaff and dirt. This material was then passed over an inspection belt and all rodent pellets were picked out with forceps. The rodent pellets were then sieved for the prescribed time and the number of pellets retained on each sieve and in the pan were counted.

Corn from the samples supplied by the member companies of the Corn Industries Research Foundation was used in the laboratory study of a model cleaning system. The flows for these tests are shown on Fig. 1. These samples, of one thousand grams each, were contaminated with rodent pellets obtained from farm cribs. A count of rodent pellets was made on each stream and the total weight of corn was determined for each stream.

Studies of cylindrical grader performance were conducted on a No. 1 Carter Precision Grader with a one-third horsepower drive motor. The grader cylinder was 11.75 inches in diameter and 5 feet in length. The grader was modified by internal divisions into 5, one foot sections using four metal partitions. The partitions were constructed so as to conform as closely as possible to the contour of the cylinder without interfering with its movement. Samples were thus obtained from each one foot interval along the cylinder. The sample takeoff was constructed so that the material could be returned to the system when samples were not being taken. In order to make changes in the cylinder slope, the grader was mounted on a belt conveyor, which was used for returning the material to the system, and the conveyor mounted at one end on railroad jacks. Feed rate was controlled with a Wallace and Tiernan, Merchen Electric Gravimetric Feeder (Cat. No. 311.010). Cylinder speed was varied by changing motor sheaves and drive belts. The

EXPLANATION OF PLATE I

Flow diagram for laboratory study of a model cleaning system. First separation on either 20/64 or 19/64 inch round hole test screen.

PLATE I

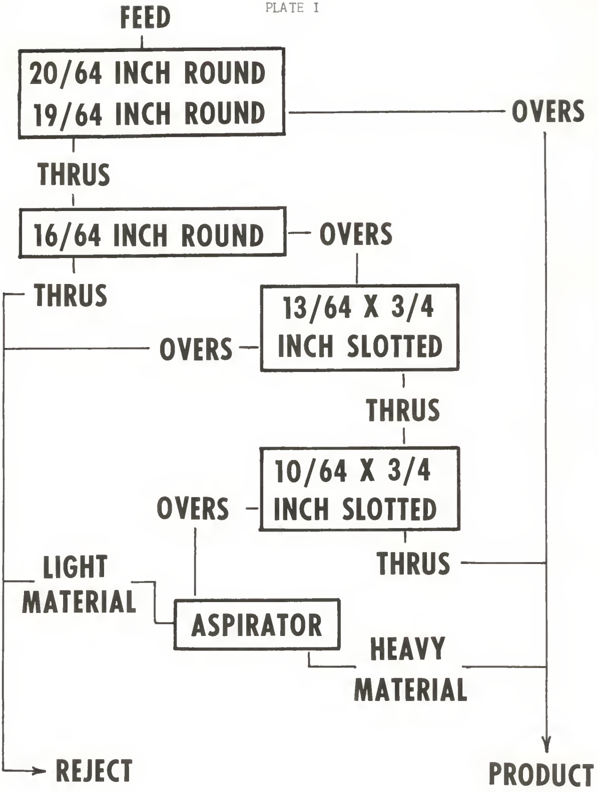
FEED
20/64 INCH ROUND
19/64 INCH ROUND
OVERS
THRUS
16/64 INCH ROUND
OVERS
THRUS
13/64 X 3/4
INCH SLOTTED
OVERS
THRUS
10/64 X 3/4
INCH SLOTTED
OVERS
THRUS
LIGHT
MATERIAL
ASPIRATOR
HEAVY
MATERIAL
REJECT
PRODUCT

FIG. 1

critical speed was calculated as 77.5 rpm. The remainder of the equipment consisted of a bucket elevator, a horizontal screw conveyor, a feed bin, and a hold bin. Figure 2 is a schematic diagram of the equipment arrangement.

Corn was obtained locally for all testing during this phase of the research. All material was first cleaned on a Eureka cleaner located in the Kansas State Feed Mill. The top screen was a 5/8 by 3/4 inch oval screen and the bottom screen was a 9/64 inch round hole screen. First aspiration was set at maximum while no second aspiration was used. Feed rate was set for approximately three bushels per minute. The cleaned corn was then sacked-off and elevated to the test system. A new lot of corn was cleaned and used for each test replication. This procedure was used for all test series with the exception of series four. For this series an additional treatment was made on the test material; the corn was graded using the 19/64 inch indented round hole cylinder after preliminary cleaning on the Eureka cleaner. The material passing the screen was collected and used for the series four test runs.

Contamination was added to the cleaned corn for the series five test. This material consisted of rodent pellets and some corn which had been obtained from several farm cribs, which had been given a preliminary sieving through a 7/8 by 3/4 inch oval screen and over a 9/64 inch round hole screen. Approximately two gallons of this material was added to 22 bushels of corn.

Each test series was conducted so that it could be analyzed statistically. The experimental setup was that of a randomized complete block design with a factorial arrangement.

Test procedure was as follows. After transferring the test material to the feed bin, three probe samples were taken for determination of kernel size distribution. This determination was then conducted as previously described. Test variables were then adjusted to the desired settings and the equipment

EXPLANATION OF PLATE II

Schematic diagram of equipment setup for studies of cylindrical grader performance.

PLATE II

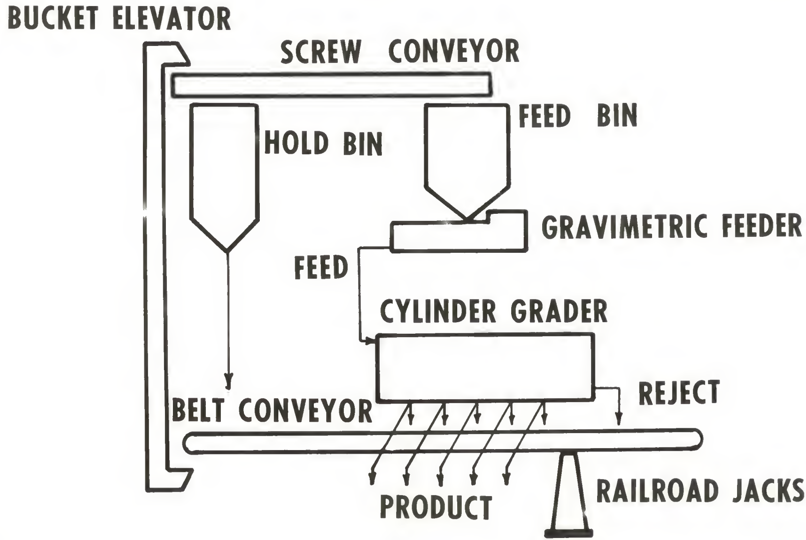

FIG. 2

was started. After allowing a five minute period for equilibrium to be established within the grader, sampling was started. Six samples were taken of the material which did not pass the screen during the test. These samples were designated as reject. The material passing the screen was collected in five cans corresponding to the five grader divisions. The contents of these cans were designated as product. The material which was not collected as samples was conveyed to the hold bin. About four or five tests could be completed with one filling of the feed bin. The product material was then weighted and each weight recorded. The samples from divisions two and three were then combined as were the samples from divisions four and five. These combined samples along with the sample from division one were then reduced to approximately two hundred and fifty grams using a sample divider. The reject and product samples were then sieved using round hole test sieves. These sieves were of the same hole designation as the screen used during the test run. Three samples were sieved simultanously for a period of five minutes using the Eriez vibratory feeder setup. The weight of material retained on and that passing the sieve was then recorded for each sample.

After all samples were analyzed the material was added to that in the hold bin as it was being transferred to the feed bin. In order to assure proper mixing, the material was then returned to the hold bin while recycling part of the material. The material was again transferred to the feed bin and the replication was continued. Upon completing a replication the system was emptied and new corn was obtained for the next replication.

Tests were divided into five series. The efficiencies as determined for tests in the first four series were based strictly upon the separation of corn into two fractions. The overall efficiency of the separation was based on both the recovery in the product of the desired material in the feed and the rejection from the product of the undesirable material in the feed (3). The nomenclature used, along with formulas for calculating efficiencies are given below:

$$\text{Recovery efficiency} = \frac{x_p\ P}{x_f\ F}$$

$$\text{Rejection efficiency} = 1 - \left(\frac{(1 - x_p)\ P}{(1 - x_f)\ F}\right)$$

$$\text{Overall Efficiency} = \frac{x_p\ P}{x_f\ F}\left[1 - \left(\frac{(1 - x_p)\ P}{(1 - x_f)\ F}\right)\right]$$

$$F = R + P$$

$$x_f\ F = x_r\ R + x_p\ P$$

Where x_p = mass fraction of desired material in product
x_f = mass fraction of desired material in feed
x_r = mass fraction of desired material in reject
P = total mass of product
F = total mass of feed
R = total mass of reject

Efficiencies for the fifth series of tests were based on the removal of rodent pellets between the sizes of 12/64 and 19/64 of an inch in diameter. The following formula was used for the calculation of rodent pellet removal efficiency:

$$\text{Removal Efficiency} = \frac{y_{12}^{19} - x^{19}}{y_{12}^{19}}$$

Where y_{12}^{19} = number of rodent pellets in the feed with diameter smaller than 19/64 inch but larger than 12/64 inch.

x^{19} = number of rodent pellets in reject with diameter smaller than 19/64 inch.

Test factors considered for each test series are tabulated in Table 1.[1]

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[1] All tables are located in the appendix.

RESULTS AND DISCUSSION

Corn Kernel Size Distribution

Kernel width of yellow dent corn was found to be normally distributed as measured by kernel weight retained on a series of test screens. The variance among samples ranged from 3.29 to 7.10 sixty-fourths of an inch squared while the sample means ranged from 18.7 to 21.7 sixty-fourths of an inch.

Sample variances when grouped as to origin were found to be normally distributed. These observed variances are tabulated in Table 2. The variances of these distributions deviated from homogenitity slightly. However, due to the robustness of the F test as used in the analysis of variance this departure from the usual assumptions should not have had a great influence on the results when used with this data. The analysis of variance (12) for this data is presented in Table 3. The F ratio was significant at the 0.01 level and it was concluded that there were differences among the means of the variance distributions. Fisher's lsd (12) procedure was used for multiple comparisons among the distribution means. The results of this test are presented in Table 4. The mean variances lying above the same horizontal line are not significantly different; those over different horizontal lines are significantly different.

Sample means when grouped as to origin were not normally distributed and in order to test for differences among the distributions of means a non-parametric test, the Kruskal-Wallis one-way analysis of variance (9), was used. The observed value of mean kernel widths are tabulated in Table 5 and the ranks for this data are given in Table 6. The Kruskal-Wallis analysis for this data is presented in Table 7. The results of this test indicate that there are significant differences among the distributions of mean kernel width. The null hypothesis was rejected with the conclusion that there were differences among the populations with respect to their observed medians.

The observed differences in the variance and mean kernel width distributions could be caused by a multitude of factors such as growing year, variety, amount of fertilizer used, etc. However, not knowing what these factors were and assuming that these factors were equally distributed over the samples involved; it was concluded that the differences observed were due to different buying patterns among the companies involved in this study.

Kernel thickness distributions showed much more homogentity than the distributions of kernel width. Mean kernel thickness and the variance in kernel thickness are presented in Table 8 for a total of fifty-one samples. Mean kernel thickness had a range from 11.0 to 12.1 sixty-fourths of an inch, while the range of the distribution variances was from 2.76 to 5.76 sixty-fourths of an inch squared. The kernel thickness of yellow dent corn was found to be normally distributed for all samples studied.

Rodent Pellet Distributions

The distribution of rodent pellets larger than 12/64 's of an inch was obtained for a set of five samples. The number of pellets retained on each test screen is recorded in Table 9 with the second last row being the number of pellets larger than 6/64 's of an inch but smaller than 12/64 's of an inch. The χ^2 test for goodness of fit (9) was used on this data and is given in Table 10. The results of this test show that there were significant differences among the distributions of rodent pellets. In an effort to determine where these differences arose the Kolmogrov-Smirnov two-sample test (9) was used as a multiple comparison test. All of the differences which could be detected arose in the small end of the distribution; that is, deviations in the cumulative which could be detected arose in the tail of the distribution where the rodent pellet diameter was small. Table 11 presents the data along with the formula for calculating critical values for the Kolmogrov-Smirnov test. As the deviations which were significant, repeatedly occurred in the small end of the distribution, it was concluded that these differences were due to overlapping populations of rodent pellets of two classes which were in different percentages in the different samples. The cumulative distributions for these five samples are shown in Figs. 3 through 7. No comparison was made between these distributions and those reported by Mehltretter and Watson (8) due to differences in the methods of measurement and preparation of the samples.

Laboratory Cleaning Test

The laboratory cleaning tests were set up as a combination of screenings and aspirations, as shown in Fig. 1. Using the 20/64 's screen as a first cut resulted in an average recovery of 46.6 per cent of the corn while retaining only 0.2 per cent of the rodent pellets. The final clean stream from this system contained on an average 86.9 per cent of the total corn and 1.0 per cent of the rodent pellets, leaving 13.1 per cent of the corn to be separated from the remaining 99.0 per cent of the rodent pellets. Using the 19/64 's screen as a first cut resulted in an average recovery of 67.7 per cent of the corn while retaining 0.4 per cent of the rodent pellets. The final clean stream from this system contained on an average 88.3 per cent of the

EXPLANATION OF PLATE III

Size distributions for five samples of rodent pellets. All distributions truncated at a pellet diameter of 12/64 of an inch.

Fig. 3 Rodent pellet sample one
Fig. 4 Rodent pellet sample two
Fig. 5 Rodent pellet sample three
Fig. 6 Rodent pellet sample four
Fig. 7 Rodent pellet sample five

PLATE III

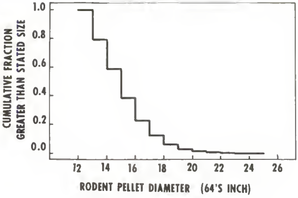


FIG. 3

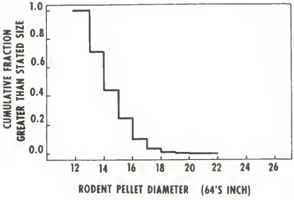


FIG. 4

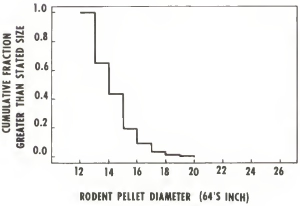


FIG. 5

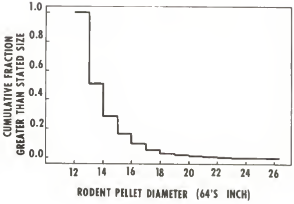
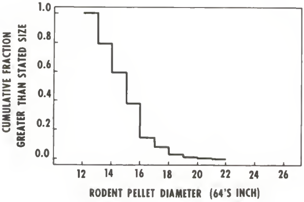


FIG. 6



total corn and 1.1 per cent of the rodent pellets, leaving 11.7 per cent of the corn to be separated from the remaining 98.9 per cent of the rodent pellets. Individual test results are given in Table 12.

Cylindrical Grader Test

The effect of screen type on grader efficiency was studied in the first series of test. The indented round hole screen showed an average overall efficiency of 96.1 per cent while the flat round hole screen showed an average overall efficiency of 87.7 per cent as measured over a total of twenty-four tests for each screen. During this test series the effect of several other variables were studied. These were feed rate, cylinder slope, and cylinder speed. The analysis of variance for this test series is given in Table 13. In addition to the significant effect upon grader efficiency due to screen type, it was found that two other main effects and two interactions resulted in significant changes in grader efficiency. These were feed rate, cylinder speed, screen type by cylinder slope interaction, and feed rate by cylinder speed interaction. The most important of these four significant effects is that of the screen type by cylinder slope interaction. An increase in cylinder slope from zero inches per foot to one inch per foot increased the efficiency of the indented screen from 95.9 per cent to 96.2 per cent while the efficiency of the flat screen decreased from 89.1 per cent to 86.2 per cent. This interaction can be attributed to the fact that the flat screen presents a smooth surface to the particles as they enter the grader and allows them to slide easily through the cylinder resulting in a shorter retention time and fewer chances for the particle to pass the screen. In the indented cylinder, however, the rough surface prevents this slippage to some degree. Increasing the slope may in fact aid in the positioning of the particle for passage. The relative value of the increase or decrease of efficiency due to other significant effects is not of importance as such, because they are averages over both cylinder types. For comparison purposes these results are tabulated in Table 14.

Of main interest in the second series of tests was the effect of screen size upon grader efficiency. The analysis of variance for this series of tests is given in Table 15. Significant differences at the 0.05 level due to screen size and screen size by feed rate interaction were found. These results are presented in Fig. 8 and all data is in Table 16. Each point on the graph is the average of three trials. It is of interest to note the rapid decrease in overall efficiency of the 16/64 inch screen as the feed rate increases as compared to the slight decrease in overall efficiency of the 19/64 inch screen and the rising overall efficiency of the 22/64 inch screen. As screen size increased more of the feed material was able to pass through the screen in the first few feet allowing the remaining material more opportunities to strike the screen surface and thus affect a separation. With the 16/64 inch screen, overall efficiency decreased rapidly as the feed rate was increased to thirty-five pounds per minute indicating that the limiting capacity of the grader was being approached. In the case of the 19/64 inch screen this limiting capacity had not yet been approached as there was only a slight decrease in the overall efficiency with increased feed rate. Response of overall efficiency with increased feed rate on the 22/64 inch screen took on an entirely different concept. Due to the fact that almost all of the material which would pass the screen would do so in the first few feet at the low feed rates, material which should not have passed the screen was being forced through the openings and thus decreased

EXPLANATION OF PLATE IV

Effect of feed rate upon the performance of cylindrical graders. All screens used were of the indented type. All test were made under conditions of constant cylinder speed (58.0 rpm) and constant cylinder slope (1/2 inch per foot).

PLATE IV

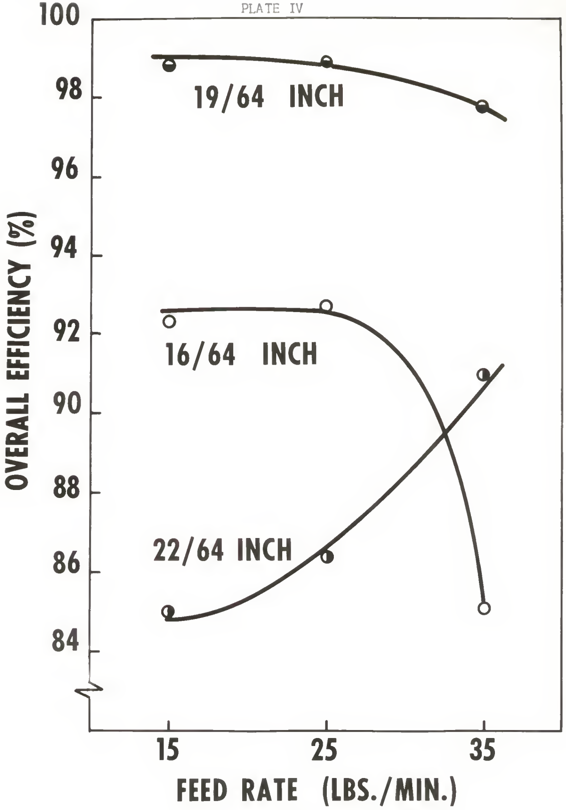


FIG. 8

the overall efficiency of separation. As the feed rate was increased less of this material passed the screen and the overall efficiency increased. Further increases in feed rate would result in locating an optimum for this size screen.

Although no direct comparison can be made between runs in series one and runs in series two on the results obtained for the indented 16/64 inch screen, due to different operating conditions, the difference in overall efficiencies observed is attributed to the difference in the distributions of the feed material. The percentage passing the 16/64 inch screen for the test in series one averaged 9.8 per cent while for the series two test the average per cent passing was 2.0 per cent.

The third series of tests were conducted on a 19/64 inch indented screen. All main effects and two first order interactions were found to be significant at the 0.05 level for both overall efficiency and recovery efficiency. The analysis of variance are given in Tables 17 and 18 and data for this test series is presented in Tables 19 and 20. Figures 9 through 14 graphically present the results on overall efficiency while Figs. 15 through 20 present the results on removal efficiency. Each point represents three replications. Increasing feed rate resulted in lower efficiencies under all combinations of cylinder speed and slope.[1] However, this decrease was not constant and significant interactions were detected. With increasing feed rate, efficiency decreased more rapidly at low speeds and zero angle. Both cylinder speed and cylinder slope were significant factors, increasing the speed through the range under study resulted in a monotonic increase of efficiency while

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[1] Both overall efficiency and removal efficiency responded in the same manner and hence the term efficiency here implies both.

EXPLANATION OF PLATE V

Effect of cylinder slope and cylinder speed upon the performance of cylindrical graders. Feed rate used as a parameter to show significant interactions. All test using 19/64 inch indented cylinder. Performance measured as overall efficiency of separation.

PLATE V

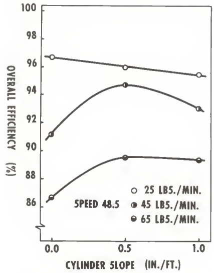

FIG. 9

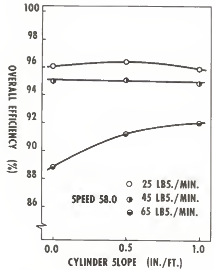

FIG. 10

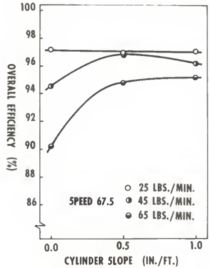

FIG. 11

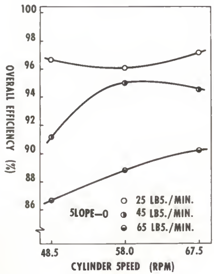

FIG. 12

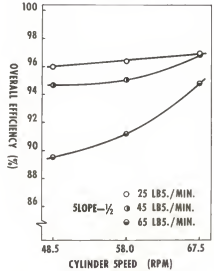

FIG. 13

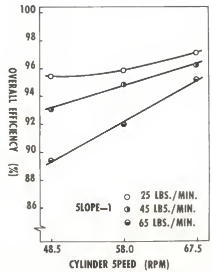

FIG. 14

EXPLANATION OF PLATE VI

Effect of cylinder slope and cylinder speed upon the performance of cylindrical graders. Feed rate used as a parameter to show significant interactions. All test using 19/64 inch indented cylinder. Performance measured as removal efficiency.

PLATE VI

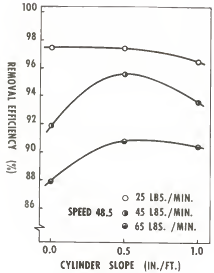

FIG. 15

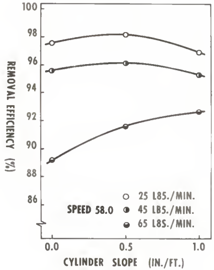

FIG. 16

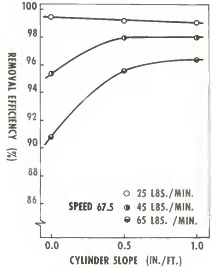

FIG. 17

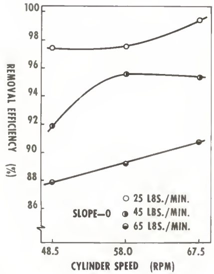

FIG. 18

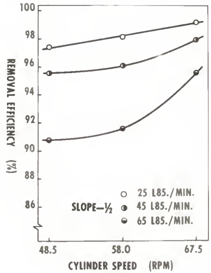

FIG. 19

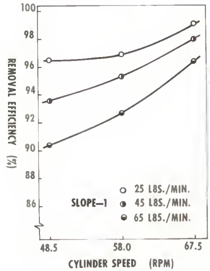

FIG. 20

increasing the slope resulted in an increase in efficiency followed by a slight decrease in efficiency. The decrease in efficiency with increasing feed rate is due to particle congestion and competition for passage through the screen openings. Improved efficiency with increased speed was attributed to more turbulent particle action resulting in more tumbling of the particles and less sliding. Increased cylinder slope had its most marked effect upon performance at high feed rates. This was attributed to faster passage of the material and hence less cushioning of the particles due to a dense bed within the cylinder.

The fourth series of test were conducted using a 16/64 inch indented screen on material which had passed the 19/64 inch screen. All main effects and two first order interactions were found to be significant at the 0.05 level for overall efficiency. Removal efficiency was nearly equal to overall efficiency in all cases and hence a separate analysis of variance was not calculated in this case. A rejection of 0.998 or greater in all cases lead to this result. The interactions which were found to be significant were the feed rate by cylinder speed interaction and the feed rate by cylinder slope interaction. Responses to the main effects were the same as found for test series three. The analysis of variance for this test series is presented in Table 21 and data for the test series is presented in Table 22. The results are graphically presented in Figs. 21 through 26.

The efficiency of rodent pellet removal using a 19/64 inch round hole test screen was not effected by changing either the cylinder slope or the feed rate of the material to the grader. These tests were conducted at a cylinder speed of 67.5 rpm. Efficiency of pellet removal is presented in Table 23 while the analysis of variance for this data is presented in Table 24. The efficiency of pellet removal over all runs was calculated as 97.5

EXPLANATION OF PLATE VII

Effect of cylinder slope and cylinder speed upon the performance of cylindrical graders. Feed rate used as a parameter to show significant interactions. All test using 16/64 inch indented cylinder. Performance measured as overall efficiency of separation.

PLATE VII

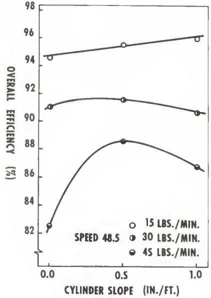

FIG. 21

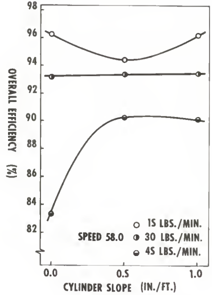

FIG. 22

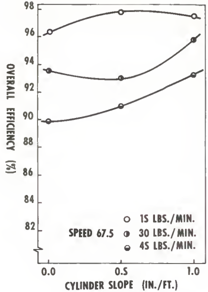

FIG. 23

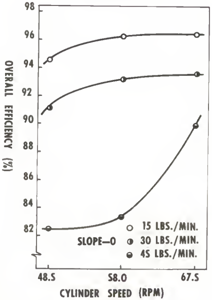

FIG. 24

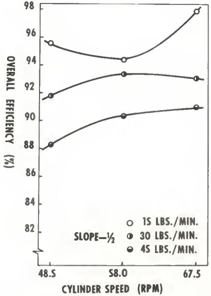

FIG. 25

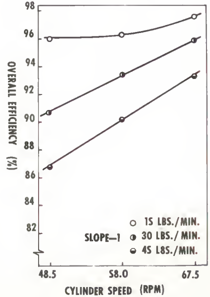

FIG. 26

per cent.

An attempt was made to extend the work done by Whitby (9), on the mechanics of fine sieving, to this separation process. Data was taken from test run two and the results are shown graphically in Figs. 27 through 32. All points are the average of three runs. Individual results are tabulated in Table 25. It appears that the first samples were taken too far along the screen to show the existance of region 1 sieving, however, there was evidence that a change in mechanism took place and region 2 sieving was observed in all cases.

SUMMARY AND CONCLUSIONS

There are wide variations in the size of yellow dent corn both as to mean kernel width and variance of kernel width. Mean kernel thickness showed less variation. The differences in the distributions of mean kernel width and variance of mean kernel width for the several companies submitting samples show that the sizing of cleaning equipment for these plants could not be the same for optimum operation.

Samples of rodent pellets were not from similar populations, however the differences which were detected arose in the small end of the distributions. These differences are attributed to overlapping of several rodent pellet populations. In choosing a screen size for a first cut these differences would not influence the expected number of rodent pellets found in the clean corn stream.

Screen type had a significant effect upon grader efficiency. The indented screen was found to be superior to the flat screen.

Screen hole size was found to have a significant effect upon grader

EXPLANATION OF PLATE VIII

Effect of cylinder length upon the performance of cylindrical graders. All test were made under conditions of constant cylinder speed (58.0 rpm) and constant cylinder slope (1/2 inch per foot). Performance measured as removal efficiency.

PLATE VIII

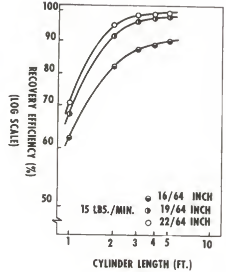

FIG. 27

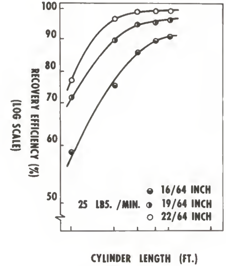

FIG. 28

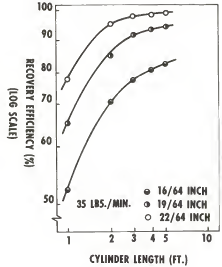

FIG. 29

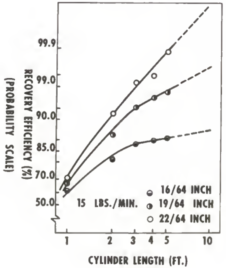

FIG. 30

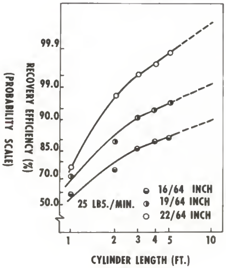

FIG. 31

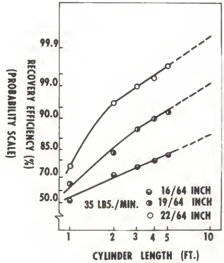

FIG. 32

efficiency. This effect would be the same if screen size was held constant and there was slippage in the kernel size distribution. The significance is then not in the hole size but in the relation of the hole size to the fraction passing that hole size.

Feed rate was found to have a significant effect upon grader efficiency in all test series except series two where the screen size by feed rate interaction was predominant.

Grader efficiency was significantly effected by cylinder slope in all test series with the exception of series one where the screen type by cylinder slope overshadowed the effect of cylinder slope.

In all test series cylinder speed had a significant effect upon grader performance. Screen type by cylinder slope and feed rate by cylinder speed were found to be significant in test series one. Test series two showed a significant interaction between screen size and feed rate. Feed rate by cylinder speed and feed rate by cylinder slope were found to be significant both in test series three and test series four.

In general, increasing the feed rate results in a decrease in grader efficiency. Increasing the cylinder speed results in increased efficiency. This response should be limited by the critical speed at which point the "centrifugal force" will overcome the force of gravity and the particles will not tumble within the cylinder.

Rodent pellet removal was not significantly effected by changes in feed rate and cylinder slope when using the 19/64 inch round hole indented cylinder for obtaining a "first cut." The removal of more than 94 per cent of the rodent pellets of size greater than 12/64 of an inch but less than 19/64 of an inch from the "first cut" clean corn stream indicates that the cylindrical grader could be utilized in a corn cleaning system with satisfactory results.

SUGGESTIONS FOR FURTHER RESEARCH

Further study upon the subject of cylindrical grader performance is needed to establish the mechanism of separation and to determine the physical laws which govern the separation of particles through this type of screen. A more complete study of the variables considered in this thesis is necessary with primary emphasis upon the effect of cylinder length. In addition to the round hole cylinder, the slotted cylinder type should be studied.

ACKNOWLEDGMENTS

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APPENDIX

Table 1. Test factors for each test series

Test factor	Test series 1	2	3	4	5
Screen Type	Flat Indented	Indented	Indented	Indented	Indented
Cylinder Hole Size (inches)	16/64	16/64 19/64 22/64	19/64	16/64	19/64
Cylinder Slope (inches per foot)	0 1	$\frac{1}{2}$	0 $\frac{1}{2}$ 1	0 $\frac{1}{2}$ 1	$\frac{1}{2}$ 1
Cylinder Speed (rpm)	48.5 67.5	58.0	48.5 58.0 67.5	48.5 58.0 67.5	67.5
Feed Rate (lbs. per min.)	15 35	15 25 35	25 45 65	15 30 45	45 65

Table 2. Observed values of variance of kernel widths (64's inch).

Source					
American Maize (A.M.)	Anheuser Busch (A.B.)	Clinton (C.)	National (N.)	A.E. Staley (S.)	Hubinger (H.)
4.16	4.05	3.88	4.00	4.16	3.29
4.40	4.14	4.18	4.03	4.35	3.47
4.59	4.38	4.18	4.06	4.41	3.49
4.60	4.48	4.30	4.10	4.47	3.68
4.60	4.50	4.31	4.23	4.50	3.80
4.61	4.52	4.33	4.25	4.54	3.82
4.81	4.54	4.47	4.42	4.56	3.85
4.90	4.56	4.58	4.56	4.63	3.91
5.00	4.66	4.76	4.57	4.73	3.94
5.05	4.73	4.92	4.82	4.87	3.94
5.11	4.74	5.04	4.84	4.90	3.95
5.15	4.74	5.14	4.92	4.92	3.95
5.19	4.75	5.17	5.00	5.00	3.98
5.35	4.87	5.34	5.02	5.06	4.02
5.47	4.93	5.36	5.07	5.15	4.05
5.49	5.02	5.38	5.15	5.24	4.09
5.67	5.03	5.40	5.25	5.24	4.12
5.84	5.07	5.67	5.30	5.25	4.16
6.04	5.11		5.40	5.25	4.17
6.15	5.15		5.53	5.30	4.18
6.20	5.57		5.57	5.45	4.26
6.20	5.75		5.58	5.51	4.39
6.67	5.86		5.60	5.63	4.42
7.10	5.90		5.63	5.64	4.47
	5.91		5.72	5.80	4.48
			5.85	5.90	4.61
			5.90	6.46	4.78
			6.29	6.52	4.88
					4.90

Table 3. Analysis of variance of corn kernel width variance distributions.

Source of variation	D.F.	Ss	Ms	F
Companies	5	19.7539	3.9508	10.38**
Error	146	55.5456	0.3804	
Total	151	75.2995		

** Indicates significance at the 0.01 level

$F_{0.01,\ 5,\ 145} = 3.14$

Table 4. Fishers' lsd as applied to mean variance for corn kernel width variance distributions.

$$\text{lsd} = 3.373\sqrt{0.3804\left(\frac{1}{r_1} + \frac{1}{r_2}\right)}$$

H.	C.	A.B.	N.	S.	A.M.
4.105	4.800	4.918	5.024	5.123	5.350

Table 5. Observed values of mean kernel widths (64's inch).

Source					
American Maize (A.M.)	Anheuser Busch (A.B.)	Clinton (C.)	National (N.)	A.E. Staley (S.)	Hubinger (H.)
18.7	19.1	19.2	18.7	19.5	18.6
19.0	19.1	19.4	18.9	19.6	18.7
19.1	19.1	19.4	19.0	19.7	18.7
19.2	19.2	19.4	19.2	19.8	18.7
19.3	19.2	19.4	19.3	19.8	18.7
19.4	19.3	19.4	19.4	20.0	18.9
19.5	19.4	19.4	19.4	20.0	18.9
19.6	19.4	19.4	19.5	20.0	18.9
19.6	19.7	19.5	19.5	20.0	19.0
19.7	19.8	19.7	19.5	20.1	19.0
19.8	19.8	19.7	19.6	20.1	19.1
19.8	19.9	19.8	19.6	20.1	19.1
19.9	19.9	20.0	19.7	20.2	19.1
19.9	19.9	20.1	19.7	20.2	19.1
19.9	20.0	20.1	19.7	20.2	19.2
20.0	20.0	20.2	19.7	20.2	19.2
20.0	20.1	20.2	19.8	20.3	19.2
20.2	20.2	21.0	19.9	20.4	19.3
20.2	20.3		20.0	20.5	19.4
20.3	20.3		20.1	20.6	19.5
20.5	20.4		20.1	20.6	19.5
20.6	20.4		20.1	20.6	19.6
20.6	20.4		20.2	20.6	19.7
21.0	20.5		20.2	20.7	19.9
	20.8		20.2	20.7	20.0
	21.4		20.2	20.8	20.0
			20.2	21.3	20.2
			21.0	21.7	20.4
					20.4

Table 6. Ranks of mean kernel widths.

Source					
American Maize (A.M.)	Anheuser Busch (A.B.)	Clinton (C.)	National (N.)	A.E. Staley (S.)	Hubinger (H.)
4.5	19.5	27.5	4.5	52.5	1.0
13.5	19.5	42.0	9.5	59.5	4.5
19.5	19.5	42.0	13.5	67.5	4.5
27.5	27.5	42.0	27.5	76.5	4.5
33.5	27.5	42.0	33.5	76.5	4.5
42.0	33.5	42.0	42.0	94.5	9.5
52.5	42.0	42.0	42.0	94.5	9.5
59.5	42.0	52.5	52.5	94.5	9.5
59.5	67.5	67.5	52.5	94.5	13.5
67.5	76.5	67.5	52.5	105.0	13.5
76.5	76.5	76.5	59.5	105.0	19.5
76.5	84.5	94.5	59.5	105.0	19.5
84.5	84.5	105.0	67.5	117.0	19.5
84.5	84.5	105.0	67.5	117.0	19.5
84.5	94.5	117.0	67.5	117.0	27.5
94.5	94.5	117.0	67.5	117.0	27.5
94.5	105.0	148.0	76.5	126.5	27.5
117.0	117.0		84.5	131.0	33.5
117.0	126.5		94.5	135.0	42.0
126.5	126.5		105.0	139.5	52.5
135.0	131.0		105.0	139.5	52.5
139.5	131.0		105.0	139.5	59.5
139.5	135.0		117.0	139.5	67.5
148.0	145.5		117.0	143.5	84.5
	151.0		117.0	143.5	94.5
			117.0	145.5	94.5
			117.0	150.0	117.0
			148.0	152.0	131.0
					131.0

Table 7. Kruskal-Wallis one-way analysis of variance on mean kernel width distributions.

$$H = \frac{12}{N\ (N + 1)} \sum_{j=1}^{5} \frac{R_j^2}{N_j} - 3\ (N + 1)$$

$$H = \frac{12}{(152)\ (153)} (150021 + 170156 + 89888 + 146089 + 360816 + 49242) - 3\ (153)$$

H = 33.77 (uncorrected for ties)

H has a χ^2 distribution with k - 1 d.f.

$\chi^2_{0.001,4} = 20.52$

Table 8. Mean kernel thickness and variance for fifty-one samples of yellow dent corn.

$\bar{x}$	s^2	$\bar{x}$	s^2	$\bar{x}$	s^2
11.5	3.19	11.2	3.07	11.3	3.51
11.3	2.80	11.4	3.06	11.5	3.51
11.0	3.46	11.8	3.38	11.5	3.19
11.4	2.87	11.6	2.97	11.5	3.12
11.5	3.18	11.4	3.84	11.8	4.92
11.8	3.68	11.6	3.96	11.9	3.78
11.5	3.09	11.2	3.58	11.6	3.55
11.5	3.47	11.6	3.72	11.6	3.40
12.0	3.16	11.4	4.14	11.3	3.03
11.5	3.30	11.1	3.60	11.4	4.12
11.4	2.87	11.1	3.56	11.3	3.74
11.4	2.76	11.2	3.44	11.4	3.32
11.1	3.55	11.3	3.46	11.2	3.80
11.5	3.08	11.1	5.76	11.6	3.73
11.4	3.25	11.2	4.01	12.1	4.27
11.4	2.58	12.0	4.18	11.9	4.17
11.2	2.85	12.0	3.68	11.7	3.42

Table 9. Rodent pellets cumulative count (greater than stated size).

Size 64's inch	Sample Number 1	2	3	4	5
>26	0	0	0	1	0
25-26	1	0	0	1	0
24-25	4	0	0	1	0
23-24	7	0	0	1	0
22-23	10	0	0	5	0
21-22	17	1	0	7	1
20-21	24	4	0	9	3
19-20	47	10	5	14	7
18-19	97	21	7	17	16
17-18	189	78	17	32	42
16-17	357	208	40	55	97
15-16	606	498	84	90	197
14-15	926	891	170	157	312
13-14	1244	1427	281	302	415
12-13	1573	2007	430	552	523
6<N<12	1235	3224	1196	531	1738
Total	2808	5231	1719	961	2290

Table 10. χ^2 goodness of fit test for five populations of rodent pellets.

Size 64's inch	Sample Number 1	2	3	4	5	Total
19	25.7	32.8	7.0	9.0	8.5	
	47	10	5	14	7	83
18-19	23.2	29.6	6.3	8.1	7.7	
	50	11	2	3	9	75
17-18	61.9	78.9	16.9	21.7	20.6	
	92	57	10	15	26	200
16-17	123.4	157.5	33.7	43.3	41.0	
	168	130	23	23	55	399
15-16	222.1	283.4	60.7	77.9	73.8	
	248	290	44	35	100	718
14-15	303.5	387.2	83.0	106.5	100.9	
	320	393	86	67	115	981
13-14	374.2	478.7	102.6	131.7	124.8	
	318	536	111	145	103	1213
12-13	438.0	558.9	119.7	153.7	145.6	
	329	580	149	250	108	1416
Total	1573	2007	430	552	523	5085

$$\chi^2_{0.001,\ 28} = 56.89$$

$$\chi^2 = \frac{(47 - 25.7)^2}{25.7} + \frac{(50 - 23.2)^2}{23.2} + \ldots + \frac{(108 - 145.6)^2}{145.6} = 333.51$$

$$> 56.89$$

Table 11. Kolmogrov-Smirnov two-sample test on cumulative rodent pellet distributions for five samples.

Size 64's inch	D_{12}	D_{13}	D_{14}	D_{15}	D_{23}	D_{24}	D_{25}	D_{34}	D_{35}	D_{45}
25	0.0000	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0018	0.0000	0.0018
24-25	0.0006	0.0006	0.0006	0.0000	0.0018	0.0000	0.0000	0.0018	0.0000	0.0018
23-24	0.0025	0.0025	0.0025	0.0000	0.0018	0.0000	0.0000	0.0018	0.0000	0.0018
22-23	0.0044	0.0044	0.0044	0.0000	0.0018	0.0000	0.0000	0.0018	0.0000	0.0018
21-22	0.0064	0.0064	0.0064	0.0000	0.0091	0.0000	0.0000	0.0091	0.0000	0.0091
20-21	0.0103	0.0108	0.0089	0.0005	0.0012	0.0014	0.0014	0.0127	0.0019	0.0108
19-20	0.0133	0.0153	0.0096	0.0020	0.0143	0.0037	0.0037	0.0163	0.0057	0.0106
18-19	0.0249	0.0183	0.0165	0.0066	0.0254	0.0084	0.0084	0.0138	0.0018	0.0120
17-18	0.0512	0.0454	0.0311	0.0058	0.0203	0.0201	0.0201	0.0145	0.0143	0.0002
16-17	0.0812*	0.0806	0.0398	0.0006	0.0391	0.0414	0.0414	0.0185	0.0408	0.0223
15-16	0.1230*	0.1339*	0.0414	0.0106	0.0040	0.0819	0.0819	0.0066	0.0925	0.0859
14-15	0.1448*	0.1934*	0.0078	0.0486	0.1595*	0.1526*	0.1526*	0.1109	0.2022	0.3121*
13-14	0.0801*	0.1373*	0.0017	0.0574	0.1639*	0.0826	0.0826	0.1065	0.1400	0.2465*
12-13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$D_{ij}^{0.001}$	0.0655	0.1063	0.0965	0.0986	0.1037	0.0934	0.0959	0.1254-	0.1267	0.1189

D_{ij} - Differences between samples i and j at stated size.

$$D_{ij} = S_i(x) - S_j(x)$$

$$D_{ij}^{0.001} = 1.95\sqrt{\frac{n_i + n_j}{n_i n_j}}$$

Table 12. Summary of laboratory cleaning tests.

	19/64 inch top sieve Run No. 1	2	3	4	5	20/64 inch top sieve Run No. 1	2	3	4	5
Feed-Corn (gms) Rodent Pellets (Count)	1000 375	1000 391	1000 350	1000 321	1000 314	1000 417	1000 377	1000 338	1000 368	1000 363
Over 19/64 round hole	768 1	755 3	791 0	766 2	805 0	-	-	-	-	-
Over 20/64 round hole	-	-	-	-	-	462 1	448 2	474 0	466 0	481 0
Thru 19/64 round hole to 16/64 round hole	232 374	245 388	209 350	234 319	195 314	-	-	-	-	-
Thru 20/64 round hole to 16/64 round hole	-	-	-	-	-	538 416	552 375	526 338	534 368	519 363
Over 16/64 round hole to 13/64 x 3/4 slotted	193 19	200 25	167 18	191 16	158 16	498 20	511 20	488 15	499 27	478 19
Over 13/64 x 3/4 slotted	62 10	65 16	62 15	66 7	56 12	84 16	85 14	86 10	84 18	79 15
Thru 13/64 x 3/4 slotted to 10/64 x 3/4 slotted	131 9	135 9	105 3	125 9	102 4	414 4	426 6	402 5	415 9	399 4
Over 10/64 x 3/4 slotted to aspirator	89 7	87 6	73 3	84 7	77 4	334 3	335 6	318 3	331 6	316 2
Thru 10/64 x 3/4 slotted	42 2	48 3	32 0	41 2	25 0	80 1	91 0	84 2	84 3	83 2

Table 12 (cont.)

	19/64 inch top sieve Run No.					20/64 inch top sieve Run No.				
	1	2	3	4	5	1	2	3	4	5
Aspirator light material	5	4	9	2	8	1	2	8	11	16
	6	5	1	6	2	3	3	1	6	4
Aspirator heavy material	84	83	74	82	69	333	332	310	330	300
	1	1	2	1	2	0	3	2	0	2
Thru 16/64 round hole	39	45	42	43	37	40	41	38	35	41
	355	363	332	303	298	396	355	323	341	334

Table 13. Analysis of variance for test series one.

Source of variation	D.F.	Ss	Ms	F
Replications	2	14.0129		
Screens (S)	1	850.0833	850.0833	126.03 *
Feed Rate (F)	1	60.3008	60.3008	8.43 *
Slope (A)	1	19.2533	19.2533	2.69 ns
Speed (P)	1	82.6875	82.6875	11.56 *
S x F	1	12.4034	12.4034	1.73 ns
S x A	1	31.6876	31.6876	4.43 *
S x P	1	0.0134	0.0134	0.002 ns
F x A	1	4.5364	4.5364	0.64 ns
F x P	1	31.0409	31.0409	4.34 *
A x P	1	16.9034	16.8034	2.34 ns
S x F x A	1	0.0074	0.0074	0.001 ns
S x F x P	1	0.1632	0.1632	0.02 ns
S x A x P	1	0.8007	0.8007	0.10 ns
F x A x P	1	6.7499	6.7499	0.94 ns
S x F x A x P	1	0.4410	0.4410	0.61 ns
Error	30	214.5200	7.1506	
Total	47	1331.5192		

* Indicates significance at the 0.05 level.

$F_{0.05,\ 1,\ 30} = 4.17$

Table 14. Overall efficiencies for test series one.

Cylinder Type	Cylinder Speed	Feed Rate 15 lbs. per min. Slope 0 inch per ft.	Feed Rate 15 lbs. per min. Slope 1 inch per ft.	Feed Rate 35 lbs. per min. Slope 0 inch per ft.	Feed Rate 35 lbs. per min. Slope 1 inch per ft.
Indented Cylinder	48.5 rpm	96.2 98.3 97.1	96.9 97.4 97.7	95.5 89.4 88.3	92.2 92.3 96.0
	67.5 rpm	98.9 97.8 98.8	97.2 98.1 98.4	96.6 95.8 98.4	94.4 96.2 98.6
Flat Cylinder	48.5 rpm	92.2 86.8 88.8	85.9 80.2 92.6	84.7 88.0 82.2	84.1 85.0 86.2
		92.4 91.5 88.7	89.5 84.6 86.4	90.2 91.3 92.8	82.8 88.4 89.2

Vertical order in each cell gives replications 1, 2, and 3.

Table 15. Analysis of variance for test series two.

Source of variance				
Replications	2	4.5785		
Screens (S)	2	572.6696	286.3348	15.97 *
Feed Rate (FR)	2	6.7252	3.3623	0.18 ns
S x FR	4	164.9882	41.2470	4.60 *
Error	16	286.8215	17.9368	
Total	26	1035.7830		

* Indicates significance at the 0.05 level.

$F_{0.05,\ 2,\ 16} = 3.63$

$F_{0.05,\ 4,\ 16} = 3.01$

Table 16. Overall efficiencies for test series two.

Screen Size 64's inch	Feed rate lbs. per min.		
	15	25	35
16	90.3 90.4 90.2	91.0 92.1 89.2	79.6 81.4 88.3
19	97.0 97.1 95.4	95.7 98.5 95.2	97.0 95.4 95.2
22	86.8 85.7 76.4	75.2 87.7 90.4	91.6 84.0 91.5

Vertical order in each cell gives replications 1, 2, and 3.

Table 17. Analysis of variance for test series three-overall efficiency.

Source of Variance	D.F.	Ss	Ms	F
Replications	2	16.574		
Feed Rate (F)	2	435.193	217.546	178.45 *
Cylinder Speed (R)	2	111.003	55.501	45.52 *
Cylinder Slope (S)	2	43.026	21.513	17.68 *
F x R	4	37.090	9.275	7.61 *
F x S	4	47.387	11.847	9.72 *
R x S	4	7.742	1.937	1.59 ns
F x R x S	8	10.810	1.352	1.11 ns
Error	52	63.353	1.218	
Total	80	772.178		

*Indicates significance at the 0.05 level.

$F_{0.05, 2, 52} = 3.18$

$F_{0.05, 4, 52} = 2.55$

$F_{0.05, 8, 52} = 2.12$

Table 18. Analysis of variance for test series three-recovery efficiency.

Source of Variance	D.F.	Ss	Ms	F
Replications	2	34.74		
Feed Rate (F)	2	563.84	281.92	254.00 *
Cylinder Speed (R)	2	157.63	78.81	71.00 *
Cylinder Slope (S)	2	58.42	29.21	26.37 *
F x R	4	22.17	5.53	4.98 *
F x S	4	61.42	15.35	13.82 *
R x S	4	10.42	2.60	2.34 ns
F x R x S	8	8.80	1.10	0.99 ns
Error	52	57.73	1.11	
Total	80	975.14		

*Indicates significance at the 0.05 level.

$F_{0.05, 2, 52} = 3.18$

$F_{0.05, 4, 52} = 2.55$

$F_{0.05, 8, 52} = 2.12$

Table 19. Overall efficiencies for test series three.

RPM	Slope	25: 1	25: 2	25: 3	45: 1	45: 2	45: 3	65: 1	65: 2	65: 3
48.5	0	96.0	97.6	96.6	88.9	94.6	90.2	84.8	88.1	86.9
	$\frac{1}{2}$	95.3	96.4	96.4	95.1	93.9	95.3	87.6	92.1	88.8
	1	96.0	95.7	94.8	92.5	93.9	92.8	87.7	91.5	89.2
58.0	0	95.3	97.0	96.3	96.3	95.3	93.5	88.5	89.9	88.0
	$\frac{1}{2}$	96.2	96.4	96.6	94.6	94.1	95.6	91.2	91.8	90.5
	1	96.6	95.6	95.6	92.2	95.9	96.6	91.1	93.2	91.9
67.5	0	98.2	95.3	97.9	94.7	94.9	93.7	89.8	90.0	90.9
	$\frac{1}{2}$	96.3	97.2	97.4	96.8	96.8	96.6	93.8	94.8	95.7
	1	97.0	97.2	97.0	94.8	96.9	96.9	94.9	96.0	94.6

Feed Rate (25, 45, 65); Replications (1, 2, 3)

Table 20. Recovery efficiencies for test series three.

RPM	Slope	25: 1	25: 2	25: 3	45: 1	45: 2	45: 3	65: 1	65: 2	65: 3
48.5	0	96.0	98.7	97.9	89.3	95.5	90.8	85.1	88.5	87.2
	$\frac{1}{2}$	96.8	98.1	97.7	96.0	94.9	96.0	88.1	92.8	91.5
	1	96.6	97.0	96.0	93.1	94.8	93.6	89.4	92.1	89.6
58.0	0	96.6	98.9	97.9	97.2	96.1	94.1	88.9	90.4	88.4
	$\frac{1}{2}$	97.7	98.6	98.2	95.9	95.7	96.7	91.8	92.4	91.1
	1	96.6	97.4	96.8	92.5	97.1	96.9	91.6	93.8	92.7
67.5	0	99.6	99.3	99.7	95.4	96.4	94.6	90.3	90.5	91.6
	$\frac{1}{2}$	98.4	99.5	99.6	97.4	98.5	98.0	94.5	95.8	96.4
	1	98.7	99.6	99.0	95.7	98.7	98.5	96.1	97.5	95.7

Feed Rate (25, 45, 65); Replications (1, 2, 3)

Table 21. Analysis of variance for test series four.

Source of Variance	D.F.	Ss	Ms	F
Replications	2	71.266		
Feed Rate (F)	2	821.767	410.883	123.99 *
Cylinder Speed (R)	2	162.208	81.104	25.67 *
Cylinder Slope (S)	2	68.253	34.126	10.80 *
F x R	4	39.658	9.914	3.14 *
F x S	4	73.440	18.110	5.74 *
R x S	4	14.235	3.309	6.05 ns
F x R x S	8	42.208	5.276	1.67 ns
Error	52	164.261	3.159	
Total	80	1457.296		

* Indicates significance at the 0.05 level.

$F_{0.05,\ 2,\ 52} = 3.18$

$F_{0.05,\ 4,\ 52} = 2.55$

$F_{0.05,\ 8,\ 52} = 2.12$

Table 22. Overall efficiencies for test series four.

		Feed Rate								
		15			30			45		
RPM	Slope	Replications								
		1	2	3	1	2	3	1	2	3
48.5	0	95.4	93.3	95.7	90.9	88.4	93.9	80.7	84.9	82.0
	½	95.7	94.8	96.3	97.9	88.3	94.3	88.3	86.4	90.3
	1	95.3	95.8	97.0	90.8	88.5	92.7	86.0	85.2	89.1
58.0	0	96.1	96.1	96.7	93.0	90.7	95.8	81.4	84.3	84.0
	½	96.1	94.4	92.8	92.1	92.7	95.3	88.5	90.5	91.5
	1	94.9	96.6	97.5	93.9	91.8	94.7	88.8	88.0	93.9
	0	97.5	94.3	97.4	92.0	94.3	94.4	86.8	90.5	92.4
	½	97.6	98.2	97.8	96.4	88.0	95.0	88.5	91.0	93.5
	1	96.7	98.1	98.0	98.6	94.5	94.7	91.8	92.9	95.2

Table 23. Efficiency of rodent pellet removal for test series five.

Feed Rate lbs. per min.	Cyl. Slope inch per foot	Replications				
		1	2	3	4	5
45	$\frac{1}{2}$	100.0	96.1	100.0	97.5	98.5
	1	97.2	95.5	96.5	100.0	98.9
65	$\frac{1}{2}$	95.2	94.3	98.8	98.6	96.8
	1	95.9	96.4	96.1	98.3	100.0

Table 24. Analysis of variance for efficiency of rodent pellet removal-test series five.

[1]Source of Variance	D.F.	Ss	Ms	F
Replications	4	25.27		
Feed Rate (F)	1	4.82	4.820	1.775 ns
Cylinder Slope (S)	1	0.01	0.010	0.004 ns
F x S	1	2.48	2.480	0.913 ns
Error	12	32.58	2.715	
Total	19	60.29		

Data coded

$F_{0.05, 1, 12} = 4.75$

Table 25. Recovery efficiencies per foot of cylinder length-test series two.

Screen size (inch)	Cylinder length (ft.)	Feed Rate (lb./min.) Replications								
		1	2	3	1	2	3	1	2	3
	1	68.3	71.1	72.6	76.0	76.3	78.7	74.2	80.8	80.0
	2	96.3	96.1	96.6	97.4	97.6	97.8	96.3	98.1	97.5
22/64	3	99.3	99.3	99.3	99.4	99.6	99.5	98.3	99.6	99.2
	4	99.5	99.5	99.4	99.5	99.7	99.6	98.5	99.7	99.3
	5	99.7	99.8	99.7	99.7	99.8	99.7	99.8	99.8	99.6
	1	67.8	71.6	68.3	71.1	70.8	72.0	65.8	66.7	66.7
	2	91.5	92.2	91.4	88.9	89.5	90.9	84.1	85.1	85.0
19/64	3	97.5	97.3	96.4	94.7	95.4	96.7	91.8	92.6	92.3
	4	98.6	98.6	97.5	96.5	97.0	97.2	94.5	95.3	95.1
	5	99.1	99.1	98.0	97.3	97.9	97.4	95.9	96.6	96.5
	1	63.1	62.2	63.5	60.6	57.4	60.8	48.9	50.8	57.7
	2	83.1	83.1	82.2	72.6	78.3	79.4	66.9	68.1	75.9
16/64	3	88.0	88.6	87.4	87.3	87.0	85.1	74.0	75.4	83.0
	4	89.1	89.8	88.9	89.4	90.0	87.8	77.6	79.0	85.7
	5	90.3	90.4	90.2	91.0	92.1	89.2	79.6	81.4	88.4

PERFORMANCE OF CYLINDRICAL GRADERS
IN RELATION TO CORN CLEANING PROBLEMS

by

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The purpose of this research was to study some of the factors that effect the performance of cylindrical graders, to study the efficiency of cylindrical graders in the removal of rodent contamination from corn and to determine the feasibility of utilizing this equipment for separating a major portion of the corn from the rodent contamination.

Standard one foot square test sieves manufactured by A. T. Ferrell and Company mounted on a modified Eriez Model 30 A vibratory feeder were used for particle size determinations. A No. 1 Carter Precision Grader was used for the study of cylindrical grader performance.

The size distributions of yellow dent corn and rodent pellets were studied in relation to the problem of mechanical separation. Wide variations were found in the size of yellow dent corn with respect to mean kernel width and variance of kernel width. Mean kernel thickness showed less variation. Samples of rodent pellets did not come from homogenous populations. The differences which were detected arose in the small end of the rodent pellet distributions and were attributed to overlapping populations.

Factors which had a significant effect upon cylindrical grader performance were; screen type, screen hole size, feed rate, cylinder slope, and cylinder speed. The indented hole screen was found to be superior to the flat hole screen. Generally, lower feed rate, increased slope, and increased cylinder speed resulted in higher efficiencies. In addition to the significant main effects, several interactions were found significant. Screen type by cylinder slope, feed rate by cylinder speed, screen size by feed rate, and feed rate by cylinder slope were found significant.

Rodent pellet removal using the 19/64 inch round hole test screen was not significantly effected by changes in feed rate and cylinder slope. Ninety-four per cent of the rodent pellets of size greater than 12/64 inch but less than 19/64 inch were removed from the corn of size greater than 19/64 inch.

These studies indicated that cylindrical graders could be utilized in a corn cleaning system with satisfactory results.