AN INVESTIGATION OF THE PERFORMANCE OF MECHANICAL SILO UNLOADERS

by

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INTRODUCTION

Feed and forage handling is a costly, hard job on dairy and livestock farms. In the making of silage many improvements have been made to mechanize the method of getting the ensilage into storage, but the mechanization of removing silage from storage and distributing it to livestock has not advanced as rapidly. Just recently, silo unloading as well as feeding can be made as automatic as the farmer desires. The general availability of electric power on dairy and livestock farms has brought modern silo unloaders into wide use, and the adoption of this type of equipment is spreading rapidly. It has been said that the silo unloader is probably the greatest labor saving device yet to emerge into this modern era of push-button farming.

Silo unloaders remove the hard work in the daily routine of livestock feeding. Along with this the silage, well mixed with no lumps or frozen chunks, is thereby rendered more palatable.

The first silo unloader was manufactured shortly after World War II. Today there are over a dozen manufacturers actively engaged in the production of these machines. One of these machines is manufactured in Kansas. There are nine different makes being sold and installed in Kansas at the present time. Most of them are operating satisfactorily, however a few owners believe the equipment is not doing what they expected. This can be attributed to mechanical difficulties or to insufficient understanding of the limitations of the equipment on the part of the farmer.

The recent installations of many silo unloaders on Kansas farms have stimulated an interest in this equipment throughout the state. Now, many farmers, in search for a means of chore simplification and increased efficiency, are asking for information regarding operating costs and time and labor savings.

PURPOSE

The investigation of mechanical silo unloaders reported in this thesis was initiated to obtain information on the merits of the equipment as it is being operated on Kansas farms.

The phases of this investigation were defined under three main classifications:

1. To gather information on silo unloaders regarding output capacities, power requirements, labor and time saved, and operating costs.

2. To make an analysis of the information gathered and report it in such a form that it may be useful to the layman in determining the merits of this equipment as a means of chore simplification.

3. To determine what effect different characteristics (moisture content, kind, length of cut, etc.) of silage had on output of silo unloaders.

REVIEW OF LITERATURE

The Barn Cleaner, Cattle Feeder and Silo Association (5) in its educational service bulletin states:

> Our future dairy farms must be larger and more mechanized. They will be family operated farms with more production and more capital investment in labor-saving equipment. All feed handling jobs on livestock farms will be made easier through its use of powered equipment.
>
> Next to handling manure, the jobs of putting down and distributing silage are the hard ones on livestock farms. New silo unloaders and mechanical feeders are putting these jobs in the push-button class.

Neitzke (6) reports that the use of the silo unloader is growing day by day because of the time it saves. He stated:

> It used to take ten minutes a day to throw down silage for 24 dairy cows before a silo unloader was installed at the University of Wisconsin's Electric Research Farm. Now it takes ten seconds.

Van Arsdall and Cleaver (11) report that Illinois cattle feeders have saved time spent in feeding by putting in machinery and equipment to do part of the job.

Asmus (2) found in an investigation on Ohio farms that the average size farm with a silo unloader was 250 acres. Farm sizes ranged from 70 to 650 acres. Each of these farms fed the equivalent of 70 head of dairy or beef cattle, with a range of from 20 to 300 head per farm.

The Kansas Inter-Industry Farm Electric Utilization Council (1) reported that in April, 1955 there were 419 silo unloaders in Kansas and that 373 farmers reported the silo unloader to be the next unit of electric farm equipment costing more than $64 that they would purchase.

According to Electricity on the Farm magazine (10) operating costs for mechanically unloading silage are low. Somewhere between five to eight KWH will remove enough feed for a 25-cow herd for a week.

Dobie (3) in discussing various types of mechanized feed bunks comments that these feed bunks can be mechanized further by unloading them with a silo unloader.

Asmus (2) of Ohio State University, regarding rates of unloading, stated:

> For surface unloaders there was a range of from nine to 50 pounds a minute for unloading grass silage and from 28 to 110 pounds a minute for corn silage. The bottom unloaders ranged from 22 to 53 pounds a minute for grass and from 79 to 171 pounds a minute for corn silage.

Larson (4) reported the median output of grass silage as 43 pounds per minute on New York farms.

Van Arsdall and Cleaver (11) reported average surface unloader rates of 40 pounds a minute for grass silage and 60 pounds a minute for corn silage.

Saver (9) found the average for surface unloader output to be 31 pounds a minute for grass and 49 pounds a minute for corn.

The work rate for hand forking of corn silage was reported by Asmus (2) as 91 pounds a minute, by Van Arsdall and Cleaver (11) as 190 pounds a minute and by Saver (9) as 194 pounds a minute.

Oliver (7) stated that a silo unloader uses about five kilowatt-hours of electricity per dairy cow per year. He further stated that with the time and energy saved the average farmer can add five or more additional cows to his milking herd.

The cost of unloading silage with surface unloaders was reported to be from $.73 to $1.34 per ton by Van Arsdall and Cleaver (11) and $.56 to $1.55 per ton by Asmus (2).

HAND METHODS OF UNLOADING SILAGE

As upright silos are unloaded either by hand or mechanical unloader, it seemed appropriate to include some data on hand methods in this investigation. Hand unloading included the time necessary to climb the silo, dig the silage loose, and throw it down the chute. The study included only these operations and did not include removing doors or spoiled silage. The size of the silo may affect the rate of output. It was easier to throw silage across larger silos than to walk across. Silos of a diameter more than 16 feet required either walking or double handling. The physical stature of the man pitching has an effect on the rate of climbing the silo and on the rate of handling silage.

Rates of unloading corn and sorghum silage as observed on seven farms are shown in Table 1. All operators used a ten-tined silage fork. It is to be noted that the average rate of unloading for these farmers was 190.7 pounds a minute or 5.7 tons per hour. The weight per forkful ranged from 10 to 22

Table 1. Rate of unloading corn silage from upright silo with hand fork.

Farm	Time forking (min.)	Pounds silage	Pounds per minute	Tons per hour	Forks full (number)	Pounds per forkful	Forks full per minute
1	16.25	1560	96.0	2.9	71	22.0	4.4
2	9.4	1320	139.8	4.2	88	15.0	9.4
	2.1	435	208.8	6.3	29	15.0	13.8
3	13.5	2574	190.8	5.7	117	22.0	8.7
4	19.1	3100	162.6	4.9	160	19.0	8.4
	6.2	1100	177.6	5.3	55	20.0	8.9
5	1.7	430	252.6	7.6	43	10.0	5.9
6	5.7	1320	231.6	6.9	76	17.0	13.3
	7.6	1320	174.6	5.2	73	18.0	9.6
7	8.3	2250	272.4	8.2	170	13.0	20.5
AVERAGE			190.7	5.7			

pounds and the average forkful weighed 17.1 pounds. The operator with the highest rate of unloading filled his fork to only 13 pounds per forkful but established a fast rate of forking, 20.5 forks full per minute. The average rate of forking was measured to be 10.3 forks full per minute.

The height or depth of silage in the silo affected output rate from the point of total time required for forking and climbing up and down the silo. The climbing time varied greatly with the physical stature and age of the farmer. One farmer climbed up to a 25-foot silage level and down again in 1.2 minutes; another farmer took five minutes to go up and down this same distance. It should be noted that a pitching rate of 177.6 pounds per minute was reduced to only 98.2 pounds per minute when a climbing time of five minutes was included. Small operators, obviously, can save time by pitching down more than one feeding at a time.

MECHANICAL METHODS OF UNLOADING SILAGE

Types of Mechanical Silo Unloaders

There are two general types of unloaders available for upright silos. One type, which is known as the surface or top unloader, rides freely on top of the silage or is suspended by cables from the top of the silo. Plate I shows views of this type unloader. The other type, the bottom unloader, remains fixed in the bottom of the silo. As unloading progresses the entire mass of silage continually settles. The bottom unloader fits only the special silo made by the same manufacturer.

The design and operational features of unloaders are generally similar. A flow diagram of unloader operation is shown in Plate II. Silage is cut loose and conveyed into the central pivot point by single or double augers, or by a gathering chain with spiked teeth mounted on a rotating arm. From this point the silage is picked up by a blower and blown out through an open silo door.

The bottom type unloader also uses a rotating cutting arm. A heavy chain, similar to a chain saw, on a slowly moving arm cuts the silage loose and conveys or pulls it into the center where it is dropped into a trough. A drag conveyor chain in the trough carries the silage out at ground level.

Gathering Mechanisms

The gathering mechanism is a very important part of the machine. It must be capable of chopping loose, frozen and hard packed silage and conveying it to the central discharge unit.

Augers are widely used to accomplish this task. Auger diameters vary from six to ten inches. Some makes use a single auger enclosed on the back and top, others use a pair of counter-rotating augers, shown in Plate III, which carry the silage between them to the point of discharge. For removing frozen and hard packed silage cutting knives are attached to the outer edge of the lead auger to cut loose the solidly packed material.

Another type uses a gathering chain. This chain has small paddles on spiked teeth to loosen the silage and drag it to the point of discharge.

Most of the manufacturers have a cutter device on the outer end of the gathering mechanism. This device removes frozen silage from the walls and keeps the wall clean.

Discharge Units

The most common method of discharge is through a curved or "goose-neck" discharge spout. This is shown in Fig. 1 of Plate IV. There is generally one of two methods employed to move the silage from the gathering unit through the discharge spout. Some of the manufacturers use a paddle blower while others use a rotary impeller which has swinging hammers or paddles to throw the silage rather than blow it. The manufacturers of the rotary impeller type claim this type has the advantage of requiring less power as little or no air is removed. One manufacturer uses a throwing device of a rotary impeller with swinging hammers to lift the silage from the gathering augers to a discharge auger conveyor (Fig. 2, Plate IV). The discharge auger, powered separately by a one-half horsepower electric motor provides positive delivery out the silo door. Another manufacturer adds a booster blower driven by a one-half horsepower motor in the "goose-neck" spout.

EXPLANATION OF PLATE I

Fig. 1. A single auger suspended type silo unloader showing suspension cable, top center; enclosed auger, right; weighted drive wheel, lower right; and discharge spout, lower center.

Fig. 2. A non-suspended type unloader riding on top of the silage showing the enclosed auger, top center; two drive wheels at the outer end of the auger, top center; and the discharge spout, lower center.

PLATE I

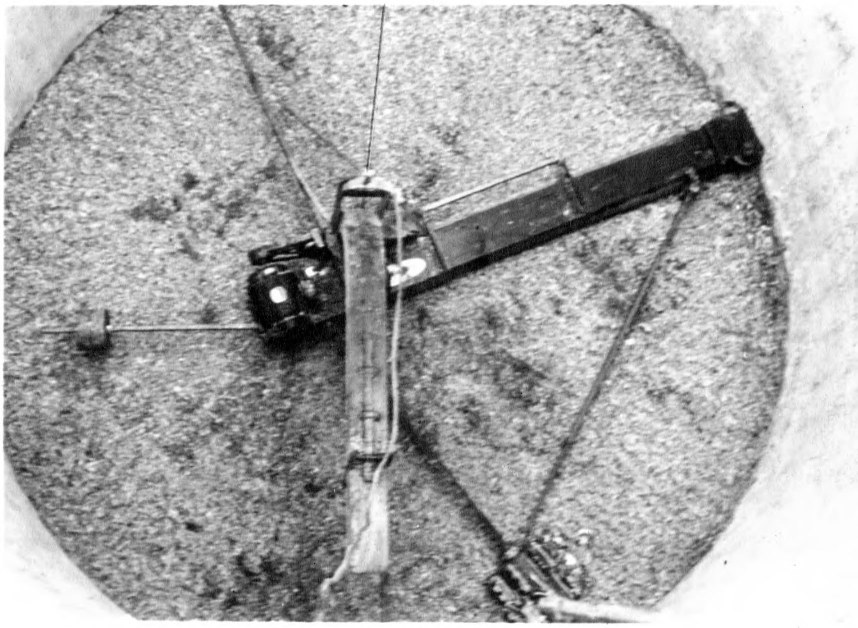


Fig. 1

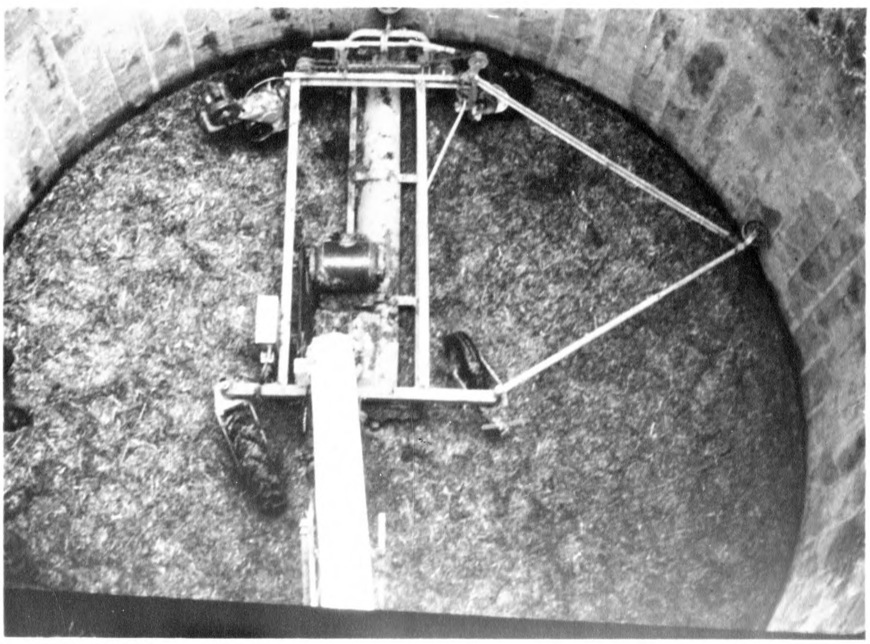


Fig. 2

EXPLANATION OF PLATE II

Fig. 1. Flow diagram for a surface silo unloader. The gathering mechanism (A) which loosens the silage and conveys it to the center. The discharge unit (B) picks up the silage from the gathering mechanism and throws it out of the silo through a curved "goose-neck" spout.

Fig. 2. This is the same diagram as Fig. 1 except that after the silage is raised through the "goose-neck" spout (C) it falls into an auger conveyor (D) and is conveyed out of the silo.

PLATE II

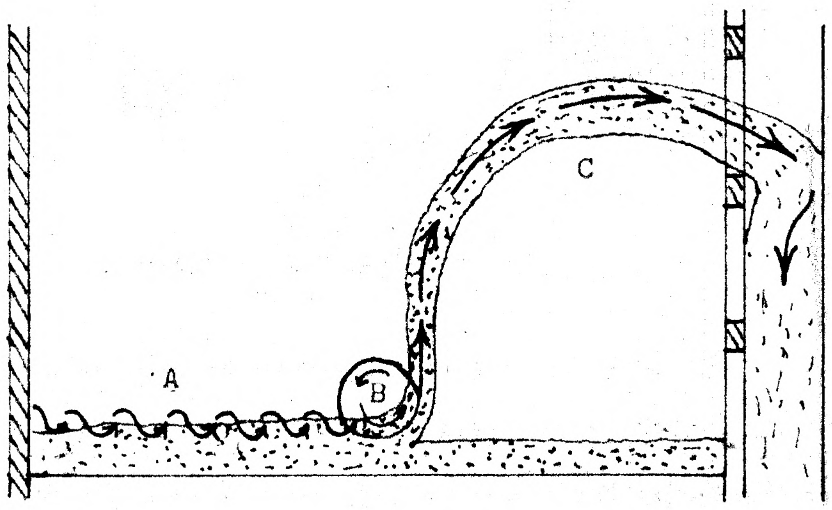


Fig. 1

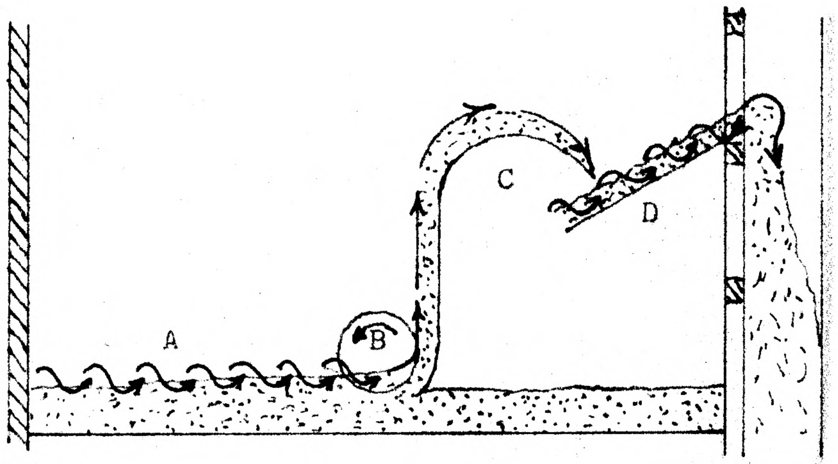
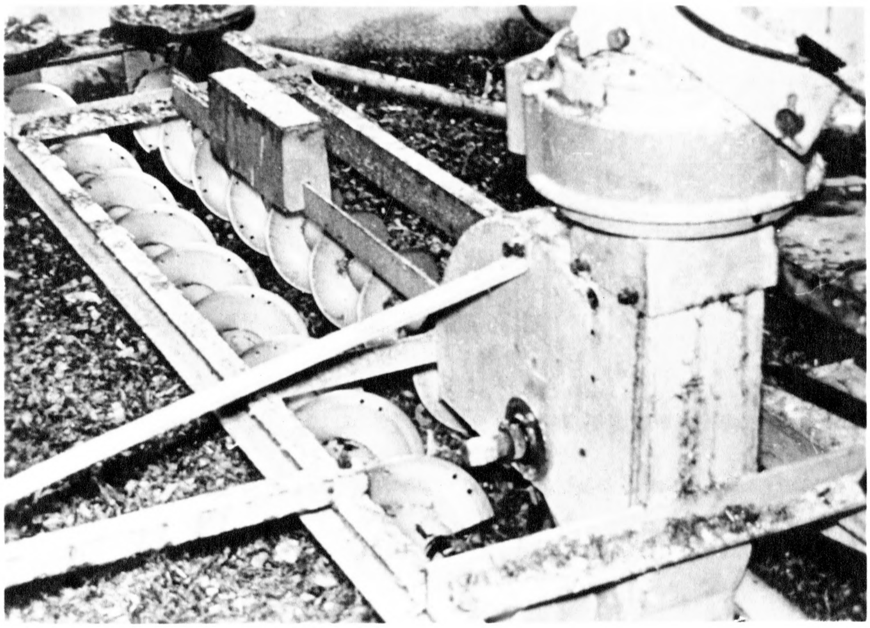


Fig. 2

EXPLANATION OF PLATE III

Twin counter rotating gathering augers, upper center, are used to cut loose the hard packed or frozen silage and convey it between them to the discharge unit, lower right.

PLATE III



Suspension and Drive

The method of suspending and driving the unloader varies with the manufacturer. Some units ride on wheels on the surface of the silage and have a built-in leveling device to keep the unit level as material is removed (Plate I, Fig. 2). Other units are suspended by cables from the top of the silo and are gradually lowered into the silage as unloading takes place, as shown in Plate I, Fig. 1.

Three methods are used to provide continous and even rotation of the unloader around the silo. They are (1) weighted drive wheels or drums on a long arm, (2) drive wheels mounted at the outer end of the gathering mechanism, and (3) a large fixed steel ring with a drive gear which meshes with it to provide a positive drive.

Power Requirements

Depending on the make of the machine one or two electric motors supply the operating power for a silo unloader. The main drive motors range from three to seven and one-half horsepower, while in some cases an additional one-half horsepower motor powers discharge boosters or propells the gathering arm around the silo.

METHODS AND PROCEDURE

Limitations of the Study

In every study or investigation limits must be placed upon what is to be included in the investigation. This study was limited to mechanical silo unloaders for upright or tower silos and soes not include mechanical unloaders

EXPLANATION OF PLATE IV

Fig. 1. Silage is discharged through the curved "goose-neck" spout, at right, by a blower.

Fig. 2. Silage is raised by a rotating impeller with swinging hammers through the curved spout, left, and dropped into a discharge auger, center, and conveyed out the silo door.

PLATE IV

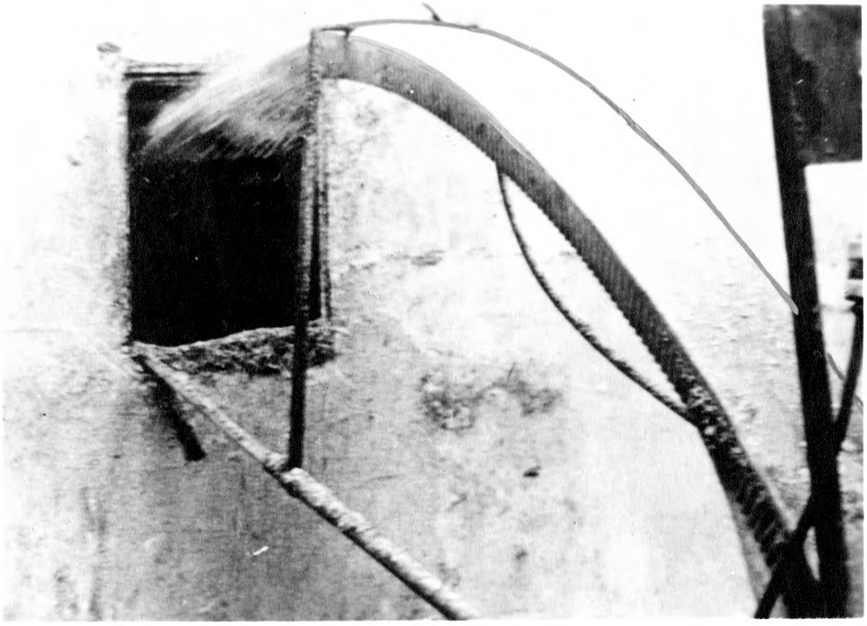


Fig. 1

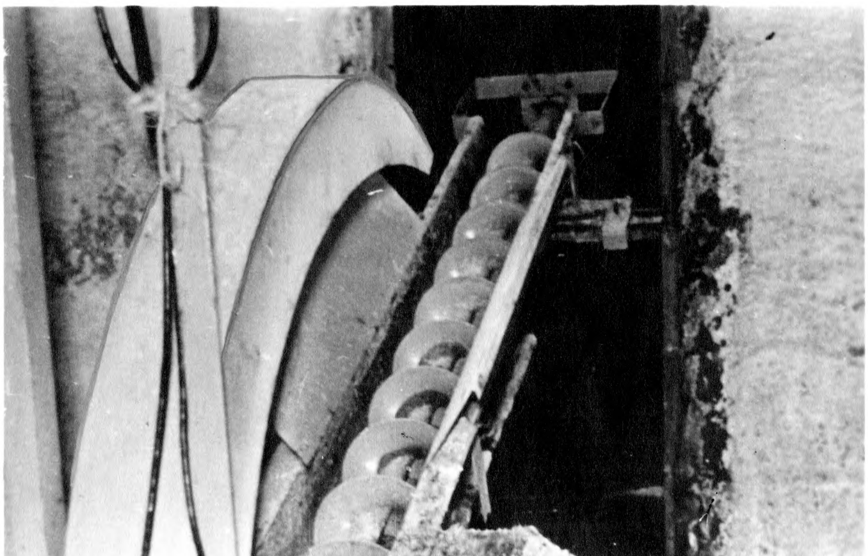


Fig. 2

for trench or horizontal silos. The study was further limited to surface unloaders, because bottom unloaders have not yet been marketed extensively in Kansas.

Location of Silo Unloaders

The first step in this investigation was to locate farmer owners of silo unloaders. This information came from a number of different sources--county agents, manufacturers, manufacturer's distributors, and farmers. The best source was through the manufacturers who supplied names and addresses of their representatives and dealers. These representatives in turn furnished the addresses of actual installations on farms throughout Kansas.

As farmer owners were located they were interviewed and selected installations were asked to cooperate in the study. Selection was made informally to obtain a well-balanced representation on the basis of geography, manufacturer, farm size, and livestock type. Selections were made as far as possible to minimize the effect of local conditions and standards of installation.

Source of Data

The data that were used in this study were obtained by personal farm visits with the cooperating farmers where the general information regarding the overall farm operation was obtained. Sample Data Sheets are used in Appendix A. Operational data given by the farmer was not used, as it was often only estimated unreliable. The performance data, with the regular farm help operating the unloaders, was recorded by the author.

INSTRUMENTATION

Pounds of silage output was weighed in the farm wagon or truck wherever truck scales were available. Where large scales were not available platform scales placed under a box having a capacity of one-half to one ton were used as shown in Plate V.

A standard watt-hour meter, shown in Plate VI, of proper current rating, voltage, and phase was connected into the electrical circuit leading to the motors for the purpose of determining the electrical energy used.

A hook-on type portable volt-ampere meter was used to determine voltage and current demand during operation. This meter is shown hooked to one wire in Plate VI.

Stop watches were used for timing the rate of unloading silage and revolutions of watt-hour meter disc.

Moisture content of the silage was determined by using the oil distillation method. The equipment used for making the determination consisted of a dietic scale of 500 to 1000 gram capacity, a mercury in glass thermometer reading up to 400 degrees Fahrenheit or 200 degrees Centigrade, a lightweight aluminum pan approximately one quart size, and a gasoline burner.

TEST PROCEDURE

Prior to the starting of a test, the procedure was as follows:

1. Data regarding installation were recorded.
   - (a) Silo size.
   - (b) Length of cut and kind of silage.
   - (c) Make of unloader.
   - (d) Motor size and full load ampere rating.
   - (e) Wire size from source of electricity to silo.
   - (f) No load voltage of silo.
   - (g) Overload protection.

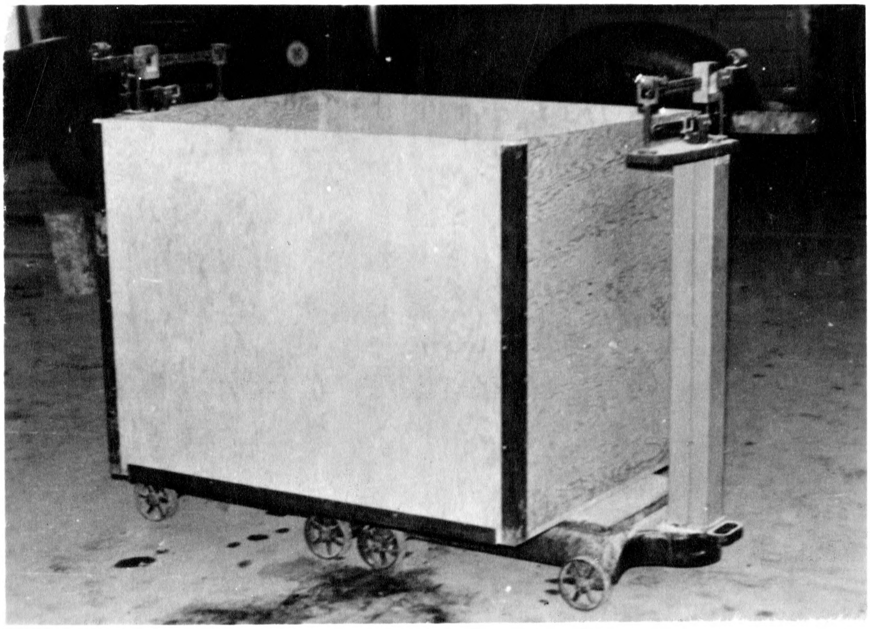
2. The watt-hour meter was connected to the electrical circuit.

3. If large scales were available, a tare weight was taken of truck or wagon before parking under silo chute. If box was used, the platform scales and box were placed under the silo chute and tare weight taken.

EXPLANATION OF PLATE V

Two sets of platform scales each having 1000 pounds capacity on which a plywood box was placed to weigh silage when truck scales were not available. The box has a capacity of 1000 to 1200 pounds.

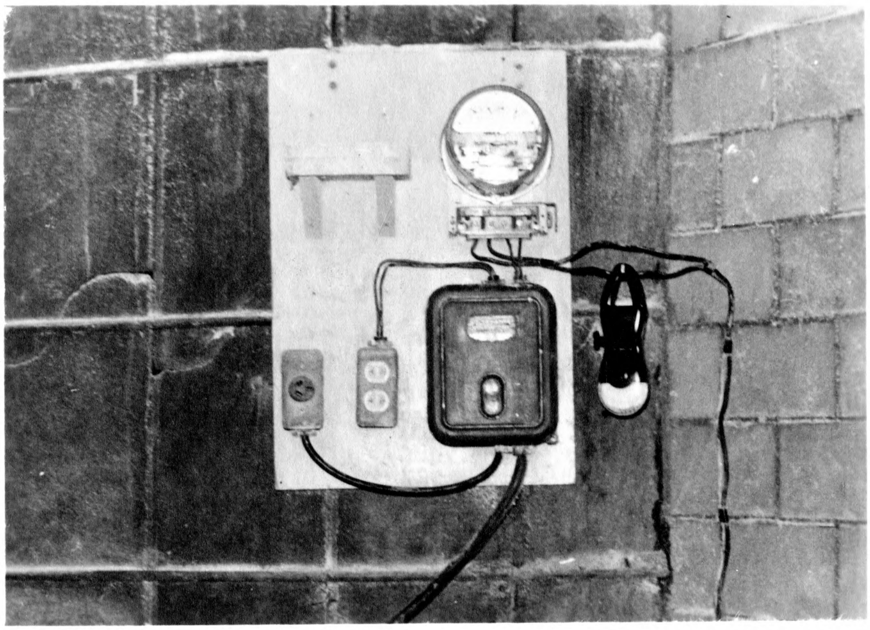
PLATE V



EXPLANATION OF PLATE VI

Instrument panel showing watt-hour meter and magnetic switch. The outlet at the lower left of panel is for plugging in a remote control switch that may be operated from inside the silo. To the right of the panel is a hook-on type ammeter used to determine current demand.

PLATE VI



4. Hook-on type ampere meter was hooked to one side of circuit, as shown in Plate VI.

To start the test the unloader was turned on and a stop watch was started to record time of test. During the test another stop watch was used and watt-hour meter disc revolutions were counted.

Other data recorded during operation was the current flow to motors and the loaded line voltage at silo.

When test was completed the weight of silage thrown down during test was recorded. Samples were taken to determine per cent of moisture silage contained.

MOISTURE DETERMINATION TESTS

The moisture content of the silage was determined by the oil distillation method. The equipment used is shown in Plate VII. The following procedure was used to make this determination.

1. A 100 gram sample of silage was weighed.
2. Vegetable oil was added until sample was covered.
3. Weight of container, sample, and oil was recorded.
4. Container was then placed over burner and heated until the thermometer held in the oil raised to 145 degrees Centigrade (293° F.).
5. Container was then reweighed and this weight subtracted from weight recorded in Step 3. The loss in weight in grams equals the percentage of moisture as a 100 gram sample was used.

RESULTS OF PERFORMANCE TESTS

The tests were run with the regular farm help operating the equipment; This yielded widely varied information. It was found that machines were being operated without proper adjustment and by making a few changes in these adjustments output could be increased. Current demand during a test was recorded to determine at what per cent of rated load the motors were operating. This current fluctuated, however large overloads w ere generally momentary. Table 2 is a summary of the unloader test data. In the column showing percentage of rated load it should be noted that most operators were loading their machines to full capacity. Some farmers operated their machines at 85 to 95 per cent of rated load. These users were cautious about loading motors on the machine to or above capacity because of past experience with clogging. They felt they would lose less time this way than they would in climbing up the silo to clean out the machine when it became clogged. The percentage of rated load at which machines were operated varied from a low of 77 per cent to a high of 135 per cent. The average for all tests was 107 per cent of motor rating.

Table 3 lists the unloading rates and energy consumption averages. The averages do not take into consideration the individual makes of unloaders. In order to get a reasonable value for rate of unloading the rates of corn and grass silage were averaged separately. When considering all unloaders tested there was a range in capacity from 2.1 to 11.7 tons an hour with an average of 6.4 tons an hour for corn and sorghum silage. For grass silage the capacity varied from 3.7 to 4.03 tons an hour with an average of 3.9 tons an hour. The average energy sonsumed was 0.88 KWH per ton for corn silage and 2.00 KWH per ton for grass silage. The energy consumption for grass silage was higher because of the lower unloading rate. Grass silage presents a different problem than corn silage. At a setting of the forage cutter all the grass is not cut the same length. Table 2 shows the length of cut for grass silage ranged from one-half to three inches. When the short and long silage is packed together it is harder to tear apart. This seems to be one explanation for the lower output with grass silage.

EXPLANATION OF PLATE VII

This plate shows the equipment used to determine the moisture content of silage. To the left is a dietic scale of 500 gram capacity used to weigh samples. On the left is a gasoline burner over which is an aluminum container containing sample and oil.

PLATE VII

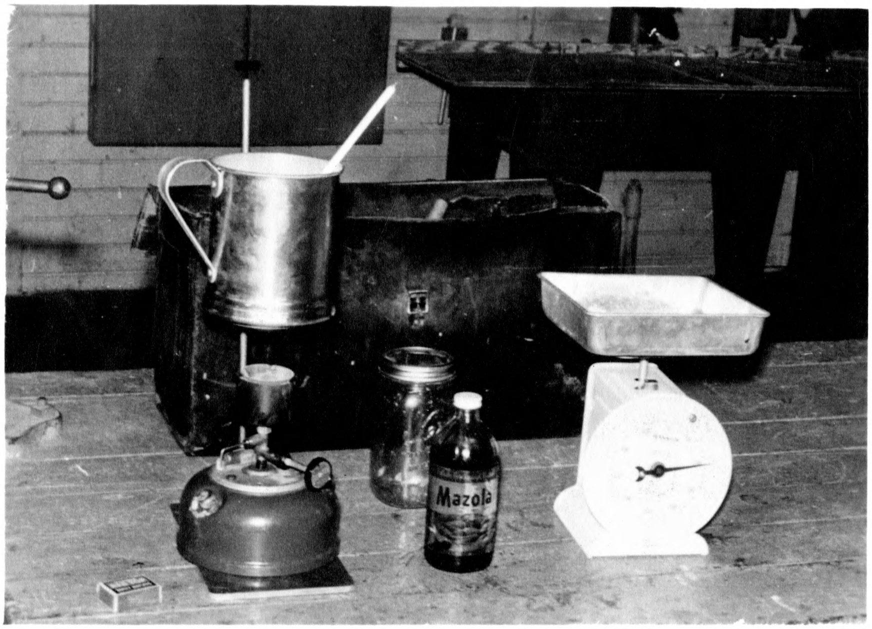


Table 2. Silo unloader test data.

Test	Silo size	Silage type	Length of cut (in.)	Per cent Moisture	Unloading Rate #/min.	Unloading Rate T/hr.	Motor size(h.p.)	Motor load (% of rated)	Energy Input (kw)	KWH/Ton
E 1	20x60	Sorghum	1/2	67	334	10.02	7½ + ½	125	10.55	1.07
A 2	18x40	Sorghum	3/8	68	153	4.58	5 + ½	82	3.78	.84
E 3	16x30	Sorghum	1/2	71	112	3.39	5 + ½	96	3.29	.97
E 4	16x30	Corn	1/2	73	139	4.17	5 + ½	105	---	--
E 5	20x60	Corn	1/2	68	321	9.45	5 + ½	117	---	--
D 6	18x50	Sorghum	1/2	67	250	7.50	5	117	---	---
C 7	18x50	Corn	3/4	67	107	5.03	5	108	3.30	.66
D 8	18x35	Sorghum	5/8	67	135	4.04	5	107	3.68	.91
B 9	14x30	Corn	3/4	73	249	7.40	3 + ½	108	3.50	.47
A 10	14x35	Sorghum & Corn	3/4	63	74	2.21	3	114	3.32	1.51
A 11	14x30	Sorghum	1/2	71	154	4.61	3	108	3.38	.73
E 12	18x45	Barley	1/2 - 3	71	126	3.79	7½ + ½	93	11.44	3.02
D 13	18x40	Alfalfa & Brome	1/2 to 2	65	134	4.03	5	110	3.89	.97

Motors

The unloaders tested were powered by three, five and seven and one-half horsepower motors. The three horsepower motor had sufficient capacity for silos not over 14 feet in diameter; however, in three installations with 14-foot silos the three horsepower machines were heavily overloaded. This accounts for the average output for three horsepower machines shown in Table 3 as being higher than the five horsepower average. While some manufacturers used enclosed frame type motors most of them used an open-frame motor of drip or splash proof design. On two installations in this study the high-capacity cooling fans on the motor sucked particles of silage into the motor and caused the starting mechanism to malfunction. To correct this condition one owner placed a protective cover over the motor and belt drive.

Fusing and Wiring

As the fusing and wiring to the unloader is generally left to the farmer or person installing the machine, a wide variety of circuits were noted. These varied from plain fuses to magnetic thermal overload motor starters. In a number of instances the motor protection device was found to be in excess of 125 per cent of rated full load current of the motor. One installation had a seven and one-half horsepower motor with a rated load of 35 amperes fused with 60 ampere fuses. This allowed for a 70 per cent overload on the motor. The original overload device had been a 40 ampere delay action fuse. When the original fuse burned out it was replaced with a one time fuse and a 60 ampere was the smallest that would not burn out under the required starting current of the motor. This was a common finding on the unloaders tested. On two of the unloaders which had more than one motor there was only a single

Table 3. Unloading rates and energy consumption averages.

	Corn & Sorghum					Grass				
Motor size	Pounds per min.	Tons per hr.	Energy: Kw.	KWH per ton	Per cent moisture	Pounds per min.	Tons per hr.	Energy Kw.	KWH per ton	Per cent moisture
3 h.p.	189	5.62	3.43	.75	70	--	--	--	--	--
5 h.p.	165	5.06	3.54	.89	69	134	4.03	3.89	.97	65
7½ h.p.	334	10.02	10.55	1.07	67	126	3.79	11.44	3.02	71
All	213	6.4	5.18	.88	69	130	3.91	7.66	2.00	68

thermal element through which both motors were fused, so in effect there was no motor overload protection for the individual motors. Other unloaders having two motors had a fuse box mounted on the unloader with two delay action fuses for each motor. Starting the unloader after blowing a fuse was not convenient with this arrangement since the operator had to climb into the silo to replace the fuse. However, this climb was also generally necessary to clean out the clogged blower or to remedy other causes for the stoppage. As long as the user replaces a blown fuse with a delay action fuse of proper size, the protection obtained should justify the additional effort.

The motors on the rotating portion of the machine are supplied 220 volts through slip rings and brushes. This arrangement has been generally satisfactory with only a few instances of trouble. On one unloader in these tests powered by a seven and one-half horsepower motor the contacts on the ring became overheated and burned out because they were not large enough to carry the 52 amperes of current for this motor. Most of the machines tested had only two slip rings, so positive grounding to the motor frame could not be assured. In many installations a ground lead was attached to the non-rotating portion of the machine, and could be expected to provide a motor frame ground part of the time through contact of the central support. This contact however, may not provide sufficient current-carrying capacity to blow fuses or other overload protecting devices in case of a line-to-ground fault.

Discharge Units

The discharge blower or impeller capacities appeared to limit the unloading rate of the machines. In all machines tested the gathering mechanism could convey more material to the discharge unit than it could handle. On one make if lowered into the silage too fast the gathering mechanism brings in enough silage to completely close off the blower inlet and plugging results. Another machine failed to blow the silage clear of the door when loaded heavily, resulting in a pile of silage inside the door. The next time the gathering mechanism reached this pile it clogged the machine. Machines having a discharge auger conveyor did not encounter the plugging problem. Output for the energy consumed with this type machine was the largest for machines tested.

Moisture Content and Length of Cut of Silage

Moisture content of silage tends to reach an equilibrium at about 68 per cent. This is believed a satisfactory moisture content for good mechanical handling. Wetter silage, 70 to 75 per cent moisture, tends to be too heavy for the blower to throw clear of the silo door and much falls back into the silo.

The most satisfactory length of cut seems to be one-half to five-eighths inch. This should be a good clean cut made with sharp cutter knives. Silage with lots of fine material tends to "mud ball" and stick in the discharge chute.

Frozen and Hard Packed Silage

During the test period there were about two weeks when the temperature did not get above freezing. All the machines observed operated well in the frozen silage and did a good job of cleaning the silo wall of frozen silage. One operator added cutting knives to the outer two feet of his gathering auger. These knives appeared to aid in cutting loose and chopping up the frozen silage.

It is known that the density of silage varies from the top to the bottom in a silo. No measure was made of this factor however density did not seem to affect the operation or machine output.

Cost of Operation

Kilowatt-hour consumption of the electric motors on the unloaders was not a significant item to most users. They felt the expenditure for electricity was worthwhile because it saved the hard labor of throwing down silage by hand. Unless other tasks could be done around the farmstead while the unloader is in operation, little saving in time could be reported. Some users did believe there was a saving in feed as the frozen chunks and lumps were all broken up and uniformly mixed, resulting in less waste due to rejected silage.

Table 4 indicates the estimated costs per ton for unloading various amounts of silage annually. These costs include electrical energy, labor, and annual overhead (interest, taxes, depreciation and repairs). In preparing this table costs given in the Agricultural Engineer's Yearbook (8) for a forage blower were assumed for silage unloaders. An average cost of $1400 for a five horsepower 18-foot unloader was used in these calculations. Depreciation was estimated on a straight line basis for a 12-year life. Four and one half per cent of new cost was used as the total annual charge for interest, taxes and insurance. Total repairs for the life of the machine (12 years) were taken as 25 per cent of new cost.

Cost of electricity at two cents per KWH were included in the table. For the machines tested the averages were 1.8 cents per ton for corn silage and 4 cents per ton for grass. The range for all unloader tests was from 0.9 to 6 cents a ton.

Table 5 shows the costs in Table 4 broken down into cost per day per head of dairy or beef cattle receiving 30 pounds daily. Sample calculations for making cost of operation estimates are shown in Appendix C.

Table 4. Costs per ton for unloading various amounts of silage annually.

Silage type	Years until obsolete	Hours to wear out	Total repair cost in % of new cost	Cost/ton for annual tonnage handled				
				100T	150T	200T	300T	500T
Corn	12	2000	25	$2.27	1.57	1.22	.88	.60
Grass	12	2000	25	2.39	1.69	1.34	1.00	.72

Table 5. Daily unloading cost per head receiving 30 pounds of silage per day.

Silage type	Cost in cents per head for annual tonnage handled				
	100 T	150 T	200 T	300 T	500 T
Corn	3.4	2.3	1.8	1.3	.9
Grass	3.6	2.5	2.0	1.5	1.1

Adjustability

Unloaders are built so that they can be disassembled and moved from one silo to another. This job requires about one half of a day for two or three men, or about 10 to 12 man-hours. The unloader is moved in units that can readily be hoisted to the top of a filled silo and reassembled. Unloaders are adjustable to silos of different sizes; that is an unloader for a 14-foot silo can be extended to a wider silo by the addition of extension parts.

CONCLUSIONS

Equipment is a negligible item in hand forking and labor accounts for almost the entire cost. The time required per ton and the value the operator puts on his own or hired labor determines the cost of removal.

For corn silage the average rate for hand forking was approximately 5.7 tons per hour (Table 1) or about 10.5 minutes per ton plus the time needed to climb up and down the silo. The cost of hand pitching, neglecting climbing time, with labor at one dollar an hour is about 18 cents a ton.

Rates of mechanically unloading ranged from 2.1 to 11.7 tons per hour with an average of 6.4 tons per hour for corn and sorghum silage. The rate of unloading ranged from 3.7 to 4.0 tons per hour with an average of 3.9 tons per hour for grass silage. The average electrical energy consumed was 0.88 KWH per ton for corn and 2.00 KWH per ton for grass silage. The cost for mechanical unloaders (Table 4), based on power costs, annual overhead and labor, varied from 0.60 to 2.39 dollars per ton depending on the annual tonnage handled. The cost per head per day of dairy or beef cattle receiving a ration of 30 pounds of silage is 0.3 cents for hand pitching and from 0.9 to 3.6 cents for mechanically unloaded.

A general conclusion of the study is that in most instances a mechanical unloader will not pay for itself in terms of time and labor saved alone. It will, however, do much to relieve the disagreeable and sometimes dangerous portion of the silage feeding chore. It will also contribute to the overall mechanization of forage handling, especially when operated with a mechanical feeder or unloading wagon. Plate VIII shows examples of modern mechanical feeding methods.

EXPLANATION OF PLATE VIII

Fig. 1. Farmer feeding silage from a mechanically unloaded wagon. The wagon was loaded with a mechanical silo unloader.

Fig. 2. A mechanical feeder in silage bunk distributes the silage. Silage is unloaded from the silo into the feeder by a silo unloader making the overall feeding operation mechanical.

PLATE VIII

Fig. 1

Fig. 2

With the use of unloaders large silos of 24 and 30 feet in diameter are coming into the picture. In the past it was almost impossible to pitch silage by hand from these large silos without double handling. Now there are unloaders available that will do this job. The advantage of the larger silo is that by increasing the diameter the amount of storage is greatly increased and thus the cost per ton is decreased.

In the tests there appeared to be little difference in the performance of the suspended and non-suspended type machines. In some cases the suspended type machines were left in the silo the entire year. They were raised to the top of the silo before it was filled. With the unloader raised, the top one or two doors of silo capacity cannot be used. The unloading rate appeared more uniform with the non-suspended machines, whereas with the suspended machine the operator must manually let the machine down into the silage.

There is some reason to believe that the silage should be leveled during filling. Density of the silage will then be more uniform from one side to the other, and the unloader will be more likely to operate on the level. Also, a good clean cut of about one-half to five-eighths of an inch in length seems to be the most satisfactory for mechanical handling.

As most farmers now having an unloader report they would never be without one again, many more farmers will no doubt purchase unloaders in attempting to simplify their chores.

SUGGESTIONS FOR FURTHER INVESTIGATION

Blower capacity appeared to limit the unloading rate of the unloaders tested. Further investigation should be made of the discharge units for the purpose of improving their performance. This may be accomplished through redesign of present methods or a completely new method. Some possible ideas that may be investigated are replacing the blower unit with vertical auger or removing blower unit and have the silage drop through a chute in the center of the silo.

Since modifications are continually taking place for such choring equipment, future investigations should keep up with the progress being made in this area. This investigation should be carried further to tie it in with the overall feeding operation.

A similar investigation of mechanical unloaders for trench or horizontal silos should also be made.

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LITERATURE CITED

(1) "A Survey of Farm and Home Electric Equipment", Kansas Inter-Industry Farm Electric Utilization Council, October, 1955.

(2) Asmus, Rodger, W., Silo Unloaders on Farms, Agricultural Extension Service Bulletin 360, Ohio State University, April, 1957.

(3) Dobie, John B., "Mechanical Feeding of Livestock", Agricultural Engineering, Vol. 37, No. 7, p. 458. 1956.

(4) Larson, L. W., "Mechanical Silo Unloaders", 1954 Progress Report, The New York Farm Electrification Council.

(5) "Modern Electric Choretime Equipment", Barn Cleaner, Cattle Feeder and Silo Unloader Assn., 330 S. Wells Street, Chicago 6, Ill. Educational Service Bulletin #2.

(6) Neitzke, C. H., A Look at Silo Unloaders, Electricity on the Farm, October, 1952, Vol. 25, No. 8, p. 8.

(7) Oliver, James H., Profits from Silo Unloaders and Barn Cleaners, Farm Electrification, Edison Electric Institute, Vol. XI, No. 1, January-February, 1957.

(8) Richey, C. B., Crop Machines Use III, Agricultural Engineers Yearbook, American Society of Agricultural Engineers, St. Joseph, Michigan, p. 95.

(9) Sauer, Gilbert Frederick, "Time Standards for Selected Beef Cattle Feeding Operations", Unpublished M. S. Thesis, University of Illinois, May, 1953.

(10) "Silo Unloader Designs", Electricity on the Farm, Vol. 30, No. 8, October, 1957, p. 10.

(11) Van Arsdall, R. N., and Thayer Cleaver, Handling Silage and Concentrates for Beef Cattle in Drylot, Illinois Agri. Ext. Cir. 714, University of Illinois, 1954.

APPENDICES

APPENDIX A

Silo Unloader Performance Data Sheet

Owner ______________________________ Address ____

Date	Test No.	Silage			Total output lbs.	Time (Min.)		Output		Loaded Amp. Reading				Meter Data			Power KW	Remarks
		Depth	Kind	% Moist.		Mach	Man	#/Min	#/ManMin	Total	__ hp	__ hp	___ hp	Disc Rev.	Time Min.	Kh		

Proj. #374 Sheet ________

Investigation of Mechanical Silo Unloaders

Name of Owner ______________________ Date ____________ Taken by ______

Address ______________________ County ______________

Location of Silo ______________________________________

No. head fed from Silo __________ Dairy ____________ Beef ____________

Method Silage Distributed ______________________________

Silo Data

Kind ______________________________ Size ____________

Date filled __________ Kind of Silage __________ Avg. length cut ______

Unloader Data

Make and Model ______________________ Length ______________

Motor Data

	Mfgr.	Type	Size	Phase	Amp Rating	Driving
1.						
2.						
3.						

Wiring Data

Source to Silo, size wire ______________ No. ft. ______________

Voltage @ Silo, Loaded ______________ Not Loaded ____________

Overload Protection ______________________________

____

Switching ______________________________________

____

Grounding ______________________________________

Comments:

APPENDIX B

Commercial Unloaders Observed in this Study

A. VanDale Silo Unloader

VanDale Farm Machines Inc.
Wayzata, Minnesota

B. Silo-Matic Unloader

VanDusen and Co., Inc.
Wayzata, Minnesota

C. Badger Silo Unloader

Badger Northland Inc.
Kaukauna, Wisconsin

D. Clay Silo Unloader

Clay Equipment Corporation
Cedar Falls, Iowa

E. McLean Silo Unloader

Silage Equipment Co., Inc.
Wichita, Kansas

APPENDIX C

Sample Calculations for Total Operating Cost of Silo Unloaders

Estimates for cost calculations were assumed to be comparable to those for a forage blower. These were taken from the Agricultural Engineers Yearbook (8).

Average initial cost for 18 ft. unloader with 5 h.p. motor -- $1400.00

Depreciation   12 year life assumed

$$\frac{1400}{12} = 116.67 \text{ \$/yr}$$

Interest, taxes and insurance

4 1/2% of new cost annually

1400 x 0.045 = 63.00 $/yr

Repairs

Total cost for 12 year life assumed 25% of new cost

1400 x 0.25 = 350

$$\frac{350}{12} = 29.17 \text{ \$/yr}$$

Cost of electricity

Average use from test data

Corn   0.88 KWH/ton @ 0.02 $/KWH = 0.018 $/ton

Grass   2.00 KWH/ton @ 0.02 $/KWH = 0.04 $/ton

Labor

Corn   6.4 T/hr @ 1.00 $/hr = 0.16 $/ton

Grass   3.9 T/hr @ 1.00 $/hr = 0.26 $/ton

APPENDIX C (concl.)

Cost per ton if 200 tons handled annually

Depreciation	116.67	
Int., Taxes, Ins.	63.00	
Repairs	29.17	
TOTAL	208.84	$/yr

$$\frac{208.84}{200} = 1.045 \text{ \$/ton}$$

COSTS	CORN	GRASS
Yearly costs	1.045	1.045
Electricity	0.018	0.04
Labor	0.16	0.26
TOTAL COST PER TON	1.223 $/ton	1.345 $/ton

AN INVESTIGATION OF THE PERFORMANCE OF MECHANICAL SILO UNLOADERS

by

MARTIN DECKER

B. S., Kansas State College
of Agriculture and Applied Science, 1950

AN ABSTRACT OF

A THESIS

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Rates of unloading ranged from 2.1 to 11.7 tons per hour with an average of 6.4 tons per hour for corn and sorghum silage. The rate of unloading ranged from 3.7 to 4.0 tons per hour with an average of 3.9 tons per hour for grass silage. The average energy consumed was 0.88 KWH per ton for corn silage and 2.00 KWH per ton for grass silage. The human work rate average for hand pitching was 5.7 tons per hour.

Equipment is a negligible item in hand forking and labor accounts for almost the entire cost. This cost, neglecting climbing time, with labor at one dollar an hour was determined to be about 18 cents a ton. The estimated total operating costs of mechanical unloaders varied from $0.60 to $2.39 a ton depending on the annual tonnage handled or from 0.9 to 3.6 cents per head per day receiving a ration of 30 pounds of silage.

While some manufacturers used enclosed motors most used an open-frame motor of drip or splash proof design. On two installations the high capacity cooling fans on the motors sucked particles of silage into the motor and caused the starting mechanism to malfunction.

Methods of motor protection varied from plain fuses to magnetic motor starters. In a number of cases the motor protection device was in excess of 125 per cent of rated full load current of the motor. On two unloaders having two motors, both motors were fused through a single thermal overload element, so in effect there was no motor overload protection.

Most manufacturers use slip rings and brushes to supply power to the motors on the rotating portion of the machine. This arrangement has given little trouble, however many machines have only two slip rings so positive grounding of motor frames cannot be assured with 220-volt system.

A general conclusion of the study is that in most instances a mechanical silo unloader cannot be expected to pay for itself in terms of time and labor

Feed and forage handling is a costly, hard job on livestock farms. Recent installations of silo unloaders on Kansas farms have stimulated an interest in this equipment throughout the state. Many farmers in search of a means of chore simplification are asking for information about this equipment regarding operating costs, and time and labor savings.

The purpose of this study was to obtain information on the merits of silo unloaders as they are being operated on Kansas farms. The phases of investigation were defined under three classifications (1) to gather information regarding total operating costs, output capacities, power requirements, and time and labor saved, (2) to determine the merits of this equipment as a means of chore simplification, (3) to determine the effect of the characteristics of silage on unloader performance.

All the makes of unloaders tested were powered by three, five, and seven and one-half horsepower electric motors. The design and operational features of all were similar. Each had a cutting arm which was slowly rotated about the central pivot point. Silage was cut loose and conveyed to the center by either single or double augers mounted on the rotating arm. It was then blown through a curved or "goose-neck" spout to a silo door and down the chute.

In this study it was learned that many of the machines were in need of minor adjustments. When this condition was corrected an increase in output resulted. Current demand during operation showed the current fluctuated, however large overloads were generally momentary. The current demand compared to motor ratings showed that most operators were operating their machines near full capacity. However, some operated at 85 to 95 per cent of rated load. The percentage of rated load varied from 77 to 135 per cent with an average of 107 per cent.

saved. It will however, do much to relieve the disagreeable and sometimes dangerous portion of the silage feeding chore. Unloaders will also contribute to the overall mechanization of chore simplification, especially when operated with a mechanical feeder or unloading wagon.