GRINDING EAR CORN WITH SMALL ELECTRIC MOTOR DRIVEN FEED GRINDERS

by

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B. S., University of Georgia, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

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INTRODUCTION

Can the small electric motor driven feed grinder be adapted to grinding ear corn? So far it has not been. This study has been undertaken to find the problems involved in making this adaptation practicable. The operator of a small farm who does not grind in sufficient quantity to warrant the purchase of a large expensive feed grinder finds a small feed grinder entirely satisfactory for grinding small grains. However, the small feed grinder is not generally suited for grinding ear corn.

The small feed grinder, to be effective, has to be readily adaptable to automatic operation. This automatic operation is easily arranged when grinding small grains, but no method of automatically feeding ear corn to the grinder has been developed. The labor cost when hand feeding the small feed grinder makes the total cost of grinding too high to be practical. Some method, then, of automatically feeding ear corn to the small electric motor driven feed grinder is an immediate need of the farmer.

At the present time, rural electric lines furnish electrical energy for motors up to 7 1/2 horsepower; however, a 5 horsepower motor is the maximum size that is recommended.

REVIEW OF LITERATURE

A few years ago the cob in ear corn was considered useless as a feed for livestock. In recent years, however, agricultural colleges have been doing research to determine the value of corn cobs in livestock ration. Gerlough, Burroughs, and Kunkle (1) state that the cobs in corn and cob meal are worth about 60 percent as much as shelled corn in producing gains on beef cattle. Table 1 shows the data they give for a 252-day test on beef steers.

Table 1. Ground shelled corn versus corn and added cob meal.

December 8, 1942, to August 17, 1943 - 252 days
Lot 1 and 4 - fed regular corn and cob meal
Lots 2 and 5 - fed ground shelled corn
Lots 3 and 6 - fed corn and added cob meal

Lots 1, 2 and 3 group fed —— Lots 4, 5 and 6 individually fed

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Number of steers	20	20	20	12	12	12
Weight, start of test	490	486	489	480	479	479
Daily Ration						
Ground shelled corn	10.11	11.26	8.55	7.66	8.80	6.36
Ground cobs	2.30	-	3.88	1.74	-	2.89
Soybean oil meal	2.00	2.00	2.00	2.00	2.00	2.00
Mixed hay	4.19	4.16	3.83	2.80	2.79	2.78
Average daily gain	1.99	1.97	1.93	1.76	1.72	1.62
Feed per cwt. of gain						
Ground shelled corn	508	573	444	436	512	392
Ground cobs	115	-	202	99	-	178
Soybean oil-meal	100.3	101.5	103.9	113.7	116.2	123.1
Mixed hay	210	212	199	159	162	171
Value of cobs in terms of shelled corn	57%		64%	77%	-	67%

Source: Gerlough, Paul, Wise Burroughs, and L. E. Kunkle. Mimeo. Series No. 52:2-5, 1949.

The cobs show a surprisingly high return in those tests. Whether their value is due to physical or to chemical properties is not known. The tests by Gerlough, Burroughs, and Kunkle at the Ohio Agricultural Experiment Station do, however, show that it is worth while to grind and feed corn and cob meal.

There are many benefits derived from grinding feed for livestock. Some of the advantages of grinding grain for livestock given by Fenton and Logan (2) are as follows:

1. Grinding reduces the amount of grain passing through the animals undigested.

2. Grinding increases palatability.

3. Grinding reduces waste, because the animals cannot nose out the less palatable feed.

4. Grinding permits more advantageous mixing of feeds and balancing of the ration.

5. Grinding increases digestibility by allowing digestive juices to act more readily.

The preceding advantages include ear corn as well as other grains. The cob in ear corn is worthless as a feed unless it is ground and mixed with the corn.

The fineness of grinding is an important factor to consider when grinding ear corn or any grain. E. A. Silver (3) states that the fineness of grinding is important from the nutrition as well as from the power viewpoint. Table 2 shows the classification of moduli of fineness for various finenesses of grinding on ear corn.

Table 2. Classification of moduli of fineness for various finenesses of grinding on ear corn.

Grain	Whole grain	Coarse grinding	Medium grinding	Fine grinding	Very fine grinding
Ear corn	-	4.80 (5.40-4.20)	3.60 (4.20-3.00)	2.40 (3.00-2.10)	1.80 (2.10-1.50)

Experiment station studies seem to indicate cheaper gains from feeding livestock with more coarsely ground feed. Coarse grinding in turn increases the capacity of the mill and lowers the electrical energy consumption in grinding and causes less wear on the mill. For this reason, livestock men are now grinding their grains at a much coarser grade than in previous years. Table 3 was prepared by Russell (4) to show the recommended fineness of grinding of ear corn for various animals.

Table 3. Fineness of grinding recommendations for ear corn.

Feed	Beef cattle	Dairy cattle	Swine	Sheep	Lambs	Horses	Chicks	Hens
Ear corn	Coarse	Medium*	Whole	Coarse	x	Whole	x	x

*Not recommended for calves.

xNot recommended.

It is always interesting to the farmer to know whether it is cheaper to grind the grain himself or to use the facilities of custom grinders. Fenton and Logan (2) give the following discussion on grinding on the farm versus custom mill grinding. Custom mill grinding involves the following items:

1. A charge for grinding which varies from 10 to 15 cents per hundred pounds.

2. Loading the grain on the wagon or truck.

3. Hauling it to the mill to be ground.

4. Waiting while the grain is ground.

5. Hauling it back.

6. Unloading the ground grain on the farm.

The total expense of custom grinding varies with the distance which the grain must be hauled, the condition of the roads, and the value of the farmer's time consumed. If all items are included, the cost of grinding at the custom mill is so large that it is practicable only where the amount ground per year is not large enough to warrant the investment in a mill on the farm.

The selection of a grinder will depend upon the conditions under which the farmer expects to grind his feed. It depends upon whether he wants a small automatic mill or a large mill requiring much labor to operate. The two largest items of expense in grinding are labor costs and the fixed charges. The small automatic electric motor driven feed grinder decreases labor and fixed charges as compared to the large mill. Fenton and Logan (2) state that electric power is especially well adapted to the automatic operation of feed grinders. The electric motor furnishes a steady, dependable, source of power, and one that can be started or stopped by automatic devices. They (2) further state that the hammer mill is probably best adapted to automatic operation because it is not injured by running empty nor by small particles of such foreign matter as nails and bolts.

It is necessary to know the estimated life of the feed grinder in order to figure the annual depreciation. Heady, Hopkins, and McKibben (5) gave an estimated life of 16.6 years for the feed grinder. Butz and Lloyd (6) gave an estimated life of 19 years for the feed grinder. Byers (7) gave an estimated life of 18 years for the feed grinder. An average of these three figures gave an estimated life of 17.8 years resulting in an annual depreciation of 5.68 percent.

The right selection of an electric motor to drive the feed grinder is also important. The farmer should preferably buy a portable motor that he can use on several different machines. If a single phase motor is to be used for feed grinders, a repulsion induction motor built for 230 volts is best adapted to this job. Zink (8) states that the repulsion induction motor will start heavy loads which require a turning effort two to four times the running torque required. This ability to start heavy loads is one requirement of the hammer mill. The repulsion induction motor can easily be reversed in direction of rotation by a shift of the brushes by means of a movable yoke to which the brushes are fastened. In areas where three phase service is available, a three phase induction motor would be more economical to operate. The original cost of the three phase motor is about half the cost of a single phase motor of the same horsepower.

When an electric motor is installed, the wire size for the motor circuit must be carefully considered. The wire should be of such size as to limit the voltage drop from meter to motor to not more than 2 percent. Fenton and Stover (9) have prepared Table 4 containing data on single phase motors, including recommendations for wire sizes for motor circuits. The motor control and overload protection should also be considered when

Table 4. Data on single phase 60 cycle motors.

Horsepower	Allowable starting load amperes 220 volts	Approximate full load amperes 220 volts	Recommended wire size for motor circuits: 200' or less total distance meter to motor	Recommended wire size for motor circuits: 200' to 400' total distance meter to motor
1	27	6.0	No. 10	No. 10
1 1/2	30	7.6	10	8
2	40	10.0	8	8
3	60	14.0	8	8
5	100	23.0	6	4
7 1/2	120	35.0	4	2

installing the electric motor. Zink (8) states that either a manual or magnetic starter in conjunction with thermal overload protection should be used in the motor circuit. These starters are rated according to ampere carrying capacity.

THE PROJECT

This investigation was concerned with the performance of the one to five horsepower electric motor driven feed grinders while grinding ear corn. During the course of the investigation, the following factors were determined:

1. The electrical energy used per 1,000 pounds of ear corn ground.

2. The capacities in pounds per hour and pounds per horsepower hour with each grinder.

3. The effect of fineness modulus on the electrical energy used and capacity of each grinder.

The preceding information was used to determine the following:

1. The practicability of crushing ear corn preparatory to grinding.

2. The approximate cost of grinding ear corn with the small electric motor driven feed grinder.

This project was also concerned with the development of an automatic feeding device for ear corn.

PRELIMINARY INVESTIGATIONS

The three hammer mills tested were chosen because their construction represented most of the small hammer mills on the market today. An ear corn crusher was also tested in conjunction with the tests of the hammer mills.

Tests of Hammer Mills

The following hammer mills were tested: a Bell No. 10 hammer mill, a three horsepower mill obtained on loan from the C. S. Bell Company; a Smalley No. 5 hatchet mill, a five horsepower mill obtained on loan from the Smalley Manufacturing Company; and a Viking one horsepower hammer mill obtained on loan from the Viking Manufacturing Company. Throughout the discussion of the tests of these hammer mills, the Bell No. 10 hammer mill will be referred to as the three horsepower hammer mill; the Smalley No. 5 hatchet mill will be referred to as the five horsepower hammer mill; and the Viking one horsepower hammer mill will be referred to as the one horsepower hammer mill.

Equipment. Hammer Mills. The three horsepower hammer mill was of the swinging hammer type with 12, high carbon, heat treated, steel hammers. This mill was equipped with a blower for elevating the ground feed from the hammer mill to a sacking tower or feed bin. The blower was separate from the grinding head and was driven from the same shaft. The grain was fed in above the hammers which reduce the grain to the desired fineness. The fineness was determined by the screen located beneath the hammers. The ground feed was than forced through the screen where the blower picks the ground feed up by suction and discharges it either to the sacking tower or feed bin. The three horsepower hammer mill had 100 square inches of screen area. This mill was equipped with a sacking tower attachment and dust collector for these tests.

The three horsepower hammer mill runs at a speed of 3,500 R.P.M., which is the minimum speed recommended by the manufacturer. Since the farmer who is the ultimate beneficiary of this information will run the mill at the speed recommended by the manufacturer, the performance data on the mill at this speed will be most beneficial to him. No attempt was made to vary the speed of the mill. The three horsepower hammer mill as equipped for these tests is shown on Plate IV.

The five horsepower hammer mill is classified as a combination mill because it is equipped with knives in addition to the hammers. This mill is a swinging hammer type; but, in contrast to the three horsepower hammer mill, the grinding head and blower elevating the ground feed are combined into one unit. The grinding head with hammers extended is 24 inches in diameter and has 24, high carbon heat treated steel hammers. The grinding head is also equipped with two cutter knives 9 1/4 inches in length, with tool steel cutting edges to chop the ear corn as it is fed into the grinding head. These cutter knives are located on the diametral plane of the grinding head. The five horsepower mill has a total screen area of 340 square inches. This mill also was equipped with dust collector and sacking tower attachment for these tests. The five horsepower hammer mill as equipped for these tests is shown on Plate I.

The five horsepower hammer mill was run at a speed of 2,000 R.P.M. which is the minimum speed recommended by the manufacturer. A trial run was made at 2,300 R.P.M., but a five horsepower motor did not furnish sufficient power to drive the mill at this speed. However, the performance data at the manufacturer's recommended speed will be most beneficial to the farmer, since he will run the mill at this speed.

The one horsepower hammer mill is of the swinging hammer type with 15 high carbon, heat treated, steel, reversible hammers. The grinding head is 14 inches in diameter with the hammers extended. In contrast to the three horsepower and the five horsepower hammer mills, the one horsepower hammer mill has no blower for elevating the ground feed. The ground feed is discharged to a feed bin beneath the grinder. The one horsepower hammer mill is shown on Plate II. This mill was run at a speed of 3,600 R.P.M.

Power Units. The three horsepower hammer mill was driven by a three horsepower three phase motor with a double V-belt drive. The five horsepower hammer mill was driven by a five horsepower, replusion induction motor using a double V-belt drive. The one horsepower hammer mill was driven by a one horsepower repulsion induction motor using a direct drive. All of the above motors were operated on 220 volts, which is the minimum voltage at which each motor should be operated.

Measuring Devices. The measuring devices used in the tests on the hammer mills were as follows: a three-phase rotating watthour meter on the three phase motor; a single phase rotating watthour meter on the single phase motors; a recording wattmeter that could be connected for either three phase or single phase power; a stop watch for determining the time for each test; a roto-tap shaker with a set of Tyler screens for determining the fineness modulus of the feed ground; and a speed counter for determining the speed of the mills.

Experimental Procedure. The time was recorded in minutes by the use of a stop watch. Each test on the hammer mills ran for one minute.

The energy used by each of the mills was measured by a rotating wattmeter in kilowatt hours. The number of revolutions of the rotating disk on the meter was counted for the period of time that the test was run; and the kilowatt hoursof energy were calculated by the following formula:

$$\text{kwhr} = \frac{N \times K}{1{,}000}$$

where,

N = number of revolutions of disk

K = meter constant in watt hours per revolution

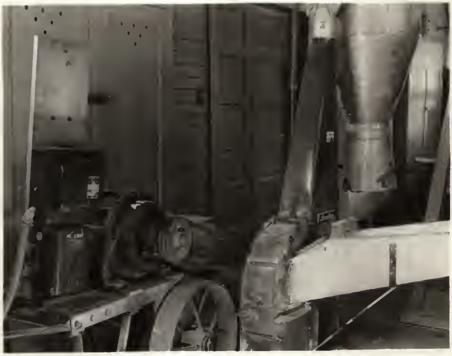
1,000 = constant to change watt hours to kilowatt hours

The horsepower output of the motor was found by calculating the average demand of the motor in kilowatts for each test, and then using the performance curves on the motor. These performance curves were obtained from the company that manufactured the motor.

EXPLANATION OF PLATE I

Close-up of the five horsepower hammer mill and five horsepower, repulsion induction motor that was used to drive it.

PLATE I



EXPLANATION OF PLATE II

Close-up of the one horsepower hammer mill as it was equipped for tests.

PLATE II

The corn ground in each test was weighed and recorded in pounds. From this information the capacity in pounds per hour was calculated.

The capacity in pounds per horsepower hour was calculated by the following formula:

$$\text{Pounds per hp. hr.} = \frac{\text{pounds per hour}}{\text{horsepower}}$$

The energy used in kilowatt hours per 1,000 pounds of corn ground was calculated by the following formula:

$$\text{Kwhrs. per 1,000 lbs.} = \frac{\text{Kwhrs. used} \times 1{,}000}{\text{pounds ground}}$$

where,

Kwhrs. = kilowatt hours of energy used in each test

Pounds ground = pounds ground in each test

For the fineness modulus determination, a 250-gram sample of corn ground by each screen used on the mills was taken and oven dried to a constant weight at 100° C. The sample was then put into the top screen of a set of standard Tyler 8-inch screens, and shaken on a ro-tap shaker for five minutes. The amount of material retained on each screen was then weighed and the percentage of feed coarser than each of the screens was calculated. The sum of these percentages divided by 100 gave the fineness modulus of the feed ground.

The moisture content of the corn was found by putting a 200-gram sample of feed in the oven at 100° C. and leaving it for 48 hours or longer if necessary and then weighing it after all the moisture had been extracted. The percentage moisture content on the dry basis was then found by the following formula:

$$\text{Percent moisture} = \frac{\text{wet weight-dry weight} \times 100}{\text{dry weight}}$$

A recording wattmeter was used to obtain a graphical record of the demand of the motor in kilowatts for each test. The recording wattmeter was also used to maintain an approximately uniform rate of feed to the hammer mills. The meter was located so that the operator could see the indicator needle and keep the demand in kilowatts approximately constant.

Results. Three Horsepower Hammer Mill. The three horsepower hammer mill was tested when grinding whole ear corn and ear corn that had previously been crushed. This mill was fed by hand, and an approximately uniform rate of feed was maintained as explained under experimental procedure. Each test on this mill ran for one minute. The corn ground was without husk and the moisture content was 16.55 percent.

The screens used in tests on the three horsepower hammer mill were as follows: 3/4 inch, 1/2 inch, 3/8 inch, and 1/4 inch. The fineness modulus of the corn ground with these screens was 4.08 with the 3/4 inch screen, 3.33 with the 1/2 inch screen, 3.15 with the 3/8 inch screen, and 3.00 with the 1/4 inch screen.

Table 5 shows the capacities in pounds per hour, capacities in pounds per horsepower hour and the electrical energy used in kilowatt hours per 1,000 pounds of corn ground. These data were condensed from the original test data to facilitate a comparison of the performance of the three horsepower hammer mill when grinding whole ear corn and when grinding crushed ear corn.

A summary of the data given in Table 5 will indicate some of the advantages of crushing ear corn preparatory to grinding with the three horsepower electric motor driven hammer mill. A description of the crushed corn is given on page 38.

The capacity in pounds per horsepower hour will be considered first because it gives a more accurate indication of the efficiency of the grinder than the capacity in pounds per hour. This is true because the capacity in pounds per horsepower hour was not affected by the rate of feed; whereas, the capacity in pounds per hour was affected. The capacity when grinding with a 3/4 inch screen was increased 60.35 pounds per horsepower hour or 16.2 percent by pre-crushing the corn. When grinding with a 1/2 inch screen, the capacity was increased 79.7 pounds per horsepower hour or 30.3 percent. Pre-crushing the corn resulted in an increased capacity of 46.5 pounds per horsepower hour or 19.1 percent when grinding with a 3/8 inch screen, and 45.54 pounds per horsepower hour or 25 percent when grinding with a 1/4 inch screen. The preceding discussion shows that pre-crushing the corn preparatory to grinding with the three horsepower hammer mill gave an average increase of capacity in pounds per horsepower hour of 22.65 percent. This means that the efficiency of the mill was increased by pre-crushing the corn.

The following discussion will consider the capacity in pounds per hour but will not show as good a comparison as did the capacity in pounds per horsepower hour. This is mainly because the mill was fed by hand and the rate of feed was not constant. The capacity of the three horsepower hammer mill, when grinding with a 3/4 inch screen was increased 45 pounds per hour or 4.7 percent by pre-crushing the corn. Pre-crushing the corn increased the capacity 53.85 pounds per hour or 7.32 percent when grinding with a 3/8 inch screen and 117.1 pounds per hour or 20.2 percent when grinding with a 1/4 inch screen. The average increase of capacity in

Table 5. Capacity and electrical energy consumption data on the three horsepower hammer mill.

Capacity	3/4" screen		1/2" screen		3/8" screen		1/4" screen	
	Whole ear corn	Crushed ear corn	Whole ear corn	Crushed ear corn	Whole ear corn	Crushed ear corn	Whole ear corn	Crushed ear corn
Lbs/hr.	958.35	1003.35	735.90	789.75	710.90	782.10	578.30	695.40
Lbs/ hp. hr.	373.25	433.60	263.70	343.40	243.70	290.20	182.36	227.90
Energy used = Kwhr/1000 lbs.	2.46	2.09	3.49	2.65	3.77	3.11	5.08	4.04

pounds per hour was 10.56 percent as a result of pre-crushing the corn.

The electrical energy used by the three horsepower hammer mill was also an important factor in determining the performance of the mill. A good comparison of the electrical energy used when grinding whole ear corn as compared to grinding crushed ear corn can be deduced from the data in Table 5. The electrical energy used in kilowatt hours per 1,000 pounds of corn ground, like the capacity in pounds per horsepower hour, does not depend upon the rate of feed. The electrical energy used by the three horsepower hammer mill was decreased 0.35 kilowatt hours per 1,000 hours or 15 percent when grinding with a 3/4 inch screen, and 0.84 kilowatt hours per 1,000 pounds or 24 percent when grinding with a 1/2 inch screen by precrushing the corn. When grinding with a 3/8 inch screen, the electrical energy used was decreased 0.66 kilowatt hours per 1,000 pounds or 20.5 percent when grinding with a 1/4 inch screen due to pre-crushing the corn. The preceding discussion shows that crushing ear corn preparatory to grinding with the three horsepower hammer mill results in an average decrease in electrical energy used of 19.25 percent.

A graphical representation of the data given in Table 5 is shown in

Figs. 1, 2 and 3. Figure 1 shows the capacities in pounds per hour when grinding whole ear corn and crushed ear corn with the three horsepower hammer mill. Figure 2 shows the capacities in pounds per horsepower hour when grinding whole ear corn and crushed ear corn. These charts show the increased capacity as a result of crushing the ear corn preparatory to grinding, and they also show the effect of fineness of grinding upon the capacity of the three horsepower hammer mill. For instance, in changing from a 3/4 inch screen to a 1/2 inch screen, the capacity is reduced 222.45 pounds per hour. This indicates that the corn should always be ground as coarsely as possible and still be suitable for livestock consumption. Figure 3 shows the electrical energy used in kilowatt hours per 1,000 pounds of corn ground when grinding whole ear corn and crushed ear corn with the three horsepower hammer mill. This chart also shows the effect of fineness of grinding upon the electrical energy used by the hammer mill. In changing from a 3/4 inch screen to a 1/2 inch screen, the electrical energy used was increased about one kilowatt hour per 1,000 pounds of corn ground.

Figure 4 is a recording wattmeter diagram for the three horsepower hammer mill when grinding whole ear corn with a 3/4 inch screen. Figure 5 is a similar diagram when grinding crushed ear corn with a 3/4 inch screen. These diagrams show graphically the demand of the mill in kilowatts at any time during its operation. The fluctuations in this kilowatt demand and the number and magnitude of the peak demands are shown very vividly in these diagrams. A comparison of Fig. 4 and 5 shows the reduction in the number and magnitude of these peak demands when grinding crushed ear corn as compared to grinding whole ear corn. Crushing the

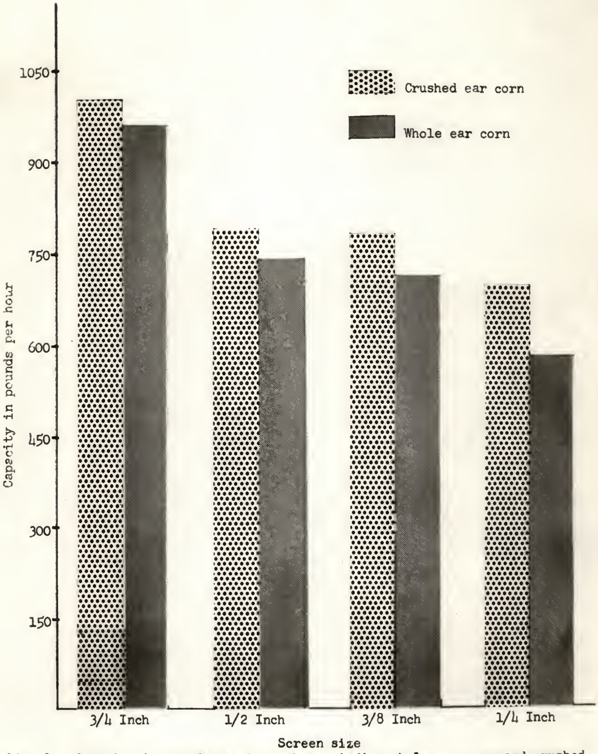


Fig. 1. Capacity in pounds per hour when grinding whole ear corn and crushed ear corn with the three horsepower hammer mill.

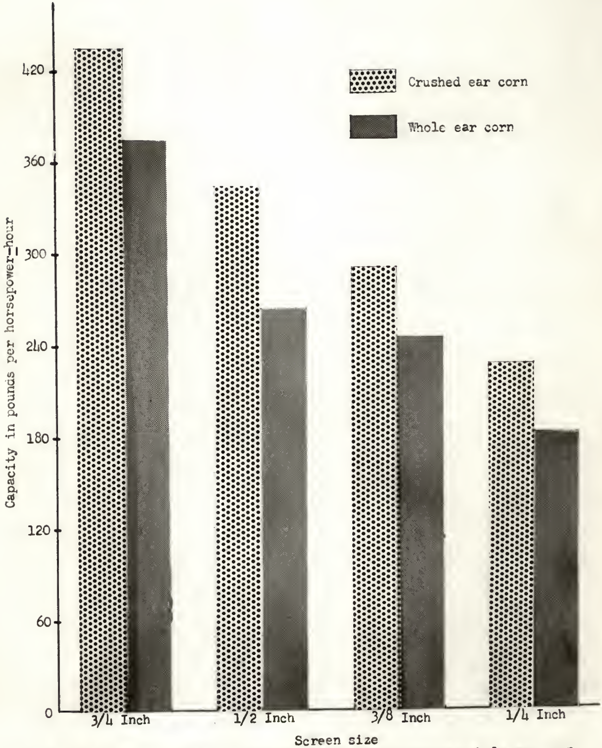


Fig. 2. Capacity in pounds per horsepower hour when grinding whole ear corn and crushed ear corn with the three horsepower hammer mill.

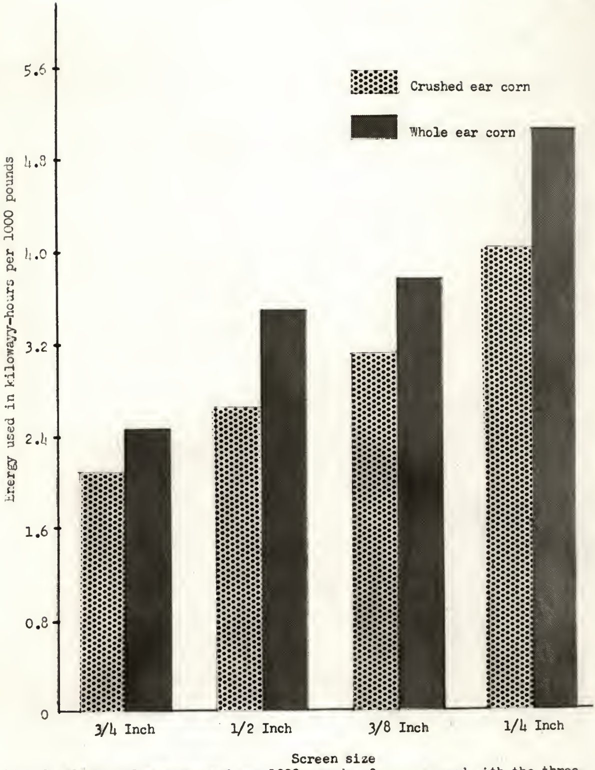


Fig. 3. Electrical energy used per 1000 pounds of corn ground with the three horsepower hammer mill.

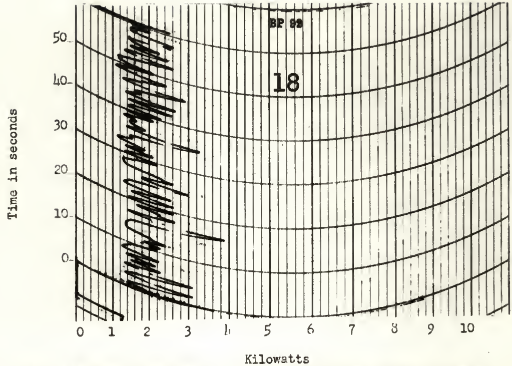


Fig. 4 Wattmeter diagram on the three horsepower hammer mill when grinding whole ear corn with a 3/4 inch screen.

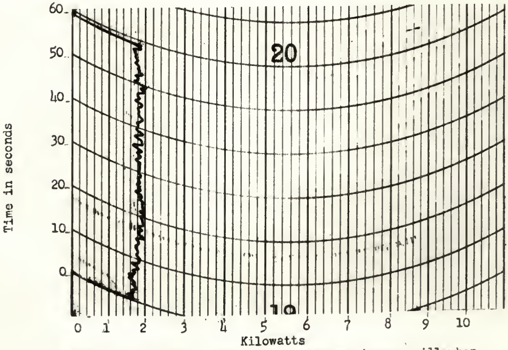


Fig. 5. Wattmeter diagram on the three horsepower hammer mill when grinding crushed ear corn with a 3/4 inch screen.

corn preparatory to grinding results in a much smoother load. The number and magnitude of the peak demands in Fig. 4 are indicative of the shock loading on the mill when grinding whole ear corn. This shock loading is greatly reduced by crushing the ear corn preparatory to grinding, and the life of the hammer mill is increased.

Five Horsepower Hammer Mill. The five horsepower hammer mill was tested when grinding whole ear corn and crushed ear corn. The corn was from the 1949 crop and was without husk, and the moisture content was 13.74 percent. This mill was fed by hand and an approximately uniform rate of feed was maintained by the use of the recording wattmeter as explained under experimental procedure.

The screens used in the tests on this mill were as follows: 3/4 inch, 3/8 inch, and 3/16 inch. The fineness modulus of the corn ground with these screens was 3.38 with the 3/4 inch screen, 2.93 with the 3/8 inch screen, and 2.67 with the 3/16 inch screen.

Table 6 shows the capacities in pounds per hour, capacities in pounds per horsepower hour and the electrical energy used in kilowatt hours per 1,000 pounds of corn ground. These data have been condensed from the original test data to facilitate a comparison of the performance of the five horsepower hammer mill when grinding whole ear corn and crushed ear corn. A summary of the data given in Table 6 will indicate some of the advantages of crushing ear corn preparatory to grinding with the five horsepower hammer mill.

The capacity of the five horsepower hammer mill when grinding with a 3/4 inch screen was increased 21 pounds per horsepower hour or 10.2 percent by pre-crushing the corn. When grinding with a 3/8 inch screen, the capacity was increased 20.70 pounds per horsepower hour or 21.7 percent. The corresponding increase when grinding with a 3/16 inch screen was 5.16 pounds per horsepower hour or 11.1 percent. The capacity of the five horsepower hammer mill in pounds per horsepower hour was increased an average of 14.33 percent as a result of crushing the ear corn preparatory to grinding. This increase represents an increase in the efficiency of the hammer mill, since more corn was being ground per horsepower hour.

The increased capacity in pounds per hour also shows that it was advantageous to crush ear corn before grinding with the five horsepower hammer mill. The capacity was increased 262 pounds per hour or 24.1 percent when grinding with a 3/4 inch screen. When grinding with a 3/8 screen, the capacity was increased 154.61 pounds per hour or 29.8 percent. Pre-crushing the corn increased the capacity 24.3 pounds per hour or 8.5 percent when grinding with a 3/16 inch screen. The average increase of capacity in pounds per hour was 20.8 percent as a result of crushing the ear corn preparatory to grinding with the five horsepower hammer mill.

The electrical energy used, when grinding with the five horsepower hammer mill, was decreased by pre-crushing the corn preparatory to grinding. This factor was important from the standpoint of cost of grinding ear corn. The decrease in electrical energy used when grinding with a 3/4 inch screen was 0.50 kilowatt hours per 1,000 pounds of corn ground or 11 percent. When grinding with a 3/8 inch screen, the electrical energy used was decreased 1.85 kilowatt hours per 1,000 pounds of corn ground or 19.05 percent. The decrease in electrical energy used was 1.76 kilowatt hours per 1,000 pounds of corn ground or 9.05 percent when grinding with a 3/16 inch screen. The average decrease in electrical

Table 6. Capacity and electrical energy consumption data on the five horsepower hammer mill.

Capacity	3/4" screen		3/8" screen		3/16" screen	
	Whole ear corn	Crushed ear corn	Whole ear corn	Crushed ear corn	Whole ear corn	Crushed ear corn
lbs/hr.	1088.15	1350.15	537.19	691.80	287.10	311.40
lbs/ hp. hr.	205.50	226.50	95.27	115.97	46.52	51.68
Energy used = Kwhrs/1000 lbs.	4.55	4.05	9.72	7.87	19.47	17.71

energy used per 1,000 pounds of corn ground was 13.03 percent as a result of crushing the ear corn preparatory to grinding with the five horsepower hammer mill.

A graphical representation of the data given in Table 6 is shown in Figs. 6, 7, and 8. Figure 6 shows the capacities in pounds per hour when grinding whole ear corn and crushed ear corn with the five horsepower hammer mill. Figure 7 shows the capacities in pounds per horsepower hour when grinding whole ear corn and crushed ear corn with the five horsepower hammer mill. These charts show the increased capacity when grinding crushed ear corn as compared to grinding whole ear corn. They also show the effect of fineness of grinding upon the capacity of the five horsepower hammer mill. For instance, in changing from a 3/4 inch screen to a 3/8 inch screen the capacity is decreased 550.96 pounds per hour. This indicates that the corn should be ground as coarse as possible and still be suitable for livestock consumption. Figure 8 shows the electrical energy used in kilowatt hours per 1,000 pounds by the five horsepower hammer mill when grinding whole ear corn and crushed ear corn. This chart shows the decrease in electrical energy used when

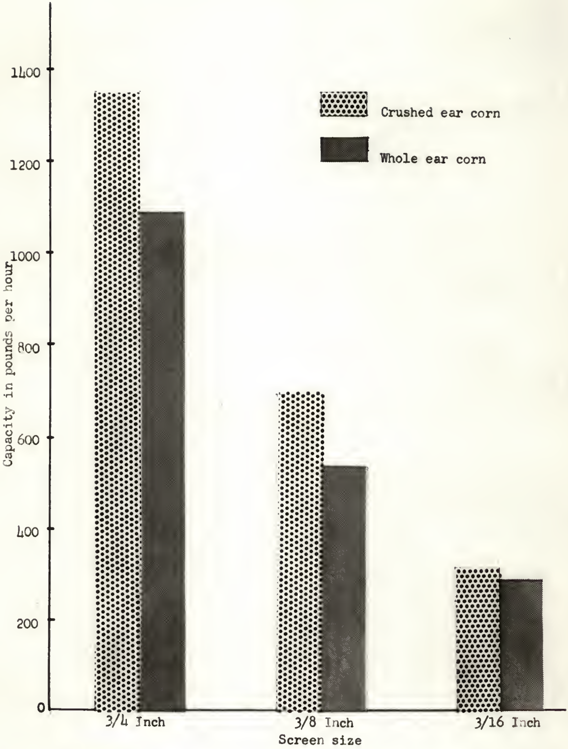


Fig. 6. Capacity in pounds per hour when grinding whole ear corn and crushed ear corn with the five horsepower hammer mill.

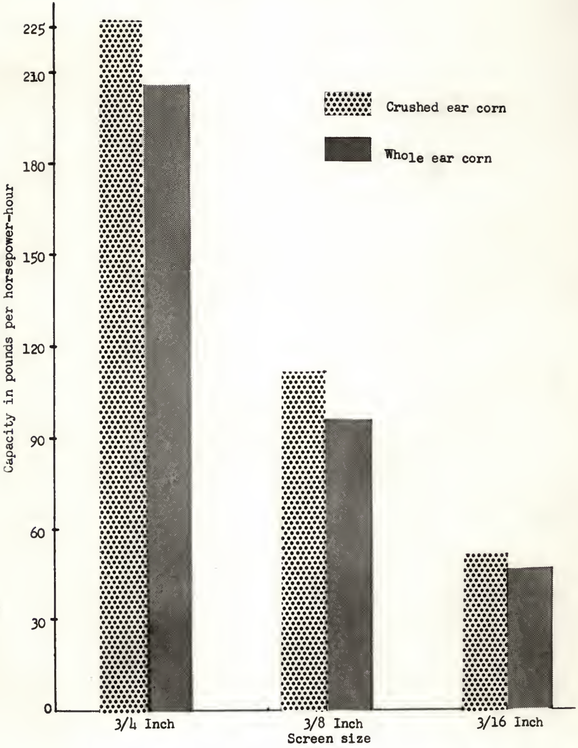


Fig. 7. Capacity in pounds per horsepower-hour when grinding whole ear corn and crushed ear corn with the five horsepower hammer mill.

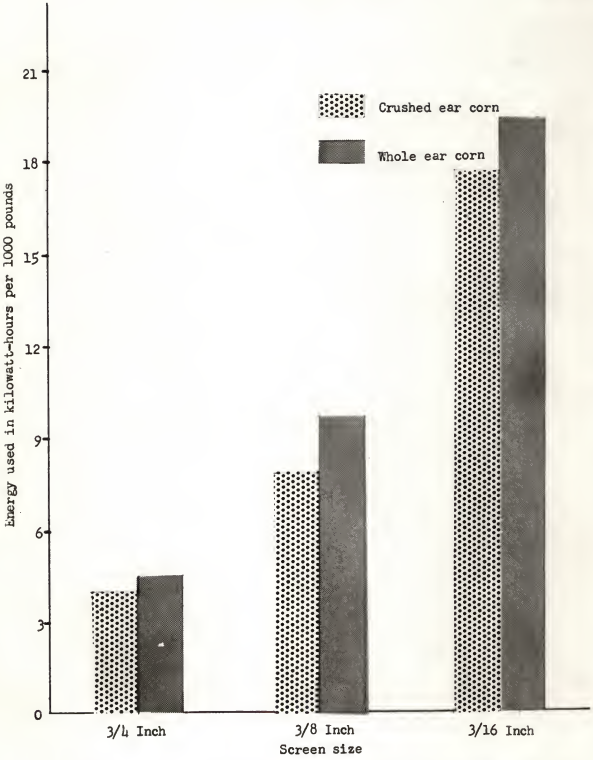


Fig. 8. Energy used in kilowatt-hours per 1000 pounds of corn ground with the five horsepower hammer mill.

grinding crushed ear corn as compared to grinding whole ear corn. This chart also shows the effect of fineness of grinding upon the electrical energy used by the five horsepower hammer mill. The electrical energy used was increased 5.17 kilowatt hours per 1,000 pounds of corn ground in changing changing from a 3/4 inch screen to a 3/8 inch screen.

Figure 9 shows a recording wattmeter diagram for the five horsepower hammer mill when grinding whole ear corn with a 3/4 inch screen. Figure 10 shows a similar diagram when grinding crushed ear corn with a 3/4 inch screen. These diagrams have the same meaning as the similar diagrams for the three horsepower hammer mill, and a full description was given under results of tests on the three horsepower hammer mill.

The preceding discussions on the three horsepower hammer mill and the five horsepower hammer mill show very definitely that it is advantageous to crush ear corn before grinding. The increased capacity in pounds per horsepower hour means that the grinders operated at a higher efficiency when grinding crushed ear corn than when grinding whole ear corn. This fact is supported by the decrease in electrical energy used, which also indicates a higher efficiency of grinding.

One Horsepower Hammer Mill. The one horsepower hammer mill was tested only when grinding ear corn that had previously been crushed, since it was too small to grind whole ear corn. The corn was clean and without husk, and the moisture content was 15.80 percent on a dry basis. This mill was fed by hand and an approximately uniform rate of feed was maintained by the use of the recording wattmeter as explained under experimental procedure. Although the one horsepower hammer mill was equipped with an automatic feeding device for feeding small grains to

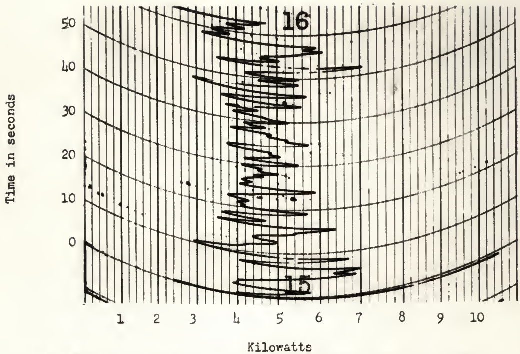


Fig. 9 Wattmeter diagram on the five horsepower hammer mill when grinding whole ear corn with a 3/4 inch screen.

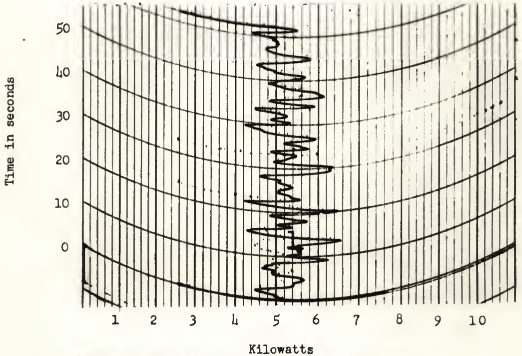


Fig. 10. Wattmeter diagram on the five horsepower hammer mill when grinding crushed ear corn with a 3/4 inch screen.

the mill at a uniform rate, this automatic feeding device was not used with crushed ear corn because the pieces of cob would jam the feed roll.

The following screens were used in the tests on the one horsepower hammer mill: 1/2 inch, 3/8 inch, 1/4 inch, and 3/16 inch. The fineness modulus of the corn ground with these screens was 4.23 with the 1/2 inch screen, 3.99 with the 3/8 inch screen, 3.31 with the 1/4 inch screen, and 2.91 with the 3/16 inch screen.

Table 7 shows the capacities in pounds per hour and pounds per horsepower hour and the electrical energy used in kilowatt hours per 1,000 pounds of corn ground. These data were condensed from the original test data on the one horsepower hammer mill. The capacity in pounds per horsepower hour of the one horsepower hammer mill is higher than either of the other mills tested. The electrical energy used in kilowatt hours per 1,000 pounds of corn ground is less than either of the other mills tested. This is to be expected since the one horsepower hammer mill was not equipped with a blower for elevating the ground feed.

Figure 11 shows the relationship between the fineness of grinding, capacity, and electrical energy consumption of the one horsepower hammer mill when grinding crushed ear corn. These curves show how rapidly the capacity decreases when the fineness modulus is decreased. On the other hand, the electrical energy consumption increases quite rapidly as the fineness modulus is decreased. The fineness modulus to which the corn is ground is the controlling factor in determining the capacity and electrical energy consumption of the one horsepower hammer mill.

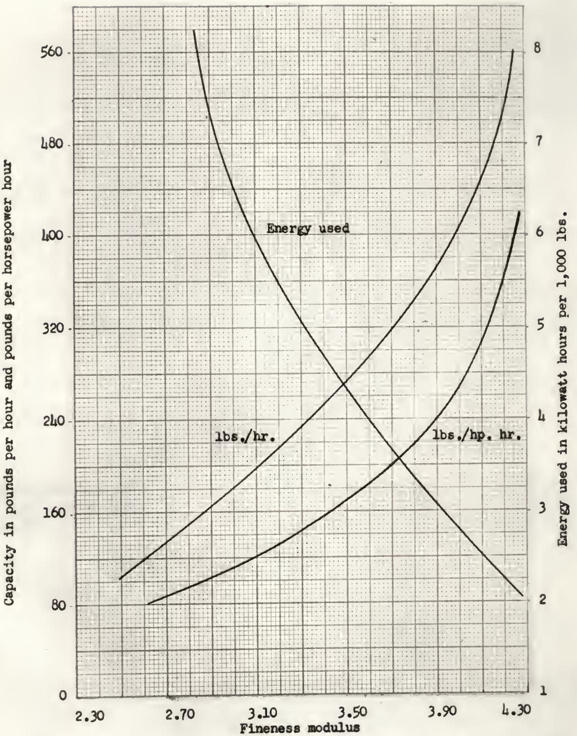


Fig. 11. The relationship between fineness modulus, capacity and electrical energy used by the one horsepower hammer mill when grinding crushed ear corn.

Table 7. The capacity and energy consumption of the one horsepower hammer mill grinding crushed ear corn.

Screen size	Capacity lbs/hr.	Capacity lbs/hp./hr.	Energy used Kwhr/1,000 lbs.
1/2"	538.95	367.50	2.16
3/8"	370.50	243.75	3.06
1/4"	249.00	159.55	4.70
3/16"	166.65	103.80	7.22

Tests of Crusher

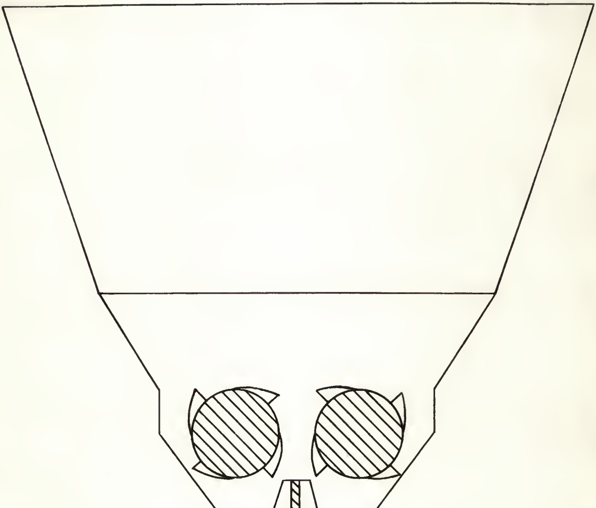
The crusher used in these tests was obtained on loan from the Viking Manufacturing Company. This crusher was not designed, specifically, for ear corn, but preliminary tests indicated that it had possibilities. It will be referred to as the roller crusher.

Equipment. Crusher. Plate III shows a schematic cross section view of the roller crusher to give an idea of its construction. The housing of the crusher was made of cast iron and was cast in two pieces. The rollers were made of solid cast iron with projections around the circumference to force the corn through the rollers. The rollers were connected by spur gears, and the driver roller turned 1 1/2 times as fast as the driven roller. This difference in speed of the rollers tends to give a more uniform rate of feed through the rollers. The bearings on the roller shafts were brass full journal bearings. These bearings are adequate because of the low speed at which the crusher runs. There is a breaker bar located beneath the rollers and the corn is forced against this bar by the rollers and crushed.

EXPLANATION OF PLATE III

A schematic cross section of the roller crusher.

PLATE III



Power Unit. A three horsepower, three phase motor was used to drive the crusher. This motor was found to be more than adequate to drive the crusher since the maximum horsepower required in these tests was .55 horsepower. This motor was used because curves were available to determine the horsepower output of the motor.

Measuring Devices. The measuring devices used on the tests of the roller crusher were the same as used on tests of the hammer mills.

Experimental Procedure. The tests of the roller crusher were run to determine the variation in capacity, electrical energy used, and the horsepower required at different speeds of the crusher. The capacity, electrical energy used, and the horsepower required were determined by the same method as previously explained under experimental procedure for the hammer mills. The speed of the crusher was measured at no load and on the faster of the two rollers which was used as the drive roller. A worm gear speed reducer in combination with different pulley sizes on the motor was used to vary the speed of the crusher.

Results. The corn as it was discharged from the crusher was in very good condition for grinding with the small feed grinder. The corn was all shelled off the cob and the cob was crushed into pieces, the largest of which was approximately one inch in length. The corn used in the tests on the roller crusher was without husk. If it is desired to crush corn with husk on it, the breaker bar will have to be removed from the crusher.

Tests were made on the roller crusher at the following speeds: 24 R.P.M., 52 R.P.M., 65 R.P.M., and 112 R.P.M. The results of the tests made on the roller crusher are shown in Table 8. The data in Table 8 show that the horsepower required and the capacity increase as the speed is increased. The electrical energy used by the crusher was decreased by increasing the speed. The capacity in pounds per hour varies from 387.7 at 24 R.P.M. to 1,782 at 112 R.P.M. The capacity in pounds per horsepower hour varies from 1,821.5 at 24 R.P.M. to 3,280 at 112 R.P.M. The electrical energy used in kilowatt hours per 1,000 pounds of corn crushed varies from 0.817 at 24 R.P.M. to 0.317 at 112 R.P.M.

Figure 12 shows the relationship between speed, horsepower required, and capacity in pounds per hour of the roller crusher. The speed plotted against horsepower required is a straight line showing the increased horsepower required when the speed is increased. The slope of the line when the speed is plotted against the capacity in pounds per hour shows the corresponding increase in capacity of the crusher with increased speed. Figure 13 shows the relationship between speed, capacity in pounds per horsepower hour and electrical energy used per 1,000 pounds of corn crushed. When the speed is plotted against the capacity in pounds per horsepower hour, the increase in capacity is shown to be very rapid up to about 80 R.P.M., when it begins to level off slowly. When the speed is plotted against the electrical energy used in kilowatt hours per 1,000 pounds, there is a sharp decrease in electrical energy used up to about 50 R.P.M. and then the decrease becomes more gradual. These curves indicate that the crusher is more efficient when operating at speeds above 50 R.P.M.

The tests of the roller crusher indicate that it can be operated with a 1/2 horsepower motor at speeds below 100 R.P.M. The capacity in pounds per hour at speeds below 100 R.P.M. is sufficient to crush ear corn for the one to five horsepower hammer mill.

Table 8. The capacity and electrical energy consumption of the roller crusher crushing ear corn.

Speed, R.P.M.	Horsepower	Capacity lbs/hr.	Capacity lbs/hp. hr.	Energy used kwhrs./1,000 lbs.
24	0.21	378.7	1,821.5	0.817
52	0.35	892.5	2,590.0	0.450
65	0.41	1,121.8	2,772.5	0.393
112	0.55	1,782.0	3,280.0	0.317

TEST OF COMBINED CRUSHER AND HAMMER MILL

The results of tests on the roller crusher indicated that it could possibly be used as mechanical feed for ear corn. It was decided to use the crusher in combination with the three horsepower hammer mill and drive both the hammer mill and crusher with a three horsepower motor. Preliminary tests indicated that the three horsepower hammer mill would be better adapted to an automatic feed than either of the other hammer mills tested.

Equipment

Hammer Mill and Crusher. The main problem in combining the three horsepower hammer mill and the roller crusher was reducing the speed of the crusher. The crusher had to be driven slowly enough so that the capacity of the crusher would be the same as the capacity of the hammer mill. This was accomplished by placing a jack shaft on the crusher, thereby giving a stepped speed reduction. The jack shaft was driven from the motor by a V-belt drive, and the crusher rolls were driven from the jack shaft by a detachable chain and sprockets. The speed

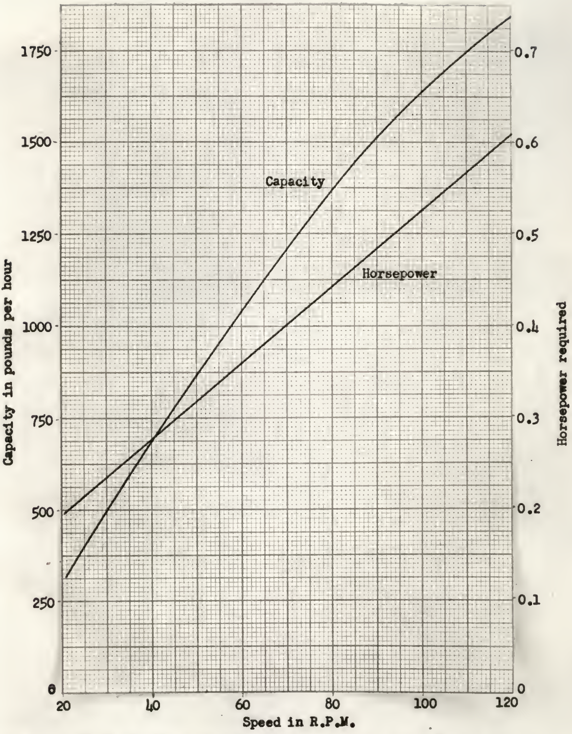


Fig. 12. The relationship between speed, capacity in pounds per hour, and horsepower required by the roller crusher.

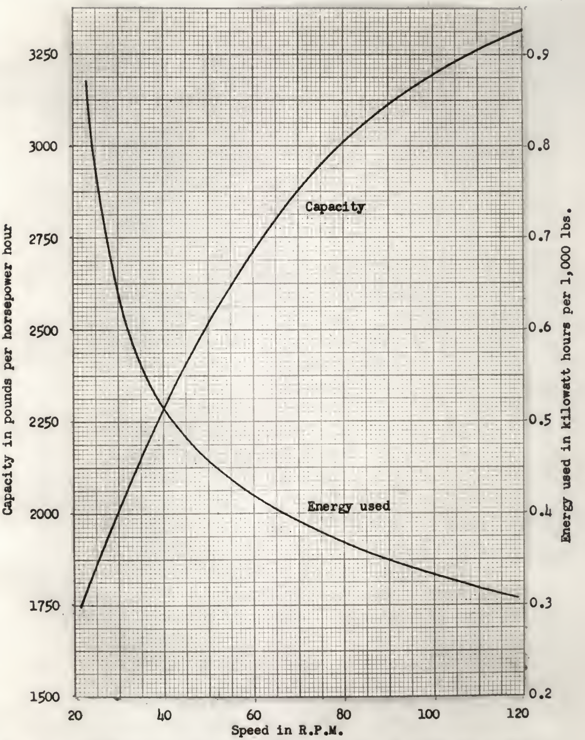


Fig. 13. The relationship between speed, capacity in pounds per horsepower hour, and the electrical energy used by the roller crusher.

ratio of the jack shaft to the crusher rolls was ten to one. A fifteen inch diameter V-pulley was mounted on the jack shaft, and the speed ratio of the jack shaft to the motor depended upon the size pulley that was used on the motor. The speed of the crusher was varied by changing the pulley size on the motor.

A chain drive was used from the jack shaft to the crusher to insure a positive drive of the crusher. The speed of the crusher was too slow to permit using a V-belt drive. The speed at which the crusher was driven in combination with the hammer mill was determined by using Fig. 12 and Table 5. The capacity of the hammer mill was taken from Table 5 and then by using Fig. 12 a speed of the crusher was chosen to give this capacity. Then by knowing the speed ratio between the motor and the crusher, a pulley size was chosen for the motor to give the necessary speed of the crusher.

Power Unit. A three horsepower three phase motor was used to drive the hammer mill and crusher combination. This motor furnished plenty of power to drive both machines. The average horsepower required when grinding with a 3/4 inch screen in the hammer mill was 2.65 horsepower.

Measuring Devices. The same measuring devices were used during tests of the hammer mill and crusher combination as were used during the tests of the hammer mills.

Experimental Procedure. The same experimental procedure was followed as when testing the hammer mills, the only exception being that the hammer mill was fed by the crusher instead of being fed by hand. The methods of determining the capacity and electrical energy used were the same as described under experimental procedure for tests of the hammer mills.

Results. The crusher and hammer mill combination was tested when grinding ear corn without husks. The moisture content of the corn was 16.55 percent on a dry basis. The following screen sizes were used in the hammer mill: 3/4 inch, 1/2 inch, and 3/8 inch. The speed at which the crusher was run for each screen size was determined from Table 5 and Fig. 12.

The results of tests of the hammer mill and crusher combination are shown in Table 9. These data were condensed from the original test data. The maximum horsepower required to drive the hammer mill and crusher combination was 2.83 horsepower. A three horsepower motor gives sufficient power to crush and grind ear corn with the hammer mill and crusher combination.

Figure 14 shows a recording wattmeter diagram for the hammer mill and crusher combination. This diagram shows the demand of the hammer mill and crusher in kilowatts at any time during its operation. The fluctuation in this kilowatt demand, and the number and magnitude of the peak demands are shown in this diagram. It is desirable in the operation of the feed grinder to keep these fluctuations and peak demands to a minimum. This diagram was made when grinding with a 3/4 inch screen in the hammer mill and shows that the load is comparatively smooth.

COMPARISON OF AUTOMATIC FEED TO HAND FEED

A comparison of the capacity and electrical energy used by the three horsepower hammer mill when using the crusher as an automatic feed and when the mill was fed by hand will show some of the advantages of automatic operation. The performance of the mill while being fed whole ear

Table 9. The capacity and electrical energy consumption of the crusher and hammer mill combination when grinding ear corn.

Speed of mill, R.P.M.	Speed of crusher R.P.M.	Capacity lbs/hr	Capacity lbs/hp. hr	Energy used Kwhr/1000 lbs	Screen size used
3,500	65	1,104.4	417.0	2.20	3/4"
3,500	47	800.7	315.6	2.89	1/2"
3,500	47	775.9	284.9	3.24	3/8"

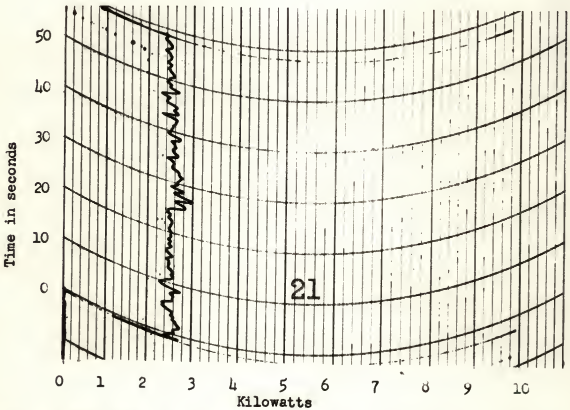


Fig. 14. Watt meter diagram on the crusher and hammer mill combination when grinding with a 3/4 inch screen.

corn by hand will be compared to the performance of the mill while being fed by the roller crusher. These data which were taken from Tables 5 and 9 are tabulated in Table 10 to facilitate the comparison.

The capacity of the three horsepower hammer mill when grinding with a 3/4 inch screen was increased 43.75 pounds per horsepower hour or 11.72 percent when using the crusher as an automatic feed instead of feeding the mill by hand. When grinding with a 1/2 inch screen, the capacity was increased 51.9 pounds per horsepower hour or 19.68 percent when using the automatic feed instead of feeding the mill by hand. The corresponding increase when grinding with a 3/8 inch screen was 41.2 pounds per horsepower hour or 16.9 percent. Figure 15 is a bar chart showing graphically the capacity in pounds per horsepower hour of the three horsepower hammer mill when hand fed compared to using the crusher as an automatic feed. An average increased capacity in pounds per horsepower hour of 16.1 percent shows that the efficiency of the three horsepower hammer mill is increased by using the crusher to feed the ear corn to the mill. This increased capacity is due to the ear corn being crushed and then fed at a uniform rate to the hammer mill.

The capacity in pounds per hour was also increased by using the crusher as an automatic feed instead of feeding the three horsepower hammer mill by hand.

When grinding with a 3/4 inch screen, the capacity was increased 146.05 pounds per hour or 15.25 percent. The capacity when grinding with a 1/2 inch screen was increased 64.8 pounds per hour or 8.8 percent by using the crusher as an automatic feed instead of feeding the mill by hand. The corresponding increase where grinding with a 3/8 inch screen

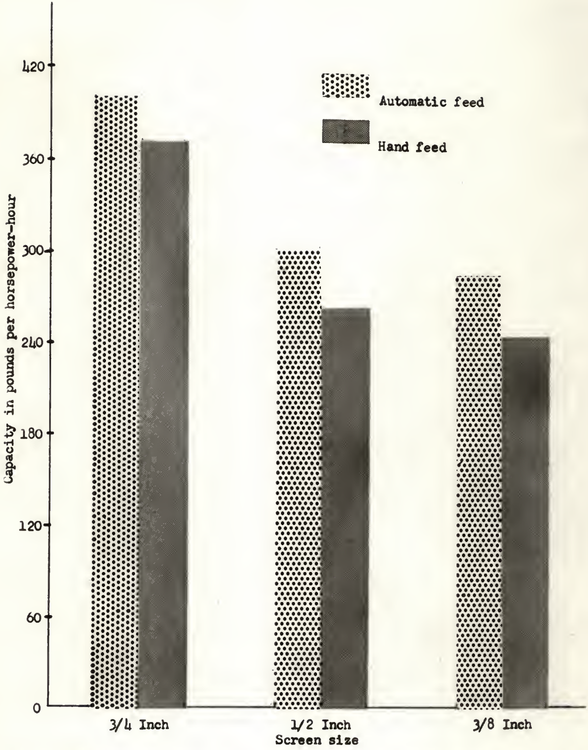


Fig. 15. Capacity in pounds per horsepower-hour when grinding ear corn with the three horsepower hammer mill using hand feed and automatic feed.

Table 10. Capacity and electrical energy consumption of the three horsepower hammer mill with hand feed and automatic feed.

Capacity	3/4" screen		1/2" screen		3/8" screen	
	Hand feed	Auto feed	Hand feed	Auto feed	Hand feed	Auto feed
Lbs/hr.	958.35	1,104.4	735.9	800.7	710.9	775.9
Lbs/hp. hr.	373.25	417.0	263.7	315.6	243.7	284.9
Energy used = kwhr/1000#	2.46	2.2	3.49	2.89	3.77	3.24

was 65 pounds per hour or 9.15 percent. Figure 16 shows graphically the comparison of automatic feeding to hand feeding as it affects the capacity in pounds per hour of the three horsepower hammer mill. The average increase of capacity in pounds per hour was 11.06 percent.

The electrical energy used by the three horsepower hammer mill was also affected by using the crusher as an automatic feed compared to feeding the mill by hand. When grinding with a 3/4 inch screen the electrical energy used was decreased 0.26 kilowatt hours per 1,000 pounds of corn ground or 11.8 percent. The electrical energy used when grinding with a 1/2 inch screen was decreased 0.60 kilowatt hours per 1,000 pounds or 20.8 percent by using the crusher as an automatic feed instead of feeding the mill by hand. The corresponding decrease when grinding with a 3/8 inch screen was 0.53 kilowatt hours per 1,000 pounds or 16.35 percent. Figure 17 shows graphically the comparison of automatic feeding to hand feeding as it affects the electrical energy used by the three horsepower hammer mill. The average decrease of electrical energy used in kilowatt hours per 1,000 pounds of corn ground was 16.32 percent.

The preceding discussion shows some of the advantages of a uniform rate of feed over the method of hand feeding the three horsepower hammer

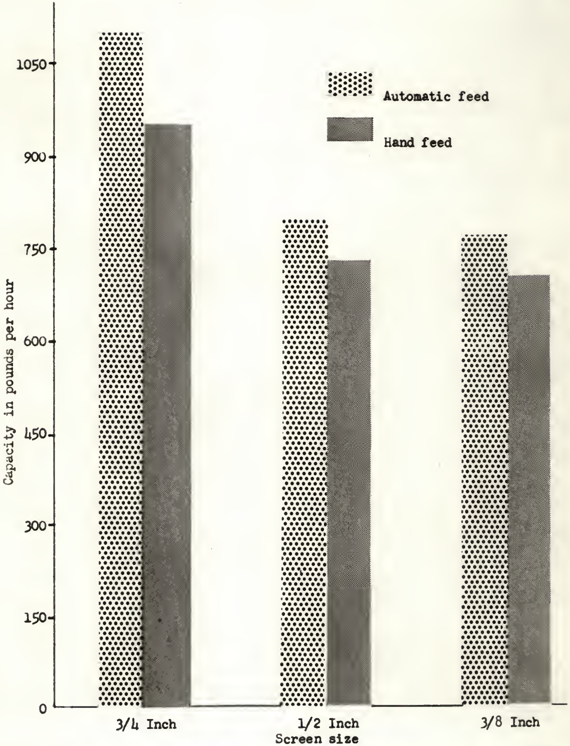


Fig. 16. Capacity in pounds per hour when grinding ear corn with the three horsepower hammer mill using hand feed and automatic feed.

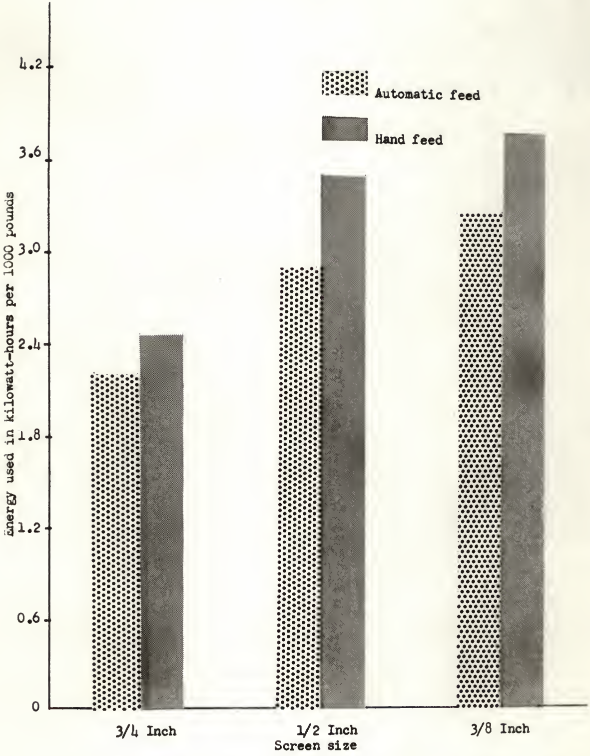


Fig. 17. Electrical energy used per 1000 pounds of corn ground with the three horsepower hammer mill using hand feed and automatic feed.

mill. It further shows that it is advantageous to crush ear corn preparatory to grinding with the small feed grinder.

APPROXIMATE COST OF GRINDING EAR CORN

The cost of grinding ear corn with the electric motor driven feed grinder can be divided into three categories; namely, cost of electrical energy, labor costs, and overhead costs. The overhead costs include depreciation, interest on investment, and repairs. The factors controlling the cost of grinding are so variable that it is impossible to give the exact figures. However, some assumptions can be made that will give the approximate cost of grinding ear corn with the small electric motor driven feed grinder.

Approximate Cost of Electrical Energy

Table 11 was prepared to show the approximate cost of electrical energy when grinding ear corn with the five horsepower hammer mill being hand fed, with the three horsepower hammer mill being hand fed, and with the three horsepower hammer mill using the crusher as an automatic feed. This table shows the cost in cents for electrical energy to grind 1,000 pounds of ear corn, with the price of electricity ranging from 1 1/2 to 4 cents per kilowatt hour. The three horsepower hammer mill is shown to be more efficient than the five horsepower hammer mill from the standpoint of electrical energy used per 1,000 pounds of corn ground.

Table 11. Approximate cost of electrical energy for grinding ear corn.

Mill	Screen size and fineness modulus	Cost in cents to grind 1,000 pounds			
		Price of electricity in cents /kwhr.			
		1 1/2	2	3	4
Hammer mill with five horsepower motor-hand feed	3.38 - 3/4"	6.82	9.10	13.65	18.20
	2.93 - 3/8"	14.58	19.44	28.16	38.88
	2.67 - 3/16"	29.20	38.94	58.41	77.88
Hammer mill with three horsepower motor-hand feed	4.08 - 3/4"	3.69	4.92	7.38	9.84
	3.33 - 1/2"	5.23	6.98	10.47	13.96
	3.15 - 3/8"	5.58	7.45	11.31	15.08
	3.00 - 1/4"	7.63	10.16	15.24	20.32
Hammer mill and crusher with three horsepower motor-auto feed	4.08 - 3/4	3.30	4.40	6.60	8.80
	3.33 - 1/2"	4.33	5.78	8.68	11.55
	3.15 - 3/8"	4.86	6.48	9.72	12.95

Approximate Total Cost

The total cost will include the cost of electrical energy, already discussed, labor cost and the overhead or fixed costs.

The cost of labor to grind ear corn with the small feed grinder will be figured for one man only. Usually one man is sufficient to operate the three or five horsepower hammer mill when grinding ear corn. An hourly wage of 75 cents was assumed, but this may vary in different localities.

The overhead or fixed costs including depreciation, interest on the investment, and repairs were considered to be constant. Depreciation depends upon the life of the machine. The life of feed grinders was estimated to be 17.6 years, giving an annual depreciation of 5.68 percent. The life of the electric motors was estimated to be 20 years, giving an annual depreciation of 5 percent. The interest on the investment was figured at 6 percent on one-half of the original cost of the machine. The annual repair expense was estimated to be 2 percent, including such items as new screens, and the repair of damage due to breakage.

The cost of electrical energy was taken as 9.10 cents per 1,000 pounds of whole ear corn ground with the five horsepower hammer mill when grinding with a 3/4 inch screen and being fed by hand. The cost of electrical energy was taken as 4.92 cents per 1,000 pounds of whole ear corn ground with the three horsepower hammer mill when grinding with a 3/4 inch screen and being fed by hand. The cost of electrical energy was taken as 4.40 cents per 1,000 pounds of whole ear corn ground with the three horsepower hammer mill when grinding with a 3/4 inch screen and using the crusher as an automatic feed. Table 12 shows the approximate total cost of grinding ear corn with the small electric motor driven feed grinder.

The total annual fixed charges will remain the same regardless of the amount of ear corn ground per year. The quantity of corn ground per year will, however, affect the total cost per 1,000 pounds of corn ground, including the fixed charges. Table 13 was prepared to show the effect of the quantity of corn ground yearly upon the total cost per 1,000 pounds of corn ground. This table also shows a comparison of the cost of operating the three horsepower hammer mill while being hand fed and while using the

Table 12. Approximate cost of grinding ear corn with the electric motor driven feed grinder.

	Hammer mill with five horse-power motor - hand feed	Hammer mill with three horse-power motor - hand feed	Hammer mill with three horse-power motor - automatic feed
Grinder cost	$171.05	$100.98	$100.98
Motor cost	212.06	97.00	97.00
Crusher cost	-	-	50.00
Total cost	$383.11	$197.98	$247.98
Fixed charges			
Depreciation			
Mill 5.68%	9.95	5.74	8.58
Motor 5%	10.40	4.85	4.85
Interest	10.60	5.94	7.45
Repairs	7.06	3.96	4.95
Total fixed charges (annual)	$ 38.01	$ 20.49	$ 25.83
Operating costs Cents per 1000 lbs. corn ground with 3/4" screen	9.10¢	4.92¢	4.40¢
Labor costs Cents per 1000 lbs corn ground with 3/4" screen	69.00¢	78.40¢	0.00¢

crusher as an automatic feed. When grinding over 80 bushels per year, the cost per 1,000 pounds of corn ground is less for automatic feeding than for hand feeding. Using the crusher as an automatic feed is not only more convenient but cheaper for large amounts. When grinding less than 80 bushels of ear corn per year, however, the installation of the crusher is not practical from the cost standpoint.

Table 13. Effect of the quantity of corn ground yearly upon the total cost per 1,000 pounds of corn ground, including labor.

Bushels ground yearly	Cost of grinding in dollars per 1,000 pounds: Hammer mill with five horsepower motor - hand feed	Hammer mill with three horsepower motor - hand feed	Hammer mill with three horsepower motor - automatic feed
50	-	$6.68	$7.42
80	$7.58	4.49	4.66
100	6.22	3.76	3.74
200	3.57	2.29	1.89
400	2.14	1.56	0.97
600	1.68	1.31	0.66
800	1.46	1.20	0.51
1,000	1.33	1.12	0.41

INSTALLATION OF HAMMER MILL AND CRUSHER ON FARM

Upon completion of the laboratory tests on the hammer mill and crusher combination, arrangements were made with a farmer near Barnes, Kansas to install and test the hammer mill and crusher combination under actual farm conditions. The corn ground on the farm was from the 1949 crop and about 50 percent of the corn had husk on it.

At the request of the farmer, a Viking automatic feed for small grains was adapted to the crusher to enable the farmer to grind small grains as well as ear corn. A metal hopper was constructed to fit above the crusher and a 5 inch square chute was placed in one end of this hopper to carry small grains to the small grain feeding device located beneath this chute. The small grain feeding device was placed on the crusher and driven from one of the crusher rolls. A slide was placed in the metal hopper to shut off the opening to the crusher when grinding small grain. This slide could be removed when grinding ear corn. An overhead bin was constructed above the metal hopper and this bin was used for both ear corn and small grains. Plate IV shows the crusher and hammer mill installation. The overhead bin had a capacity of about 40 bushels of ear corn and was filled by an elevator. This bin was not used for storage.

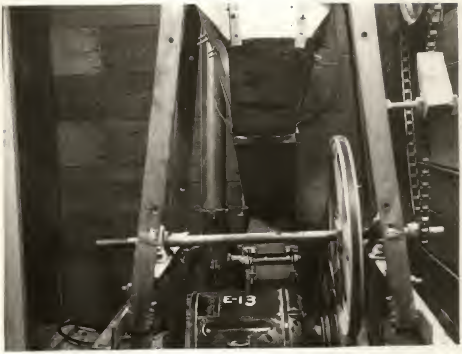
Preliminary tests on this installation showed that the ear corn had a tendency to bridge above the small grain chute in the metal hopper. To remedy this tendency of the corn to bridge, an agitator was placed just above the point where the corn had bridged. The agitator was made of a one inch shaft with four projections placed around its circumference. These projections extended out from the shaft about 6 inches and were slanted downward so that the corn could slide by them. The agitator was driven from one of the crusher rolls and given an oscillatory motion. In succeeding tests this agitator seemed to eliminate any tendency for the corn to bridge.

Automatic operation of the hammer mill and crusher was attained by placing a metal flapper with a mercury switch on one end in the hopper on the crusher. When the hopper was full of corn, the contacts on the mercury switch would close and start the motor. When the hopper was emptied, the contact on the mercury switch would open and stop the motor. The mercury switch could also be used in the small grain chute.

EXPLANATION OF PLATE IV

Close-up of the crusher and hammer mill installation, showing the three horsepower hammer mill, three horsepower motor, and the crusher drive. The jack shaft and chain drive for the crusher are shown in the foreground. The metal trough in the top foreground carries the corn from the crusher to the hammer mill.

PLATE IV



EXPLANATION OF PLATE V

A close-up of metal hopper showing the drive mechanism for the agitator shaft is shown on the left. The arm extending upward is driven by one of the crusher rolls. This arm is connected to the agitator shaft as shown on upper left side of the metal hopper. The agitator is given an oscillatory motion by this drive. The overhead bin is shown above the metal hopper.

PLATE V

SUMMARY

1. The hammer mill equipped with a separate blower was more efficient than the hammer mill with blower and grinding head combined.

2. The capacity and electrical energy used depend upon the fineness of grinding. Coarse grinding increases the capacity and lowers the electrical energy consumption of the feed grinder.

3. Crushing ear corn preparatory to grinding with the small feed grinder increased the capacity and decreased the electrical energy used.

4. The labor cost and time required makes the grinding of ear corn with the one to five horsepower hammer mill impractical when the method of hand feeding is used. The grinding of ear corn is, however, practical when an automatic feed is used.

5. The roller crusher can be adapted to the small hammer mill and used as an automatic feed. The capacity of the three horsepower hammer mill was increased 11.06 percent by using the crusher as an automatic feed instead of feeding the mill by hand.

ACKNOWLEDGMENT

Appreciation is acknowledged to Professor F. C. Fenton, Head, Department of Agricultural Engineering, for his helpful criticism in this investigation. Indebtedness is acknowledged to Mr. Ralph Lipper for his cooperation and suggestions in this investigation.

Indebtedness is also acknowledged to Mr. Earl Moyer, who furnished the corn; to Mr. B. W. Roepke, who allowed a mill to be installed on his farm; and to the machinery companies that loaned the hammer mills.

Acknowledgment is made to the Kansas Committee on the Relation of Electricity to Agriculture for their cooperation in making this investigation possible.

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