A STUDY OF SMALL GRAIN METERING DEVICES TO BE USED FOR AUTOMATIC FEED GRINDING

by

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INTRODUCTION

Automation is increasing in every field. Machines are doing more and more jobs completely or partially without the use of manpower. The farmer is gradually adopting automation. Up to this time more stress has been put on reducing field labor than chore labor. The farmer is now realizing that several of his manual chores can be eliminated by the use of electrical and mechanical means. Approximately 93 percent of the farms in Kansas now have electricity. Consequently many farmers are now putting automation to use and are looking for new and modern designs to be put to use in the future. One of the more laborious chores that has not been adapted for automatic operation thus far is that of grinding feed. Several designs for grinding individual grains without the use of manpower constitute a step toward automation. There are a limited number of designs of completely automatic feed processing systems. These systems are not adaptable to many of the farms of Kansas.

Many of the farms of Kansas are equipped with farm shops. The farmer is becoming more skilled; consequently, he is making things to be used around the farmstead. According to a recent survey (14), there is a higher potential for electric welders than for any other electrical unit costing more than $64.00 to be used on the farm outside the home. Nearly 16,000 welders are now being used on Kansas farms.

Very little research has been done to develop grain metering devices that can be built on the farm and used in automatic grinding and mixing systems.

SURVEY OF LITERATURE

Development of Measuring

The basic problem of metering grain is that of measuring a given amount of grain in a given time. Measuring has been an everyday occurrence since the beginning of mankind. Haddock and Wade (7) describe the evolution of metrology through many primitive cultures to the origin of the metric and English system of weights and measures.

At the present time both the English and metric systems of weights and measures are used in the United States. The English system is used by farm operators. Automatic meters for measuring gases and fluids have been developed and are now highly accurate instruments. Automatic metering devices for grains, however, were not practical until electrical power became available.

Electrification of Kansas Farms

Electrification of the farms of Kansas has brought about many changes. To understand why automation is not more prevalent, it is necessary to study a little history connected with this subject. In 1924 900 farms were receiving electric service (Hinrichs, 10). In 1943 there were 40,000 rural consumers. Although the average kilowatt hour use per year increased from

250 to 1400 during this time, very little power was used outside the farm home. But since 1941 the farmer has put an increasing amount of power into use. The number of rural customers in 1953 had increased to 83,000 with an average use of 2300 kilowatt hours per consumer. This increase in power used has accompanied an increase in efficiency of use.

A recent survey (14) shows that there are in Kansas 1538 electrically operated feed grinders on the farm and an immediate potential of 746 more. Electricity is allowing the farmer to gain increased efficiency in many chores, grinding grain being one of the more laborious. Of all the electric feed grinders operating in Kansas, very few operate without the use of manual labor and practically none grind, mix and measure automatically.

Economic Use of Electricity for Grinding

The tractor is not adaptable to automatic operation because of the manual functions required in operating it. The electric motor is ideal for automatic operation because, by use of time clocks and safety controls, the motor can be stopped, started and protected from overload and underload. The largest size electrical motors allowed on rural distribution lines is 5 to 7 1/2 horsepower. This limitation is a handicap because the rate of grinding is far below that of the tractor operated grinder. By automatic operation this disadvantage can be eliminated. Heinton (9) commented on the flexibility allowed by the electric motor. A motor of proper type, properly installed can be expected to operate satisfactorily. This feature is quite important in the design of any automatic system.

The total cost of grinding can be divided into power cost, labor cost, and overhead cost (Martin and Roberts, 11). The power cost depends upon the amount of grain ground, type, size and efficiency of the motor and grinder, condition of the grain and the fineness of grinding. Labor cost varies mostly with the design of the system layout. The overhead cost includes depreciation, interest on investment and repair and maintenance of the equipment.

Brackett and Lewis (2) stated that a feeder who needs more than 150 bushels of corn or 300 bushels of oats ground per year should consider grinding on the farm unless frequent trips are made to the mill for other reasons. Blauser (1) stated that by use of small grinding units, a saving can be realized if as little as one-fourth ton is ground per week.

The Need for Small Grain Metering Devices

The need for small grain metering devices is closely related to the trend toward automatic feed grinding. This trend is a result of electrical power being furnished to over 90 percent of the Kansas farmsteads (13).

In 1941 Martin and Roberts (11) reported on the use of electric motors for powering feed grinders. Their report shows a maximum rate of grinding of 4000 pounds per hour for milo, 3500 pounds per hour for shelled corn and 1500 pounds per hour for oats using a 5 horsepower electric motor. These data represent grinders designed for tractor power operation. New designs have improved the efficiency of grinders to the point that some will grind at about twice the rate of grinding in 1941.[1] A device used for metering small grains should be capable of delivering at high accuracy either full or part of the mill capacity.

Types of Feed Grinders

There are three major types of feed grinders (11):

The Plate or Burr Mill. The burr mill is the lowest priced mill of the three types. The grain is ground by passing between two plates. Fineness of grinding is adjusted by varying the pressure forcing the two plates together and by changing types of plates. This mill is well adapted to grind material coarsely. For fine grinding, the burr mill requires more power than does the hammer mill. The speed of operation is comparatively low, ranging from 200 to 1200 rpm. The grinding plates can be damaged by running empty and by hard foreign material passing through them.

The Hammer Mill. The hammer mill costs more than the burr mill and less than the roller mill. The hammers are usually short metal straps of high-grade steel. The hammers pulverize and force the grain through a screen. The pulverization causes an excessive amount of fine particles, thus making a dust problem for either coarse or fine grinding. The mill runs at a

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[1] From Commercial Literature

high speed and is rarely damaged by foreign material. Running empty will not injure the machine. Fineness of grinding can be varied by changing the screen.

The Roller Mill. The roller mill is the newest and most expensive of the three types. The mill consists of two rollers which roll in opposite directions and crush the grain between them. They are effective in cracking grain without causing a large amount of fine material. The roller mill has a higher efficiency and capacity for cracking grain than the other two mills. Foreign material will damage the rollers and running the rollers together, when not grinding, does cause unnecessary wear on them.

Effects of Types of Grinding

Cox, Smith, Parrish (3,4,12) and Turk (15) have carried out feeding tests to determine the effect of fine, coarse and rolled grains on feeding of beef cattle. Their results showed very little difference in the three methods. The individual feeder's preference, therefore, is the primary factor in determining what type mill to use.

Automatic Grinding Systems

Commercial literature can be obtained on some automatic systems which have been designed for use with the hammer mill, using overhead grain bins. There are, at the present time, no commercial automatic feed grinding systems that measure, mix and grind feed using the burr mill or the roller mill or that meter grain from ground floor storage. Forth, et al. (6) reported on a completely automatic feed grinding system. The small grains metering device, called a blending device or a fluted wheel, measures by volume. Different gate openings were used to govern the amount of grain that passed through the device. The discharge rate of this metering device was 120 to 1750 pounds per hour for shelled corn, 100 to 730 pounds per hour for oats and 100 to 460 pounds per hour for supplement. Another measuring device used in this system was a discharge bucket. This bucket measured ground grain by weight. It could hold approximately 125 pounds of ground feed and was capable of being adjusted to trip at any desired weight. The number of trips was registered by a counter, thus giving an indication of the weight of feed ground.

Some of the deficiencies of this system were reported by Forth and Lehman (5). The cause of variations in capacity, dependability, and power demands of the system were attributed to:

1. Condition of grain.
2. Setting of adjustments and controls.
3. Power supply and farm wiring problems.
4. Grinder and motor design.

Only the first two variations are effected by the metering device. The first cannot be controlled except by cleaning and proper drying of the grain. The second variation can be controlled by education on use and adjustment of metering devices and design of simpler and more accurate devices.

Harkness (8) reported on an automatic system which used a modified commercial hopper as a small grains metering device. This device was also a volumetric metering device and would be subject to the same error of grain condition as would the previous mentioned device. Control and adjustment was solved by a notched wheel that assured accurate settings of a discharge opening.

Many grain metering devices have been designed by commercial companies. The majority of these are used by the milling industry and are not adaptable for use by the livestock feeder. Some commercial metering devices, however, are adaptable for use by the feeder. These devices are described by available commercial literature.

Even though few solutions are available for feeders desiring to install automatic feed grinding systems, there is, however, considerable interest in grinding systems. Feed grinders and electrical powered motors are available and adaptable to the problems of grinding. Grain transporting equipment is also readily available. The apparent handicap to automatic feed grinding system design is the lack of metering devices that can be adapted to various grain storage units.

THE PROBLEM

Objectives

The purpose of the research herein reported was to select and design small grains metering devices that could be adapted for automatic operation in a feed grinding system. The metering devices should be adaptable to most of the existing grain storage units. They should be capable of delivering grain at rates equivalent to the grinding rates of most modern electric grinders. It is not anticipated that there will be a volume market for small grain metering devices until their value has been proven. Thus, they must be simple enough to build, operate, and maintain on the farm with the equipment readily available to the farmer. The initial cost and the cost of operation of the metering devices must be low enough to justify their use over other methods. The metering accuracy should be satisfactory for delivering a portion or all of the rations ground in modern feed mills. For purposes of testing, 95 percent accuracy was considered satisfactory.

Materials and Methods

Types of Grain. Oats, milo and shelled corn were selected to be used because they are representative of small grains that are fed by Kansas livestock feeders. Two batches of oats were used, one being uncleaned and the other being cleaned.

Timing. The time was determined by use of a stop watch. Length of test varied from one-fourth minute to six minutes depending upon the discharge rates of the metering devices and the capacity of the cans used to receive the metered grain.

Weighing. Weight was determined by use of a Fairbanks-Morse portable scale.

Speed. The speeds of the various devices were measured by the use of tachometers.

Metering Devices Designed. Four designs were proposed to be used for metering definite amounts of small grains into automatic or semi-automatic feed grinding systems. Laboratory experiments were set up to determine the capacity and accuracy of the four designs. The designs were to be modified as necessary to develop devices adaptable for use in existing grain storage units and with existing grinding mills. The four designs were:

1. Rotating disc metering device.
2. Metering hopper device.
3. Metering chute device.
4. Open auger device.

It was necessary to build the metering chute and the open auger device because they were not commercially available. The rotating disc and the metering hopper were obtained from commercial sources and modified as required.

Rotating Disc Device

The rotating disc design consisted of a circular disc which rotated in the bottom of a hopper (Plate II). An adjustable scraper guided the grain from the disc through a discharge opening. Rate of discharge was varied by adjusting the position of the scraper relative to the disc. A cut-off baffle was mounted over the scraper to assist in forcing the grain through the discharge opening. An agitator connected to the rotating disc prevented bridging and aided in preventing

EXPLANATION OF PLATE I.

The rotating disc device as tested.

PLATE I.

EXPLANATION OF PLATE II.

Top view of the rotating disc.

PLATE II.

slippage of grain on the rotating disc. The scraper was adjustable by an external handle which could be placed in six different positions by alignment of a pointer on the scraper with one of six marks on the chassis of the device. To allow better adjustment, the handle of the scraper was extended and a piece of sheet steel was bolted to the chassis. Marks were enscribed on the metal sheet to allow alignment of the scraper handle. This improved the accuracy of setting by about 300 percent.

In order to allow flexibility in speed, the rotating disc was driven from the drive shaft of a burr mill which was in turn driven by a variable speed drive. The mill speed was from 250 to 300 rpm. An eight inch pulley was placed on the mill to drive a 12 inch sheave on the fertilizer hopper. This allowed a speed of 167 to 200 rpm for the 12 inch sheave. A 12 to 44 reduction by a gear drive allowed the rotating disc to operate at a speed of 45 to 55 rpm. The linear velocity of the outer edge of the disc was thus 1.76 to 2.15 feet per second. These speeds tend to cause slipping of the grain on top of the disc.

By varying the speed it was found that the maximum speed allowable for the 12 inch pulley, without slippage of grain on the disc, was 124 rpm for milo and 110 rpm for shelled corn (Figs. 1 and 2). This speed represents a disc edge linear velocity of 1.39 feet per second and 1.18 feet per second respectively. The linear velocity was calculated as follows:

$$124 \text{ rev/min } \frac{12}{44} \cdot \frac{9 \text{ ft}}{12 \text{ rev}} \cdot \frac{1 \text{ min}}{60 \text{ sec}} = 1.33 \text{ ft/sec.}$$

The maximum discharge rate for metering shelled corn and milo at the above speed was respectively 800 to 1000 pounds per hour. Oats capacity was about 200 pounds per hour. This low oats discharge rate was caused by oats bridging across the discharge opening. There was free flow of milo from the discharge opening when the disc was stationary. Corn was cracked between the scraper and the discharge shield.

Modifications were made in an attempt to increase capacity of the three grains, prevent free flow of milo and reduce cracking of corn.

First Modification. The first modification was to remove the discharge shield and replace it with a piece of 1/8 inch plate steel. This eliminated the cracking of corn but did not eliminate the free flow of milo. This increased the discharge rate of milo and shelled corn to 1100 and 900 pounds per hour respectively but gave a minimum discharge rate of about 600 pounds per hour.

Second Modification. To prevent free flow of milo and lower the minimum rate of discharge, a 1/2 inch strap of 1/8 inch plate steel was welded to the outer edge of the first modification. This prevented the free flow of milo and lowered the discharge rate to about 300 pounds per hour. It had very little effect on the maximum capacity but it caused cracking of shelled corn between this modification and the scraper.

Third Modification. A new feed gate shield was designed. It was made of 1/8 inch plate steel and was larger than the first modification (Plate II). It was adequate in that it prevented free flow of milo, prevented cracking of corn and allowed a minimum metering rate of about 300 pounds per hour of milo. The minimum rate of milo is given because it has the highest minimum rate of the three grains. Maximum milo discharge rate was 1400 pounds per hour.

Fourth Modification. The fourth modification was made to reduce the minimum discharge rate and was accomplished by welding a strap on the upper side of the scraper. This strap was effective in reducing the minimum discharge rates to 80 pounds per hour for milo and 5 pounds per hour for shelled corn. The maximum discharge rates were 1400 pounds per hour for milo and 1100 pounds per hour for corn. The maximum discharge rate for oats was about 600 pounds per hour. The flow rate of oats was erratic due to bridging of foreign material in the discharge opening.

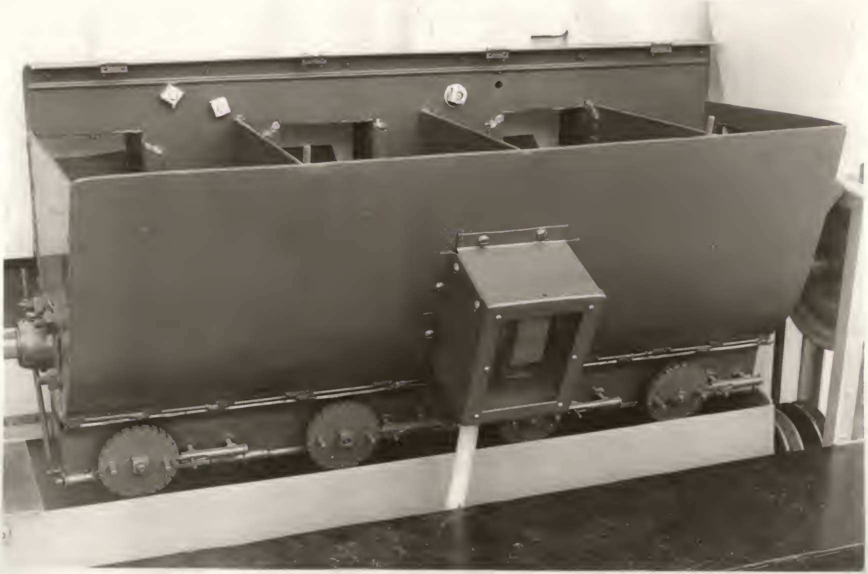
Metering Hopper

Modification of a four hole fertilizer hopper metering device transformed it into a metering device for small grains (Plate III). Partitions were placed between the four holes thus allowing four individual grains to be metered simultaneously. The gate controls used for closing the discharge openings were modified to allow individual adjustment. A rack and pinion gear was added to move the slide gate (Plate IV). The rack was welded to the slide gate. The pinion was connected by a shaft to a notched wheel on the outside of the hopper. The wheel had 25

EXPLANATION OF PLATE III.

The hopper metering device.

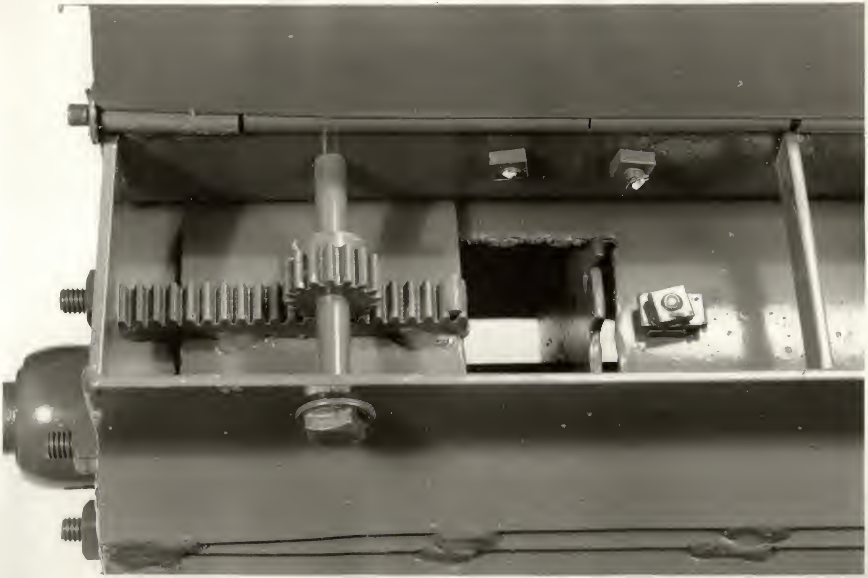
PLATE III.



EXPLANATION OF PLATE IV.

The rack and pinion gear used to control a slide gate of the hopper metering device.

PLATE IV.



EXPLANATION OF PLATE V.

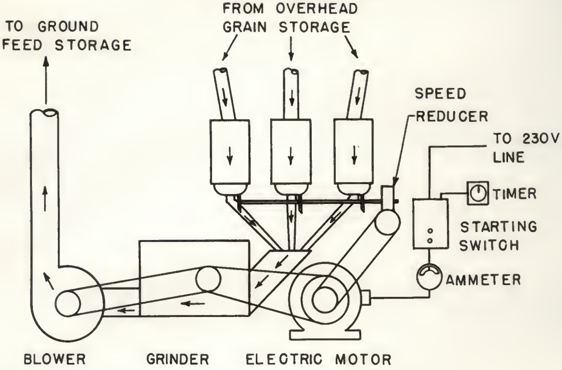
Top view of the hopper metering device showing the agitators above the discharge opening.

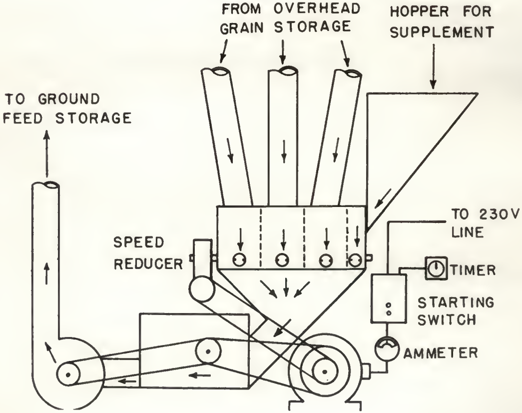
PLATE V

EXPLANATION OF PLATE VI.

Proposed flow diagram of automatic feed grinding system using the hopper metering device.

PLATE VI.


FROM OVERHEAD
GRAIN STORAGE
TO GROUND
FEED STORAGE
SPEED
REDUCER
TO 230V
LINE
TIMER
STARTING
SWITCH
AMMETER
BLOWER
GRINDER
ELECTRIC MOTOR


FROM OVERHEAD
GRAIN STORAGE
HOPPER FOR
SUPPLEMENT
TO GROUND
FEED STORAGE
TO 230V
LINE
SPEED
REDUCER
TIMER
STARTING
SWITCH
AMMETER

notches around its periphery, allowing definite adjustment of the slide gates.

As a means of closing off the flow of grain through the discharge hole, a magnetically controlled flap was arranged to fit under the discharge holes. The magnet was energized when the grinding motor was started. Energizing the magnet forced a plunger to move through a magnetic core. The plunger pulled the flaps down into a vertical position below the side of the discharge opening. When the motor stopped, the magnet would be deactivated and the plunger would force the flaps into a horizontal position below the discharge openings thus stopping the flow of grains.

An auger carried the grain from under the discharge opening to a desired location.

This device would require overhead bins with a chute from each bin to the hopper.

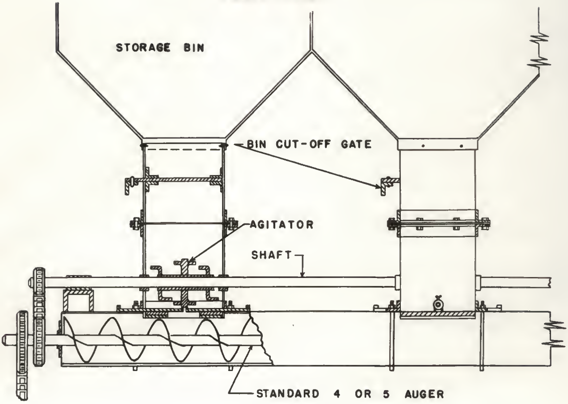
Metering Chute Device

The auger portion of this design was solely for the purpose of transporting small grains from the metering chute to some desired location (Plate VII). A drag type elevator could serve the same purpose, but due to economic reasons the auger is more satisfactory. The auger housing was supported by V-shaped rods which were in turn supported by angle-iron hangers welded to the side of the chute. The chute fit into a rectangular shaped hole on top of the auger housing. The metered grain fell from the chute through the rectangular hole into the auger.

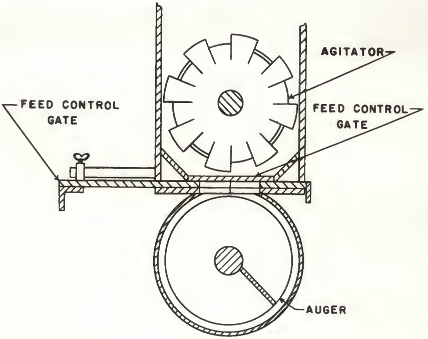
EXPLANATION OF PLATE VII.

Sectional views of the metering chute device with auger attached.

PLATE VII.



SIDE SECTION



END SECTION

The chute was designed to consist of two separate sections. One-eighth inch plate steel was used to construct it. The moving parts of the original design were two slide gates and an agitator. The upper portion consisted of four sides, a slide gate, two 6 inch x 1 1/2 inch x 1/8 inch angle irons to support the chute from the grain bin, and three 5 inch x 3/4 inch x 1/8 inch angle irons to support the slide gate and to prevent creeping of grain around the slide gate. The slide gate was 1/16 inch plate steel, 7 inches long and 5 5/8 inches wide. A small angle iron strap was welded on the end to serve as a handle. A 1/16 inch slot was cut in one side to allow use of the slide gate.

The lower section consisted of one slide gate, 4 sides, a bottom with a hole in it, an agitator, and two bearings for the agitator shaft. Three units were built, each with a different shaped bottom. The top and bottom sections were combined into a single unit for testing. The combination of the hole in the bottom of the chute and the slide gate was the metering portion (Plate VIII). One design was to use a diamond shaped hole in the bottom of the chute to allow grain discharge (Plate VIII, Fig. 1). The area of the opening would thus vary as the slide gate was closed. The metering area could be calculated from the following equations:

When $D < L/\sqrt{2}$ $\qquad$ $D > L/\sqrt{2}$

$A = L^2 - D^2$ $\qquad$ $A = 2L^2 - 2\sqrt{2}\,DL + D^2$

where A = Area in square inches.

EXPLANATION OF PLATE VIII.

Diagram of the proposed discharge openings
for the metering chute.

PLATE VIII.

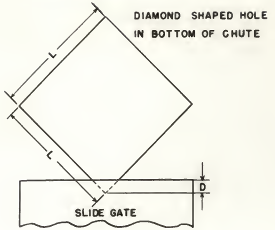


Fig 1

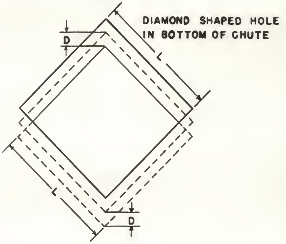


Fig 2

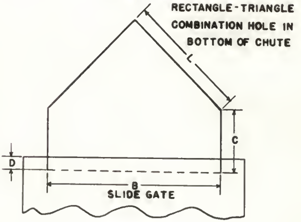


Fig 3

D = Distance the slide gate is moved over the hole in inches.

L = Length of one side of the square hole in inches.

Another design was to use two slide gates, each having in it a diamond shaped hole that matched the hole in the bottom of the hopper (Plate VIII, Fig. 2). The original shape of the hole was maintained under the agitator as the slide gates were slid simultaneously in opposite directions. The area of the discharge opening would vary according to $A = L^2 - 2\sqrt{2}DL + 2D^2$. Where A, D and L are the same as before.

A third design was to use a discharge hole of a rectangle-triangle combination (Plate VIII, Fig. 3). The slide gate was designed to cover the rectangular part of the hole first and then the triangular part. The area is given by:

$D < C$ | $D > C$

$$A = \frac{L^2}{2} + B(C-D) \qquad\qquad A = \frac{L^2}{2} - B(D-C) + (D-C)^2$$

where A = Area.

B = Width of rectangular portion.

C = Length of rectangular portion.

L = Length of one side of triangle = $\frac{B}{\sqrt{2}}$.

D = Distance the slide gate is moved over hole.

This design gave the advantage of larger capacity with fine adjustment at smaller discharge rates.

A small movement of the slide gates in all cases caused a considerable change in discharge rate. Thus, any error in setting the slide gates caused a considerable variation in discharge rate. A new bottom was designed to correct this error.

The final design of the bottom incorporated four slide gates (Plate IX). One slide gate was adjustable from each side of the hopper. The bottom was raised enough to allow the periphery of the agitator to travel below the planes of the slide gates. A 1/8 inch notch was cut in two of the slide gates to allow this positive agitation. The two notched slide gates were termed "Side Slide Gates" and the other two were termed "End Slide Gates". To insure agitation, two more agitators were added (Plate X). These were made of 1 inch x 4 inch x 1/6 inch strap iron. The ends were bent 90° in opposite directions at 1 inch from each end. The side slide gates allowed setting for maximum discharge rates, and the discharge rate was varied by adjusting the end slide gates. This area of discharge was thus the product of the distance between the side slide gates times the distance between the end slide gates.

This design allowed a finer adjustment of discharge rate and consequently a greater accuracy of metering. Figure 5 is a plot of the discharge rate of oats against the end slide gate opening at different side slide gate settings. A limited number of tests were run on milo and shelled corn to check the accuracy of metering.

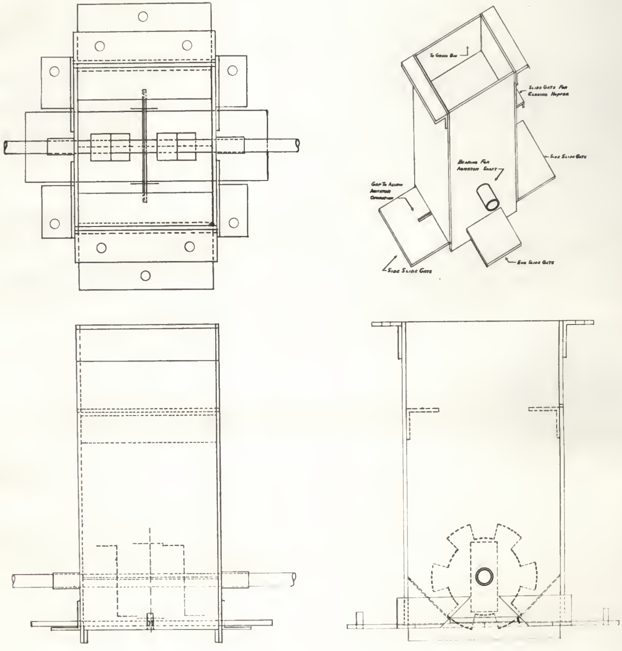
Open Auger Device

The major problem of using an open auger in a grain bin to meter grain was to design a simple means of driving the

EXPLANATION OF PLATE IX.

Diagrams of the final design of the metering chute.

PLATE IX.


To Grain Bin
Slide Gate For
Closing Hopper
Side Slide Gate
Bearing For
Agitator Shaft
Gap To Allow
Agitator
Operation
Side Slide Gate
End Slide Gate

EXPLANATION OF PLATE X.

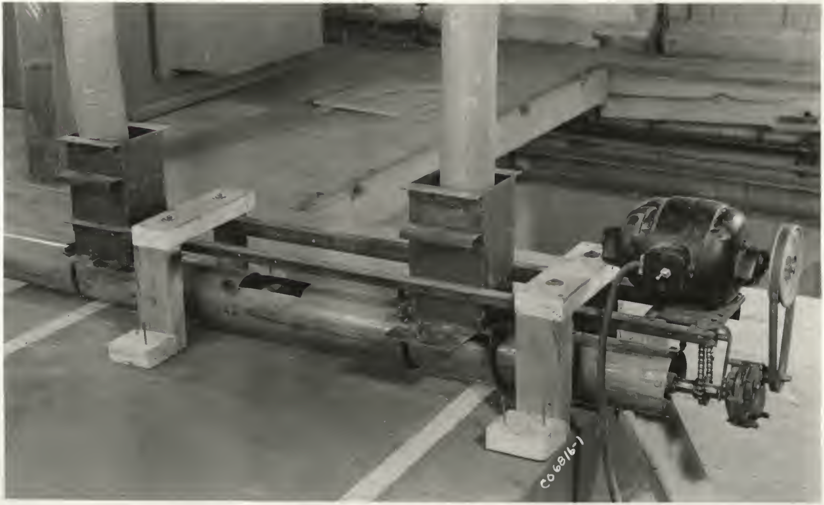
Top view of the metering chute as tested.

PLATE X.

EXPLANATION OF PLATE XI.

The metering chute as tested.

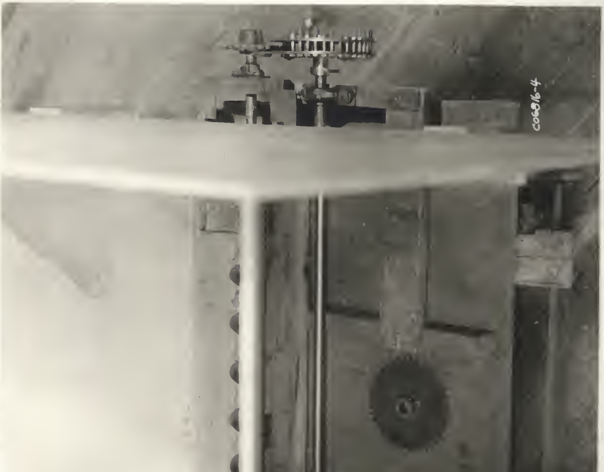
PLATE XI.



EXPLANATION OF PLATE XII.

The open auger metering device as tested.

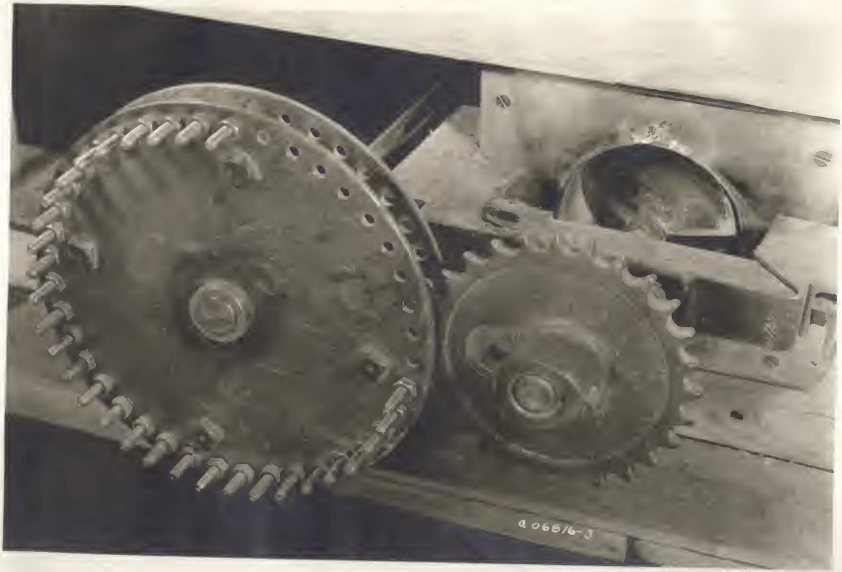
PLATE XII.



EXPLANATION OF PLATE XIII.

The pinwheel used to drive the open auger.

PLATE XIII.



auger at a variable speed. A driving mechanism was designed, built and tested for this purpose (Plate XIII). The drive consisted of an 85 to 1 speed reducer, a pinwheel, and a sprocket. The speed reducer was driven by V-belts from a 1/3 horsepower electric motor. A 1/2 inch steel shaft connected the pinwheel to the speed reducer. The pinwheel consisted of two 1/8 inch circular steel plates 9 inches in diameter. The plates were separated by 0.75 inches and held in position by four 3/8 inch x 1 1/4 inch bolts and four 1 inch x 3/4 inch sleeves. The pins were 40 removable 3/16 inch x 2 inch steel bolts placed 19/32 inches apart 1/2 inch in from the periphery of the wheel. A sprocket attached to the auger shaft was driven by the steel pins in the pinwheel. The pinwheel was mounted in a position that allowed each pin to be in contact for two pitch lengths with the sprocket which turns the sprocket 26.6°. An auger housing was made to extend 12 inches into the V-bottom bin. This housing allowed a definite discharge opening and prevented free flow of grain from the bin. Maximum speed variations were made by changing pulley sizes on the motor and speed reducer.

Tests were run at different speeds. Discharge rates were plotted against number of pins in Figure 6. The speed of the auger could be calculated as follows:

$$N_A = N_m \cdot \frac{D_m}{D_s} \cdot \frac{1 \text{ rpm}}{58 \text{ rpm}} = \frac{(P_n + 1)}{P_t} \qquad 1 \; P_n \; 39$$

Where: N_A = speed of auger (rpm).

N_m = speed of motor (rpm).

P_n = number of pins in the pinwheel.

P_t = number of teeth on sprocket.

D_m = diameter of pulley on motor (inches).

D_s = diameter of pulley on speed reducer (inches).

Because of a shortage of shelled corn, tests were run on milo and oats only.

Determination of Accuracy

Accuracy was determined by plotting the results of several tests and calculating the percent of error from discharge vs speed curves. Error was calculated for points of greatest variation from the curves in the following manner:

$$\frac{Qc-Qe}{Qc} \times 100 = \text{percent error}$$

Where: Qc = discharge rate from curve at a given speed.

Qe = discharge rate at point of greatest variation for the given speed.

Error was introduced by the following means:

1. The heterogeneous characteristics of the grain caused mainly by foreign material.
2. Error made in setting discharge rate.
3. Error caused by timing of starting and stopping tests.

The error due to foreign material is characteristic of all grains unless they are cleaned. Very little grain is cleaned on the farm before grinding; so, this error will be a feature in most farm grinding systems.

The slide gates were set by aligning marks on the slide gate and a fixed marker on the metering device. This error is eliminated in the open auger and metering hopper but could not be eliminated for the rotating disc and the metering chute.

Starting and stopping errors are most applicable to short length of operating time. These errors would be of little significance to a feeder who would be grinding for more than two or three minutes at a time. For short tests, however, these errors should be eliminated if possible. The method used in reducing this error was to catch the metered grain in a separate container before and after each test. Thus a negligible amount of error was made in starting and stopping tests.

Results of Tests

Rate of Discharge. The discharge rate of the rotating disc device was unfavorable compared to the grinding rate of most feed grinders. The maximum rate of grinding shelled corn and milo varied from a few hundred pounds per hour for small electrically powered mills to over 10,000 pounds per hour for some of the larger electrically powered mills[1]. The discharge rate of the rotating disc tested was effected by a small discharge opening. The maximum discharge rate of oats was not great enough to deem the device satisfactory for use in

[1]From commercial literature

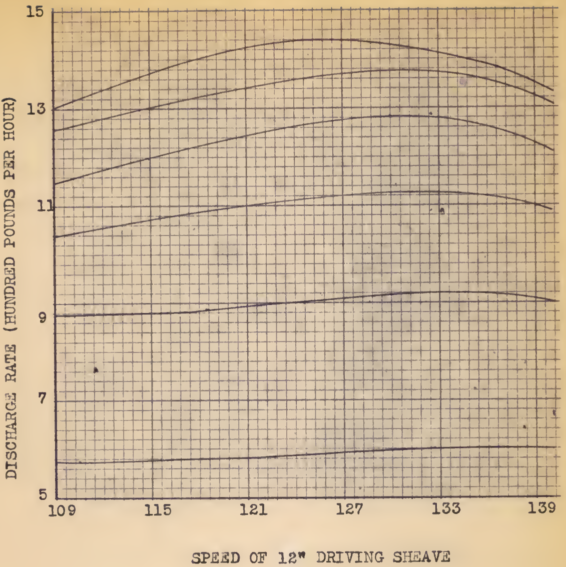


Fig. 1. A comparison of the discharge rate of milo for the rotating disc to the speed of the sheave driving the disc showing the speed at which grain begins to slip.

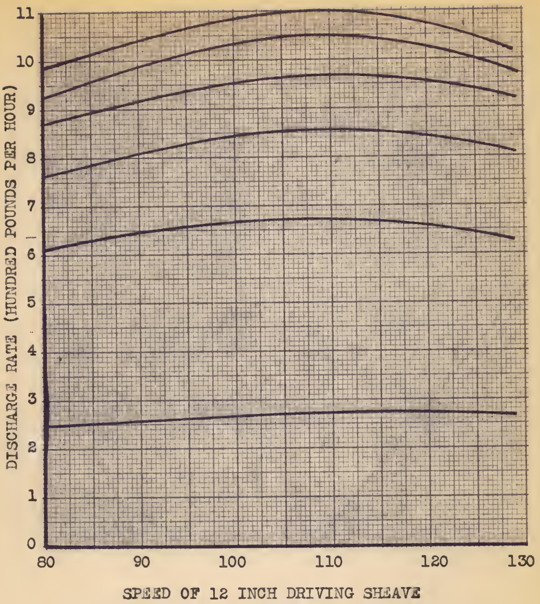


Fig. 2. A comparison of the discharge rate of shelled corn for the rotating disc to the speed of the sheave driving the disc showing the speed at which grain begins to slip.

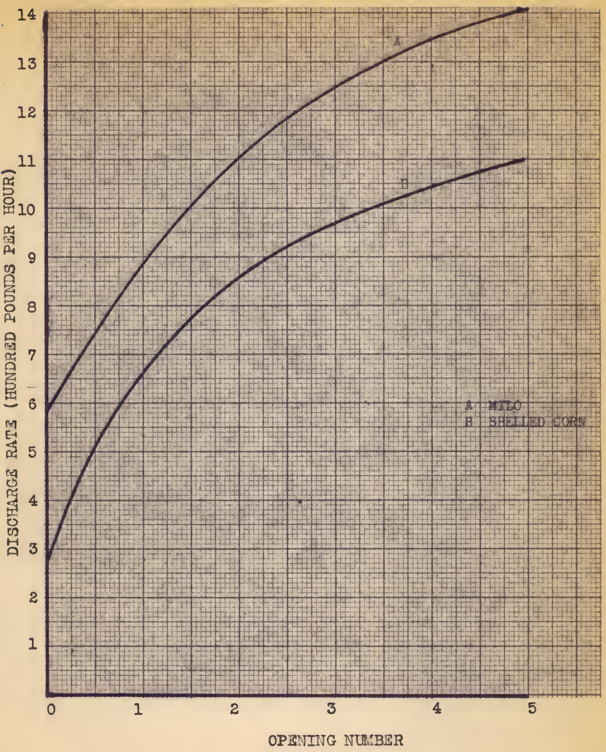


Fig. 3. A comparison of the discharge rate of the rotating disc to the six positions of the scraper. The speed of the rotating disc was thirty-three rpm for milo and thirty rpm for shelled corn.

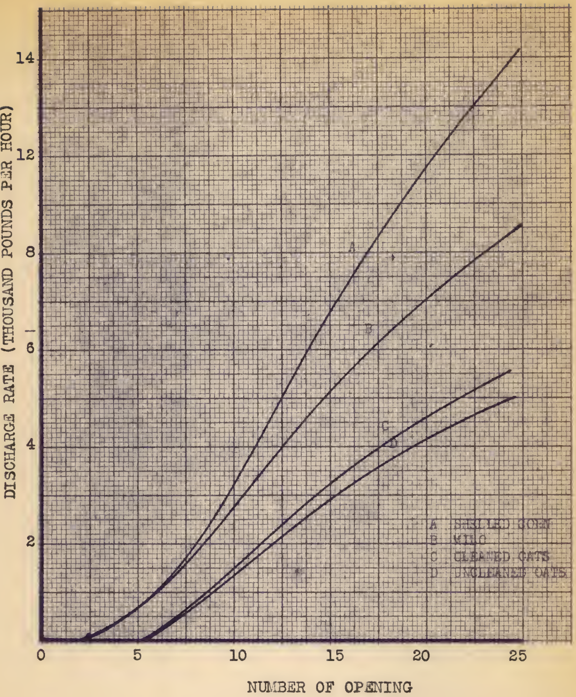


Fig. 4. A comparison of the discharge rate of the hopper metering device to the number of openings. The openings are controlled by a notched wheel containing twenty-five notches around its periphery.

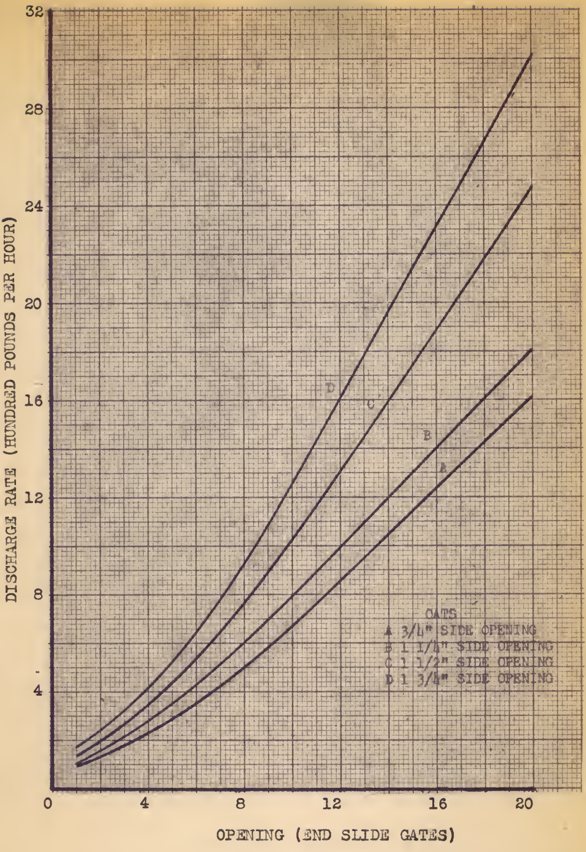


Fig. 5. A comparison of the discharge rate of the metering chute for uncleaned oats to the position of the end slide gates at four settings of the side slide gates.

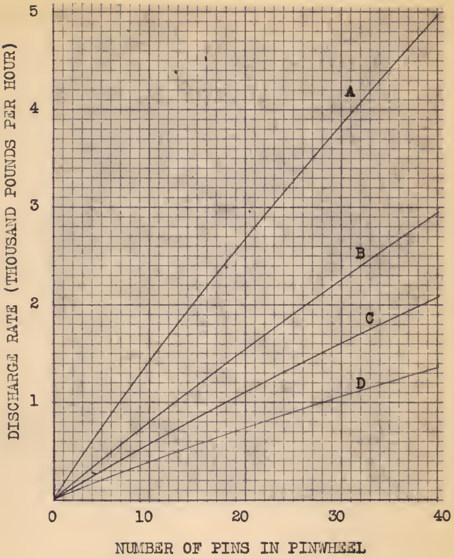


Fig. 6. A comparison of the discharge rate of the open auger small grains metering device to the number of pins present in a fourty pin pinwheel revolving at a speed of 20.3 rpm.

MATERIAL	Number of teeth on sprocket
A Milo	27
B Cleaned oats	27
C Uncleaned oats	27
D Uncleaned oats	40

conjunction with most grinders. The rate of discharge vs opening curve shows that the discharge rate varies as an exponential function of the opening. This is expected because the amount of grain in position to be scraped from the disc is a function of the circumference of the disc as the scraper moves toward the center of the disc.

The hopper metering device has a definite maximum discharge rate. This rate is equal to or greater than the maximum grinding rates of most electrically powered feed grinders. The maximum metering rate for shelled corn is over 10,000 pounds per hour. The variation per setting, of the notched wheel, is about 600 pounds per hour per setting at the higher rates of discharge. The maximum discharge rates of milo and oats were 8,000 and 5,000 pounds per hour respectively. The discharge rate vs opening curve (Fig. 4) is also non-linear because of the bridging of grain around the discharge hole.

The maximum discharge rate of the metering chute can be widely varied. Extending the length of the chute could give as high a discharge rate as desired. The discharge curve (Fig. 5) shows a non-linear variation of discharge rate vs opening. This characteristic is due to the bridging effect of oats near the edges of the opening. As the opening increases, this effect decreases causing a linear trend to the curve. The limited number of tests run on milo and shelled corn showed the discharge rate to be about twice that of oats.

The maximum discharge rate of the open auger can be varied if the driving mechanism is designed to be movable. The method of changing the maximum discharge rate would be to change the sprocket that drives the auger and adjust the pinwheel accordingly. With a 27-tooth sprocket, the discharge rate varied from 0 to 5000 pounds per hour for milo and from 0 to 3000 pounds per hour for cleaned oats. The discharge rate vs opening curve (Fig. 6) shows a linear characteristic to control. This is expected because the rate of discharge depends on the speed of the auger rather than on grain falling through a discharge hole.

Accuracy of Metering. The accuracy of all four metering devices tested is effected by grain condition. This is because the devices meter by volume. Any changes in density of the grain being metered make variations in the weight of a given volume. Another factor effecting accuracy was that of adjustment and control. This factor was eliminated in the open auger metering device by use of the pinwheel and in the hopper metering device by the notched wheel control. A third factor affecting accuracy is the discharge rate. The lower the discharge rate, the higher the error caused by a given variation, and, conversely. Some error was introduced by measuring on 1/4 minute tests. The error caused by reading to the nearest 1/4 pound could make an error as large as 60 pounds per hour. Tests this short were not necessary on discharge rates lower than 5,000 pounds per hour. Thus the error caused by running 1/4 minute tests would not amount to more than 1.2 percent.

The accuracy of the rotating disc was the lowest of the four devices, being 90 percent or better in most cases. The accuracy of the other three devices was above 95 percent in most cases and averaged about 98 percent.

Adaption to Automatic Feed Grinding Systems. The open auger is the most adaptable to any type grain storage structure. The use of the V-bottom storage bin is the only structural characteristic which is not common to most farm grain storage units. The hopper device required the use of overhead storage with sloping-floor bins. The metering chute could be used for ground-level storage providing there is adequate room under the bin for the chute and grain transporting equipment. This device would also require a sloping floor.

DISCUSSION

The primary basis for the research reported herein was to gain knowledge on discharge rates and accuracy of small grain metering devices. The small grain metering devices formerly developed do not allow the required flexibility for feed grinding system design. Nearly all the equipment designed for metering small grains has been for the milling industry. The farmer usually cannot economically justify or use a machine of this type. The metering devices designed for use by the livestock feeder are few in number and limited in use. The designs built and tested extend the adaptibility of metering devices. The open auger and metering chute allow the use of ground floor storage which is advantageous because of the amount of ground floor storage presently in use. The discharge rate of the open auger, metering chute and hopper metering device can be varied over wide ranges. These designs are simple in construction and operation and could be built and maintained by the farmer. The cost of the devices is kept at a minimum because very few commercial parts are necessary for their construction. The accuracy of the three devices compares with the accuracy of other metering devices. Their accuracy is varied by heterogeneous material in the same manner as is that of other devices that meter by volume.

CONCLUSIONS

Rotating Disc

A rotating disc of the form tested would not be suitable as a general small grain metering device. For use with milo and shelled corn, this type of device could be used with a low capacity grinder. Oats could not be metered satisfactorily. This does not mean that a rotating disc will not be developed that will meter all small grains. Adequate metering capacity was limited by the size of the discharge opening. It is believed that a rotating disc could be designed that would not be limited by discharge opening and would serve as a small grains metering device. There would still be present, however, the disadvantage that overhead bins would be required.

Metering Hopper

The accuracy of the metering hopper is very high providing a fairly homogeneous grain is metered. Discharge rate is relatively high also. At higher discharge rates a difference in setting of one notch may make a difference of several hundred pounds per hour in discharge rate. This could be remedied by increasing the number of possible settings of the slide gate.

It would be necessary to run a discharge rate test for each "batch" of grain to be metered. If the grain to be metered has a high percent of foreign material, the discharge rate should be checked two or three times to prevent as much as possible the error due to grain heterogeneity.

Metering Chute

The metering chute could be a very suitable metering device. The chute could be used to meter ground feed into a ration as well as to meter unground grain. Some ground feeds would require additional agitation to prevent bridging. A means of automatic control could be devised to eliminate the error and inconvenience caused by manual control of the slide gates. The chute could be placed under either overhead or ground floor bins providing the ground floor bins were above a foundation. For completely automatic operation, the bin would have to be designed to allow all grain to discharge through the chute by free flow. Any suitable transporting device could be used to convey the grain from the bottom of the chute to a desired location. The particular device tested varied in maximum discharge rate according to the distance between the side slide gates. The percent of accuracy determined from the tests was better than 95 percent for practically all tests. The skill and equipment required to build metering chutes is not such as would forbid a farm operator from constructing and maintaining them. The following precautions would have to be observed during fabrication and operation to obtain good results with a metering chute:

1. The slide gates should fit snug or have a fastening lug to prevent movement during operation.
2. The grain being metered should be fairly homogeneous.
3. A test should be run for each chute before a batch of grain is metered to determine the discharge rate.
4. The size of chute and consequently the size of discharge opening should be relative to the size of grinders and conveyors that the chute is to be used with.

Open Auger

The open auger is the most adaptable to any type building. The accuracy is high and the maximum discharge rate can be varied by speed or auger size. The driving mechanism is simple to construct and easy to maintain. For automatic operation, V-bottom bins would be required. The open auger meters according to volume and consequently is subject to errors because of heterogeneity of the metered material.

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A STUDY OF SMALL GRAIN METERING DEVICES TO BE USED FOR AUTOMATIC FEED GRINDING

by

WILLIAM VAN SCHOOF

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Grinding feed is a common chore for most livestock feeders. Electrical power is now furnished to over 90 percent of the farms in Kansas. The availability of electric power has caused a trend toward automation of farm chores. There are few feed grinding systems that measure, grind, and mix automatically. A problem encountered in designing automatic feed grinding systems is the lack of adaptable grain metering devices.

The objective of this study was to design, build and test some devices that could be adapted for use in metering small grains. Four designs were proposed; two of the designs were modified fertilizer spreaders, and the other two were designed and built with available materials.

Tests were run to determine the discharge rate and the accuracy of the proposed metering devices.

One of the modified fertilizer hoppers, referred to as a rotating disc device, meters by scraping grain from a rotating disc. The discharge rate was varied by changing the position of the scraper. The accuracy was determined to be above 90 percent, in most cases, for milo and shelled corn. Oats would not meter properly because they clogged the discharge opening. The rate of metering was low compared to the rate of grinding of most electrically operated feed grinders. The small discharge opening was the cause of the low capacity.

The other fertilizer spreader is called a hopper metering device. This device meters small grains by allowing the grain to fall from a hopper through a discharge opening. The discharge rate is varied by governing the size of the discharge opening. The rate of discharge compares favorably with most electrically operated feed grinders. The metering accuracy of the hopper tested above 95 percent for homogeneous materials. A disadvantage of this device is that it requires overhead storage bins for grain supply.

A rectangular chute was designed to meter small grain. The method of metering is similar to that of the hopper metering device. A hole in the bottom of the chute allowed grain to fall through the chute. The size of the hole was governed by slide gates. Four designs were tested. The final design incorporates the use of four slide gates to vary the size and shape of the discharge opening. The discharge rate can be varied to provide the required capacity of any feed grinder. The accuracy of metering, for fairly homogeneous material, was above 95 percent in most cases.

A method of varying the speed of rotation of an auger was designed and tested. A sprocket on the auger shaft was driven by a wheel containing from 1 to 40 steel pins. The speed of the auger was varied by changing the number of pins in the wheel. The auger was placed in a V-bottom bin with one end protruding from the bin. The rate of discharge was directly proportional to the speed of the auger. The maximum rates of discharge of the auger was dependent upon the pinwheel speed, the type of grain, and the size of auger. The open auger device was the most accurate of the four devices tested.

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