SILAGE REMOVAL FROM THE HORIZONTAL SILO

By

Nathan H. Rich

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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A study was made of the complete operation for handling silage in connection with the horizontal silo. The two outstanding problems were shown to be the percent spoilage and the removal of the silage.

Long-grass silage can be made with a minimum of equipment and stored in horizontal silos of the many types, which vary from stacks above ground with no supporting walls, to trenches below ground-level either with or without lining. The long-grass silage may be more popular if the removal problem is solved. Chopped-grass silage is removed from the silo with less difficulty than long-grass but the spoilage problem is about the same.

Cutting methods to leave a smooth sealed surface when the silage is removed have been found to reduce spoilage as well as make it possible to remove the long-grass silage. Methods used for cutting include the use of the conventional hay knife, a broad-axe, a special cutter made from a rolling plow coulter with a piece of iron pipe welded on it for a handle, and the power chain saw.

During this investigation it was attempted to construct a cutter to work in conjunction with the tractor manure loader. The cutter received its power for cutting from the tractor engine. A completely satisfactory cutter was not constructed but information has been obtained that should lead to the development of equipment that will solve the problem.

Self-feeding methods are being used very successfully where conditions will allow it. Semi-self feeding where only a small amount of work is required each day to prevent waste and yet supply a sufficient amount of feed also has been found to be satisfactory for some operators.

The spoilage problem can be handled very well with proper care. The factors in proper care are time and method of harvest, storage conditions, and care in removal of the silage.

The horizontal silo may have advantages over the vertical in economy, both in initial cost and operating cost, as well as in the amount of equipment required for its use. It can be used as a supplement to the vertical silo or it can be used alone. With proper management it has a place on many more farms.

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The Great Lakes Tractor and Equipment Company is extended special thanks for the use of the tractor and loader.

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INTRODUCTION

Horizontal silos in their various forms have been used for many years. They are at present receiving a renewed interest both as temporary storage, as a supplement to the upright silo, and as a permanent structure to be used year after year. It has been indicated that if the problems of removal and spoilage could be eliminated the horizontal silo would be used much more extensively. There are areas where the horizontal silos are solving the silage storage problem for many farms. In foreign countries they are being used to reduce the amount of machinery required as well as to lower the cost of storage facilities. In this country large and small farm operators alike find many advantages, with the varying amount of equipment available, and according to the housing and feeding arrangements used.

STATEMENT OF PROBLEM

Study the over-all operation concerned with the use of horizontal silos. Look into the methods already in use and determine new methods for possible improvement.

Points To Be Investigated

1. Study over-all operation for possible methods.
2. Study present removal methods.
3. Determine where improvement of removal methods is possible.
4. Study types of structures used for horizontal silos.
5. Determine methods of reducing percent of spoilage.
6. Study methods of filling horizontal silos.

LITERATURE REVIEW

General

The review of literature as well as contact with farmers indicates that there is a great increase in the number of horizontal silos in use. There seems to be agreement that the chief problems in the use of the horizontal silo are those of spoilage and silage removal.

There are many types of construction for horizontal silos, from stacks on the surface of the ground with no supporting walls, to those completely below ground-level with permanent lining.

Long-Grass Silage

The minimum of equipment can be used when making long-grass silage. Two principal methods are used for putting long-grass silage into storage. The buck rake method requires the least equipment but its use is limited to short hauls. The other method is to use a heavy duty hay loader with a truck or wagon for hauling, equipped with an unloading mechanism. Successful Farming (6) states:

> Two tractors, a mower, and a buck rake -- that's all the machinery you need to make long-grass silage. With a crew of two or three men you can put up sixty tons a day if the haul is not too long.

Harold Prairie Jr. (23) says that long-grass silage is better than chopped:

> When the stack was opened, each cow had been getting eighty pounds of chopped silage and plenty of hay. With free-choice, the cows stuffed themselves on long-grass silage. They ate very little hay and almost no chopped silage. After three days, production went up 110 pounds on twenty cows. Two days after the stack was gone, production dropped 75 pounds.

Farmers of Australia (9) try to make long-grass silage just fast enough so that the temperature of the mass is about blood heat. If silage is too cold they will not put on another layer until it heats to blood heat. If the silage is too hot, the Aussies spray the silage with ten gallons of a solution made of one pound of salt in a gallon of water, to prevent charring.

To measure the temperature, they push an iron rod into the stack or pit and leave it there for ten minutes. When removed it should be hot enough that it can just be held in the hand. If it is this temperature they continue making grass silage.

Chopped-Grass Silage

When a field chopper is available, as on many of the larger farms, the horizontal silo still has its advantages. The trailer type wagon equipped with a power unloading system fits into the operation to complete the equipment for a very rapid harvesting operation. With the proper crew and equipment the rate of harvest is probably as fast as can be readily attained.

Removal

There are several methods of removal of the silage found to be successful. Many of the same problems exist with chopped and long-grass. Semi-self feeding (30) has been used with both and found to be an important labor-saving method. If it is desirable to move the silage to feed bunks the removal problem may interfere. The chopped silage can be removed with a tractor loader but the problem of spoilage may occur when such small amounts are removed that the complete face of the pile is not removed every two or three days. Cutting off the face of the pile to leave a smooth surface eliminates much of the spoilage. It seems to be necessary to cut the long-grass to facilitate removal. Hand cutters and power chain saws have been used to do the job.

Storage

Temporary or Permanent

The horizontal silo has proved itself in simple temporary form and also when built as a permanent structure. First cost as well as annual cost can be advantages in favor of the horizontal silo (41).

Roof or Covering

Whether the silo should be covered is a matter of choice. The top spoilage can be eliminated but the cost of covering may be greater than the value of the silage saved. It may be desirable to have a roof to keep out snow even if no material is saved.

STUDY OF OPERATION

A study of the complete operation from grass in the field, to feed in front of the animals, has been considered. The charts (Figures 1 and 2) give an idea of the many possibilities. This type of chart is very helpful in considering an operation from beginning to end in order to show the many methods of arriving at the destination. It can be compared with a road map and helps to distinguish the highways, crossroads, and detours. Figure 1 shows some of the many methods for the over-all operation while Figure 2 shows only removal or a unit operation.

There are different methods best suited according to type of operation. These differences may be due to size of operation, type of housing, distance to field, and others. A comparison of the different methods is important to determine which is best suited to any special situation.

Problems Involved

It has been indicated that the chief drawbacks of the horizontal silo are the percent of spoilage and the problem of removing the material. The study of the various methods of construction, methods of filling and packing, together with various removal methods give an indication of how to overcome these problems.

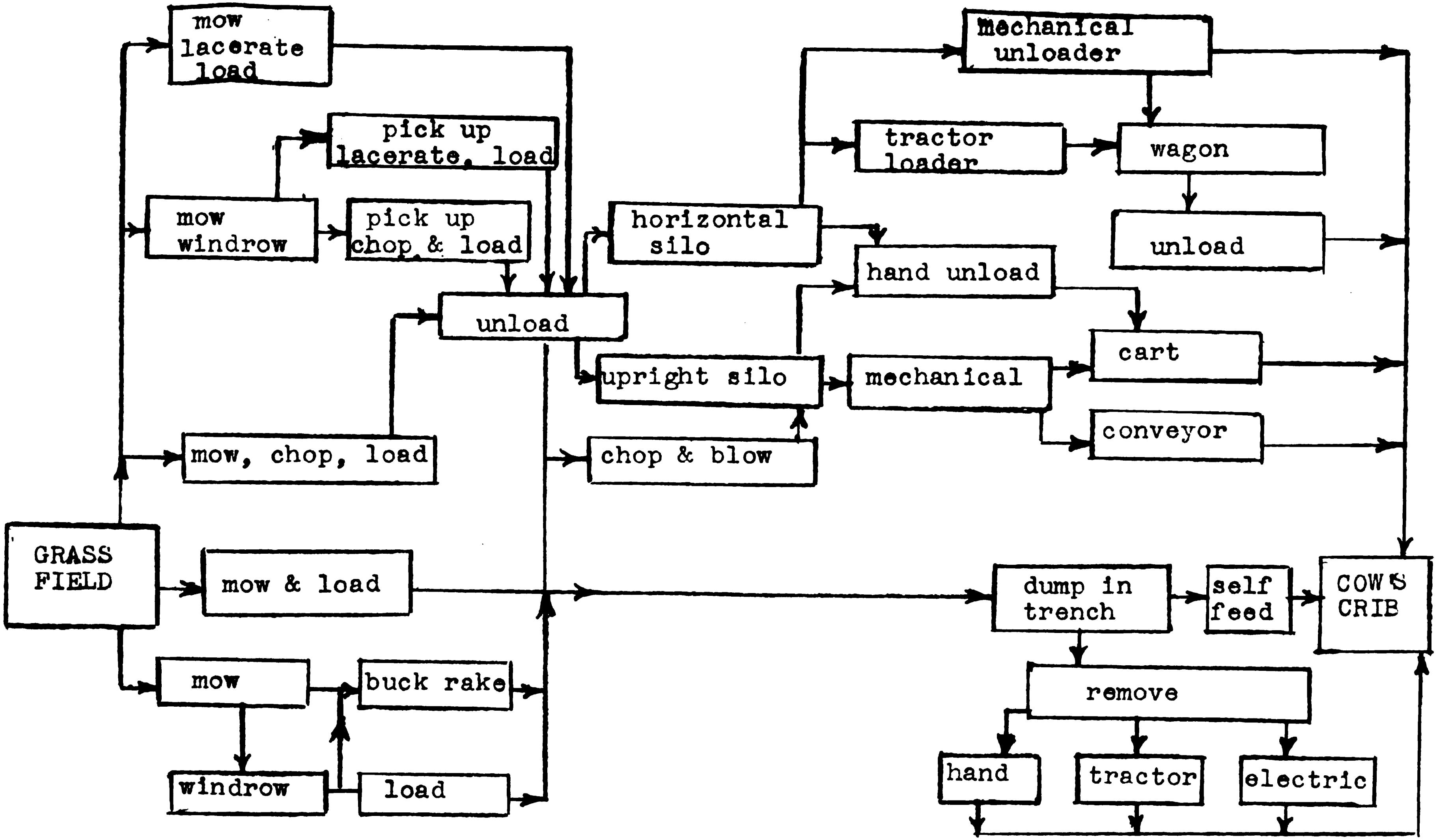

Fig. 1. Methods grass in field to silage in cow's crib.

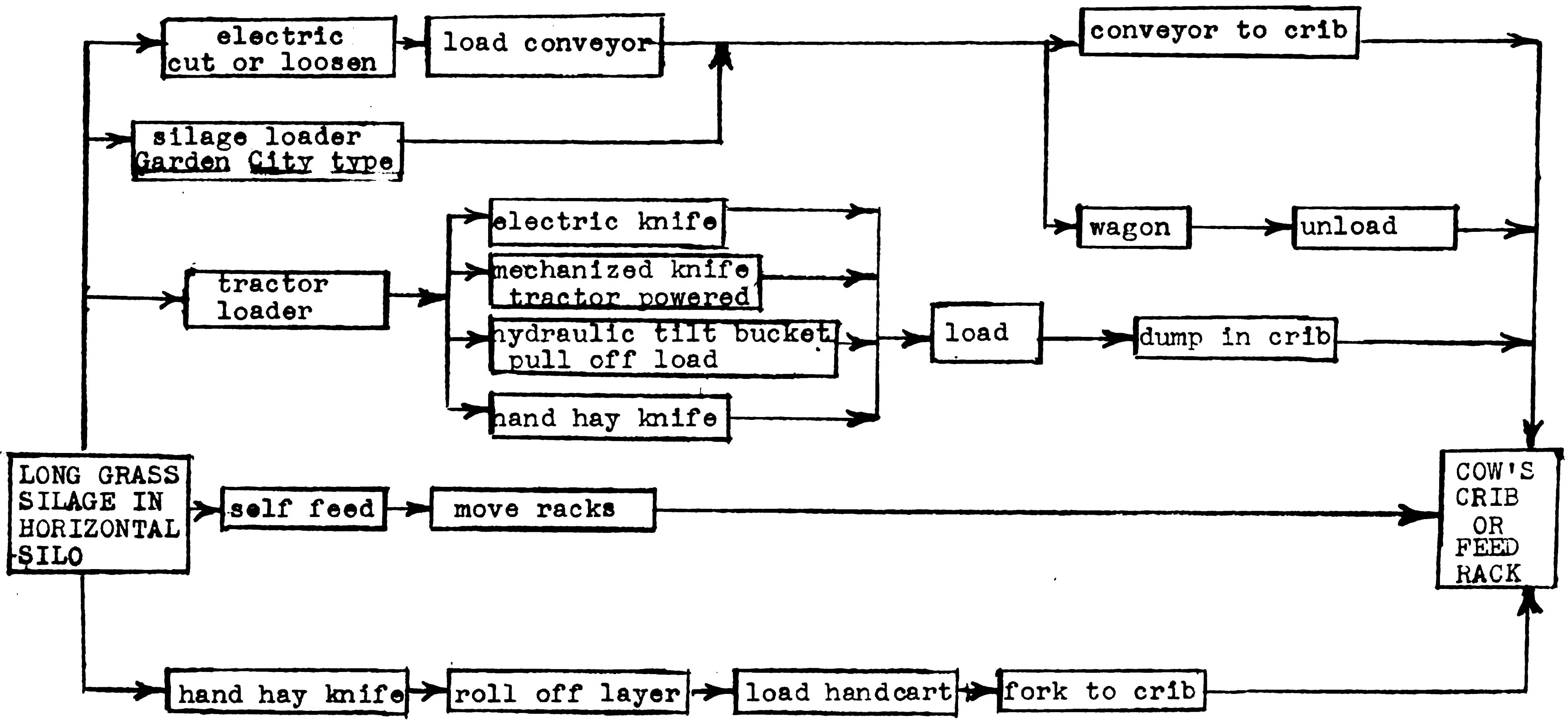

Fig. 2. Methods long-grass in horizontal silo to cow's crib.

EXPERIMENTAL PROCEDURE

Study Of Existing Horizontal Silos And Handling Procedures

Introduction

A study of some of the existing horizontal silos, including some which have been used and some newly constructed, was made in order to determine where problems exist and how some of them are solved or avoided. An explanation with pictures of some of the individual systems will help to show what is being done.

Individual Farms

Concrete floor and wood walls. Lyle Selman, operator of the Blumer farm in Alcona County, Michigan, has used a trench silo along with a vertical concrete silo built in 1950. During the spring of 1953 he completely lined his trench silo (Figures 3 and 4) which is partly above and partly below ground-level. The completed trench with concrete floor and wood walls will hold about 250 tons, or a little over three tons per foot of length. The height is nine feet, the length 80 feet, and the width 18 feet at the bottom and 19 feet at the top. The floor slopes six inches in the total length. The wall slope seems to be very important in preventing spoilage. One-half foot in the height seems to work very well, where it has been used. It allows the silage to settle and avoid air pockets

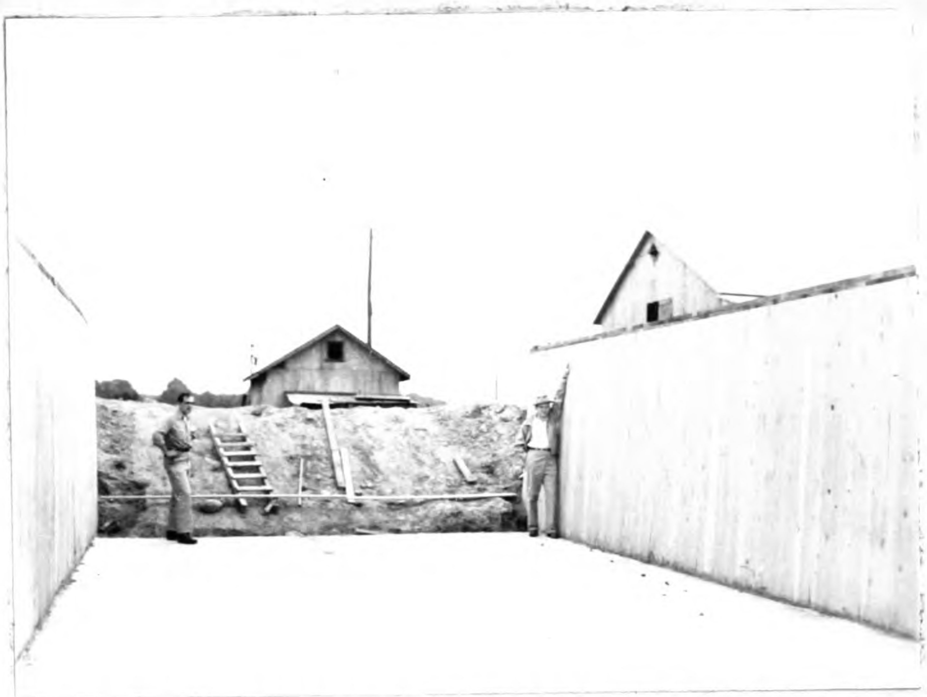

Fig. 3. Lined trench silo with concrete floor and wood walls. Entrance ramp shown at far end.

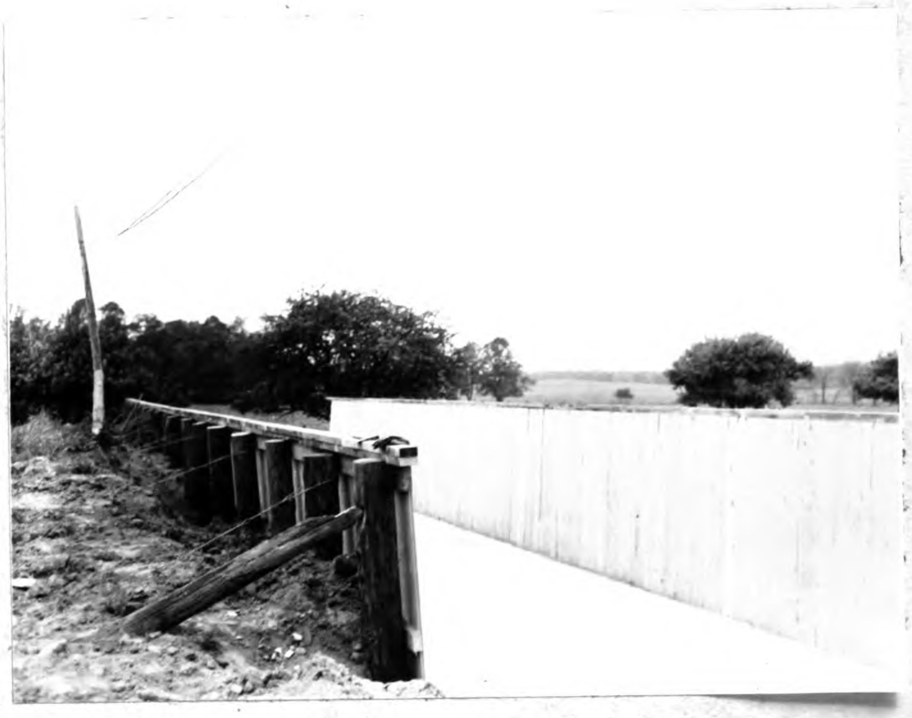

Fig. 4. From opposite end wall construction is shown. Dirt will be pushed up against the wall after filling.

where too much slope tends to make the silage separate at different levels. When packing with the tractor the wheel is run close to the wall and a good seal is obtained. The walls are built with old utility poles, five feet apart, having two-inch planks across them to which are nailed tongue and groove hemlock boards. The walls are braced at the ends with poles as well as being tied back with wire each ten feet to poles used as "dead men" in the bank which has been pushed up against the wall. The earth ramp at the entrance end of the trench silo is important in making it possible to enter the silo as it is filled.

Removal in the past has been both with a tractor loader and by hand. Feed bunks have been used in the yard near the trench silo. With the concrete floor in the silo, Selman plans to try semi-self feeding with just a pole fastened across in front of the silage to keep the cows from going into the pile before cleaning up the silage on the floor. He feels that if necessary he can still use the tractor loader and the concrete floor will pay for itself.

The concrete floor was made with readymixed concrete at a cost of $192 delivered. The lumber was cut on the farm and the poles purchased from the utility company at a very low cost as they had been discarded because of holes caused by climbing spikes.

The filling was accomplished with a two-man crew using two tractors, a direct cut field chopper, and one four-wheel trailer-type wagon with false-end-gate unloading, powered with a one-half horsepower electric motor. One tractor hauled the wagon to and from the field and did the packing in the silo. This required extra traveling for the tractor doing the packing, but a small crew harvested and stored a large amount of material in a short time.

Drive floor. The summer of 1953 was the first experience of Percy Somers and son James, Alcona County, Michigan, with a horizontal silo. They have a comparatively new barn and upright silo but they needed more storage for grass silage. They have converted the drive floor of the old barn for use as a silo (Figures 5, 6, and 7). The walls and ends are sealed with Sisalkraft paper and are well braced.

The filling was done with a four-man crew, four tractors, a pick-up chopper, a blower with power attachment for unloading false-end-gate wagons, and two false-end-gate wagons. One man operated the tractor with mower and swather attachment. The second man operated the tractor with chopper and trailing wagon. The third man operated the tractor hauling the wagons to and from the silo, and handled the unloading. The tractor used for hauling was used to operate the blower with attachment for unloading the wagons. The fourth man leveled the silage before it was packed with the fourth tractor.

This filling operation did not save much time or equipment over what would be required for a vertical silo. The gain was in the added storage space.

Fig. 5. Converted drive floor for use as silo.

Fig. 6. Filling converted drive floor with blower. Attachment for wagon unloader is shown.

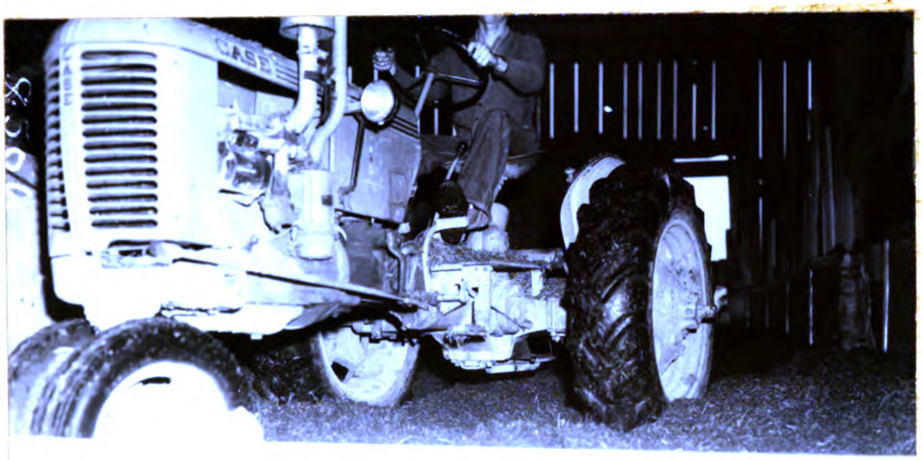

Fig. 7. Tractor used to pack silage is driven onto truck after filling operation is completed.

The removal will be handled with the tractor loader. Cutting to leave a smooth sealed surface will prevent much of the possible spoilage in this case.

<u>Dirt wall trench</u>. A trench with no lining (Figures 8 and 9) has worked very well for Laurence Gillard, Alcona County, Michigan. Where the land is quite flat the dike-type walls can be built. Semi-self feeding was successful on chopped-grass, with very little waste. The drainage problem causes some trouble in the spring when the ground thaws. With good drainage there should be no trouble with this set-up.

Fig. 8. Unlined trench silo

Fig. 9. Dike type walls and entrance ramp formed above ground-level.

The wall slope is as steep as can be attained. Clay type soils allow a steep wall while sandy soils require quite a back slope. The floor can be covered with gravel to keep it from softening in the spring. This 90 to 100 ton silo was constructed with a bulldozer for about $50. Gillard plans to construct wood walls in his silo after another year's use.

Lined and unlined. Leroy Terwilliger, Oscoda County, Michigan, used his 8' x 12' x 65' lined trench for the 1952 crop (Figure 10). During the spring of 1953 he increased the length to 140 feet, without lining the new part (Figure 11). His major change in operation was to use false-end-gate wagons in place of a dump truck. Leveling and packing was with a Ford tractor with the rear mounted cultivator for leveling. He did not have adequate drainage from his silo (Figure 10) but this condition has been improved by grading. He has put grass from 120 acres in this silo and although he prefers to feed no hay he had to buy grass 15 miles away, which he feels is too far to haul. This material will be made into hay and baled because of the distance.

Removal from the first silo was with the tractor loader. He plans to semi-self feed from the trench silo in 1953.

Portable feed bunk. Stuart Mills, Alcona County, Michigan, has solved his feeding problem with a two-wheel trailer serving

Fig. 10. Good drainage is necessary to avoid trouble in the spring.

Fig. 11. Silo extended from 65 feet to 140 feet.

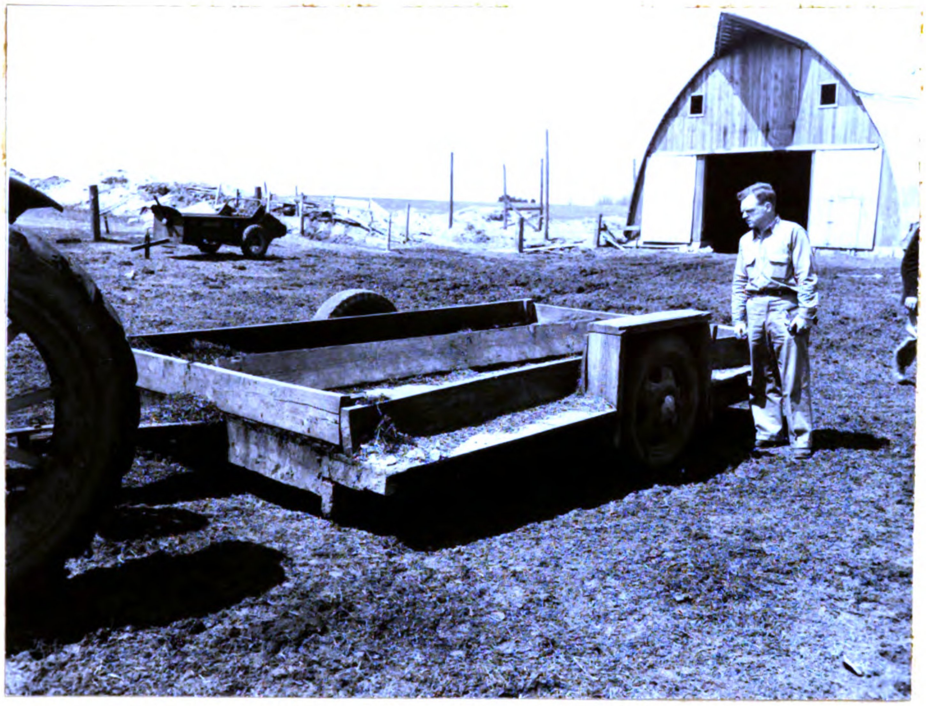

Fig. 12. Portable feed bunk saves unloading silage from wagon.

as a portable feed bunk (Figure 12). The trailer is seven and one-half feet wide by 12 feet long. The "vee" division in the center and the planks around the edges keep the waste to a very small amount. The trailer was loaded in the trench silo either by hand or with the tractor loader. When the trailer was loaded by hand a regular double-bitted axe was used to cut down the face of the pile back two to three feet from the front edge and then layers of the silage could be rolled off with a fork. The tractor loader would take the silage out, but the trench was not wide enough to allow turning of the tractor inside it, so it seemed better to do the loading by hand.

Stack with buck rake. William Engle, Alcona County, Michigan, built his first stack of long-grass silage in 1952. He felt that about a quarter or a third of the silage was wasted mainly because the alfalfa was matured too much before harvesting. Sheep were self-fed from the stack and Engle thought that another year the problems would be eliminated. The 1952 harvest was loaded from the swath with a hay loader and hauled to the stack on a truck equipped with a false floor and endless drag conveyor made from manure spreader drag bars with attachment links and chain. Two bars covered the width and were spaced about two feet apart along the chain. A chain was required at each side and one in the middle running on the three sprocket wheels at each end of the body. A hand operated ratchet arrangement at each end with a lever allowed the endless conveyor to be moved in either direction. It was found that the best way to load the truck was to load some on the back of the truck and move it forward with the ratchet system, and then load more and repeat the operation. Three piles formed the load and should not be bound together as it made it more difficult to level the load after dumping on the stack. The unloading on the stack was with the ratchet system, and small loads were much easier to handle than large ones.

Engle planned to build his stack twenty feet wide but it gradually worked out to about thirty feet. This caused difficulty in packing the edges of the stack, and it also contributed to the spoilage. The self feeding was very successful.

The 1953 crop was handled from the swath with a Super-Six buck rake. A three man crew handled the operation with three tractors, a mowing machine, and a buck rake. The tractor with the mowing machine was not kept busy all the time, but always had grass cut ready for the buck rake. The 12 foot wide buck rake picked up two seven-foot swaths at a time. The mowing machine was set to cut slightly high and the grass was not left in the swath long enough to settle. Buck rake loads averaged about fifteen hundred pounds, picking up the crop from about one-eighth of an acre each load. The buck rake was driven onto the stack and dumped (Figures 13 and 14). Some hand leveling was necessary and packing was done with the third tractor (Figure 15). The packing required fully as much time as the buck rake operation. The stack was about 20 feet wide by 80 feet long with height increasing from between three and four feet at the entrance end to between five and six feet at the opposite end. Engle feels that less hand leveling would be required if the stack were just twice the width of the buck rake. Self-feeding will be employed again for the sheep. The buck rake method is much preferred over using the hayloader and truck.

Long-grass in a trench silo. Reuben Esch, Oscoda County, Michigan, had his first horizontal silo in 1953. The trench

Fig. 13. The loaded buck rake was driven onto the stack.

Fig. 14. The buck rake dumps the grass in place to be packed.

Fig. 15. One tractor is kept busy on the stack packing the grass.

Fig. 16. Picking up the grass from the windrow.

was constructed in the corner of the field of alfalfa near where his pole barn was to be constructed. The trench was 26 feet wide by eight feet deep by 80 feet long in a bank with a high percentage of sand. The grass was mowed and then raked with a side delivery rake as a separate operation. The buck rake picked up the grass from the windrow (Figure 16) and hauled it to the trench. The tractor with the buck rake did the packing. The stacker feature was not a particular advantage where using the trench silo but was purchased for handling hay. The push-off feature is an aid in unloading the material in a more uniform layer (Figure 17). Semi-self feeding will be used in this trench for the beef cattle operation.

Fig. 17. The push-off feature helps in leveling the load on the pile.

Equipment

Arrangements were made with the Great Lakes Tractor and Equipment Company to keep the Ford tractor which was on consignment to the department, and in addition receive a Wagner WM-4 tractor loader which has the third hydraulic cylinder for controlling the bucket position.

Conventional Tractor Loader

Tests. The problem of removal appeared to be the logical place to start, as a trench silo filled with various types of materials to be fed out was available on campus. A small amount of long-grass silage was in one section of the silo so it seemed desirable to compare the difficulty of removing it with that of the chopped-grass.

The first trial was to determine if the silage could be removed with the loader as equipped. The loader handled the chopped material very well. From the standpoint of spoilage, however, it would be desirable to cut down the face of the stack, back in about two feet, to leave a smooth sealed surface. The third cylinder on the loader for controlling the bucket position is a definite advantage because the tines of the bucket can be held horizontally at any height allowing them to be driven in, to load the bucket.

Results. The long-grass caused more difficulty in removal. The tines of the manure fork could be driven into the pile but it was difficult to pull out a load. An attempt was made to drop the teeth into the pile vertically and loosen the material by rotating the fork, also by backing the tractor, but neither method was successful. If the face of the pile is cut, back in about two feet, with a hay knife or some other device, the loader can be used very well and the amount of spoilage is considerably less.

Conclusions. There seems to be much interest in a mechanically operated cutter. If a simple cutter could be developed which would mount on the tractor loader and obtain its power from the tractor, it should solve the removal problem and could be used for either chopped or long-grass silage.

Tractor Loader Modification Number 1

Construction and tests. With this in mind, an attempt was made to construct such a mechanical cutter. The first attack was to construct a fairly simple arrangement to determine what some of the problems are. This arrangement consisted of a three-sixteenths inch steel plate, with mowing machine knife sections riveted to the lower edge, mounted parallel with the tines of the manure fork. This was made to reciprocate about five inches by means of a double-acting hydraulic cylinder. It was mounted to be controlled by the same hand lever that operates the third cylinder for tilting the bucket. A three-way valve was installed in each of the hydraulic lines to the third cylinder. In order that the tines and plate could be in a vertical position at the top of the pile (Figures 18 and 19), it was necessary to alter the stops for the extreme dump position of the bucket (Figures 20, 21, and 22), and make an adapter for the upper end of the third cylinder (Figure 23). The adapter could be added by simply using one extra three-quarter inch pin as it was necessary only to raise the back end and set it forward slightly.

Results. The double-acting cylinder used was a large three-inch diameter one and the control lever was operated by hand making the reciprocation slow. The result was a tendency to slide the front of the tractor instead of cutting the material.

Conclusions. From this observation it was decided that possibly if the movement was speeded up by having an automatic valve to reverse the direction, and a smaller double-acting sylinder it might do the job.

Tractor Loader Modification Number 2

Construction and tests. Two one-inch diameter cylinders with five-inch stroke pistons were set up in opposed position to serve as a double-acting cylinder. A four-way spool valve

Fig. 18. Trial with mowing machine sections on knife.

Fig. 19. With the large cylinder and valves hand operated the reciprocation was slow.

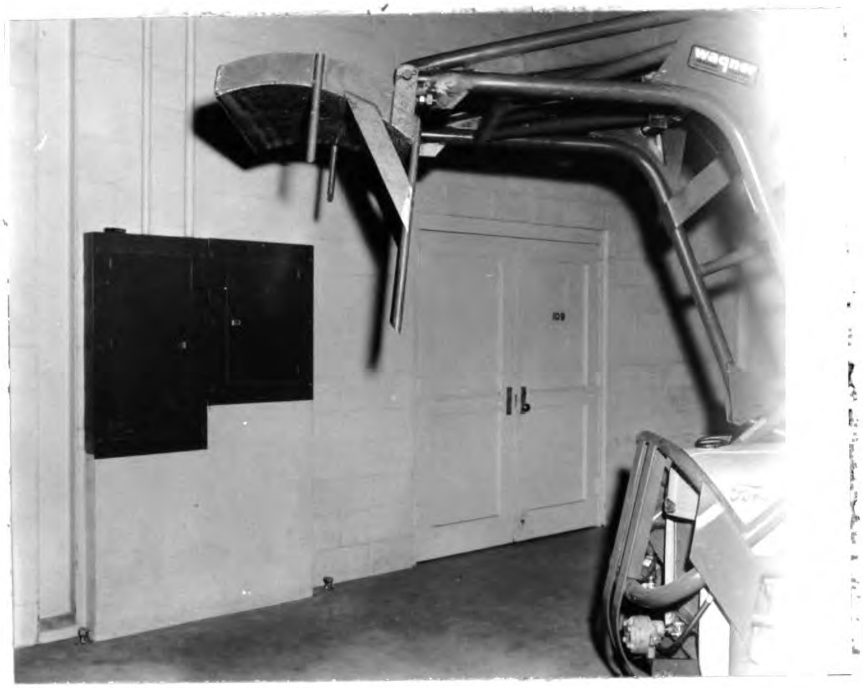

Fig. 20. Stops were altered so that tines and plate could be vertical at top of pile.

Fig. 21. Tines would normally be vertical when against the stops.

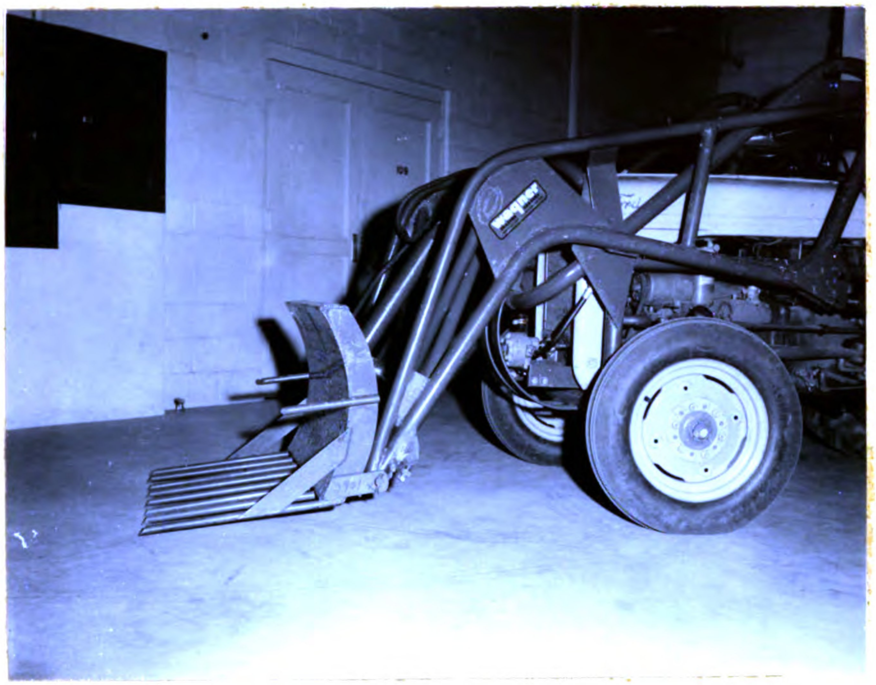

Fig. 22. With new position of third cylinder tines are tilted downward slightly with fork on the ground.

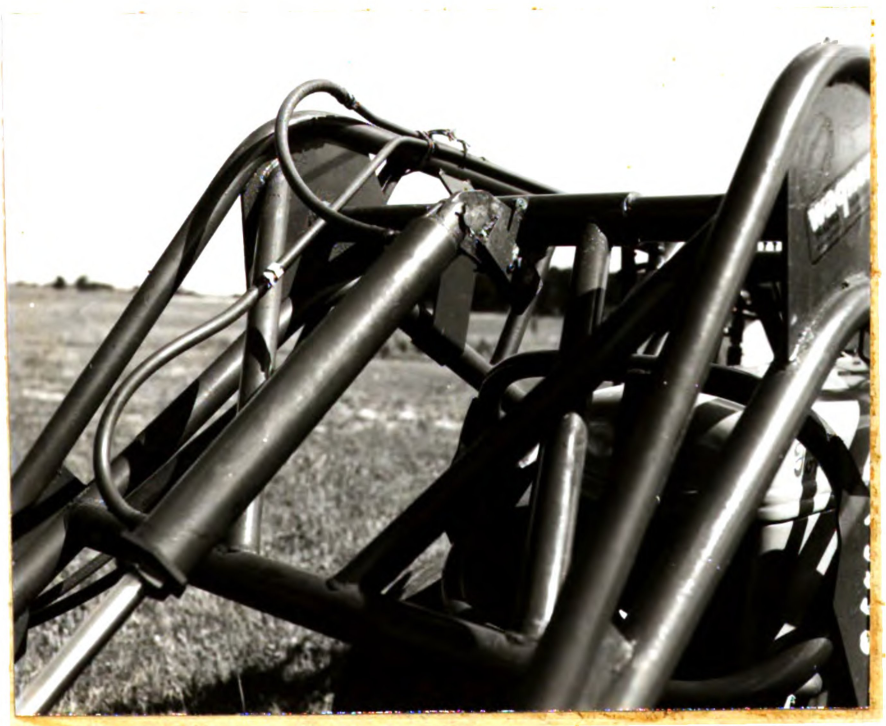

Fig. 23. Adapter at the upper end of third cylinder was necessary to have tines vertical at top of pile.

(Figures 24 and 25) was constructed and an over center spring arrangement used to change the valve position and reverse the direction of motion (Figures 26 and 27). This time the operation was controlled by pulling the lever which normally operates the third cylinder (Figure 28). The three-way valves were again used in the hydraulic lines to the third cylinder (Figure 29). One of these lines was connected to the spool valve (Figure 30) to supply the high pressure oil for operating the cylinders. The other was closed to hold the third cylinder in the desired position. A shut-off valve could have been used, or the return line could have been connected at this point. The return line from the spool valve was connected directly to the reservoir so that there was no chance of applying pressure on the return side of the valve.

With this arrangement it was possible to operate the cutter up to two hundred complete cycles per minute and vary the length of stroke up to five inches. The speed could be controlled by the engine speed as it determined the rate of output from the pump. The weight of the reciprocating mechanism caused it to have high inertia. This was realized before construction but as it was a trial model decreasing the weight to a minimum seemed inadvisable. The high inertia was very noticeable at certain intermediate speeds and would make the front of the tractor move back and forth. At slow speeds and at the higher speeds, however, the vibration was not troublesome.

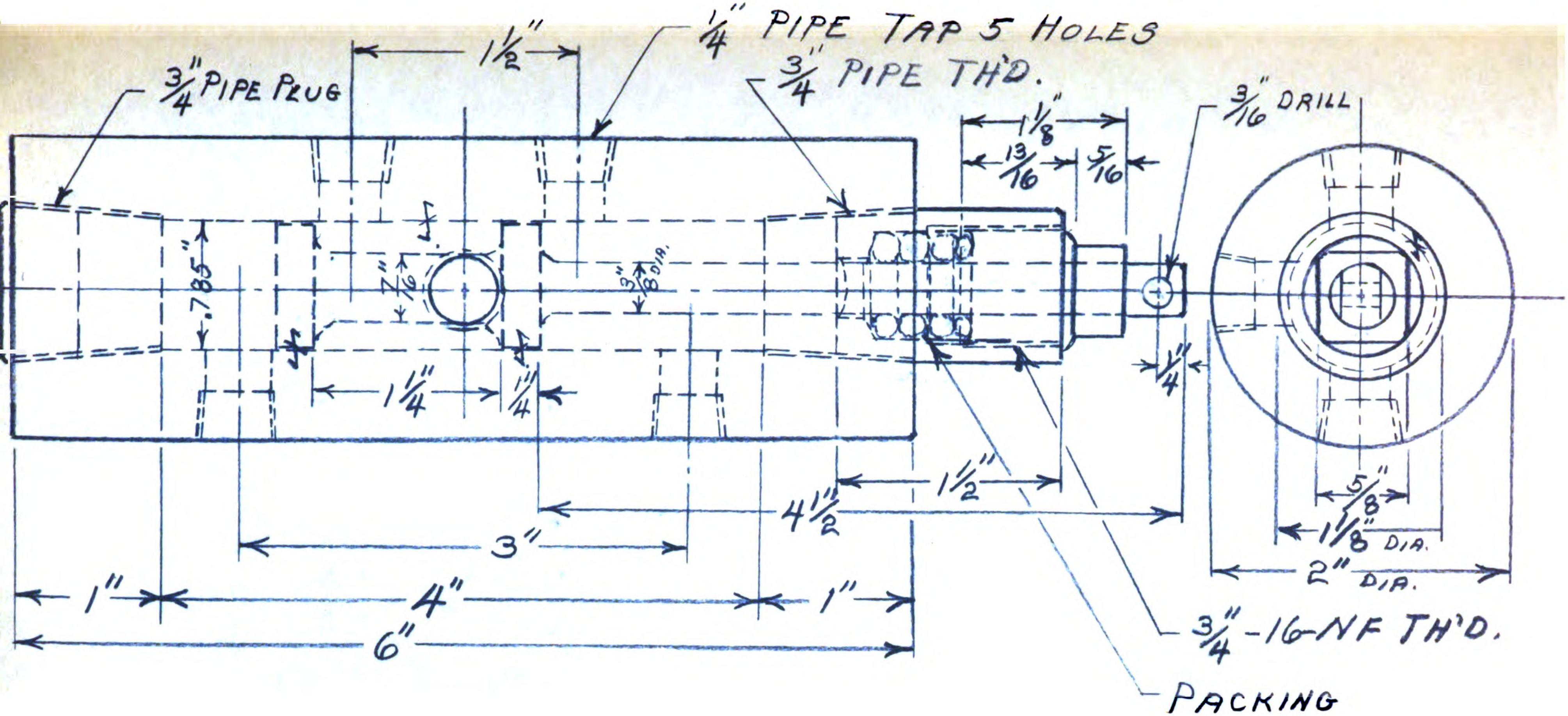

Fig. 24. Four-way spool valve assembly.

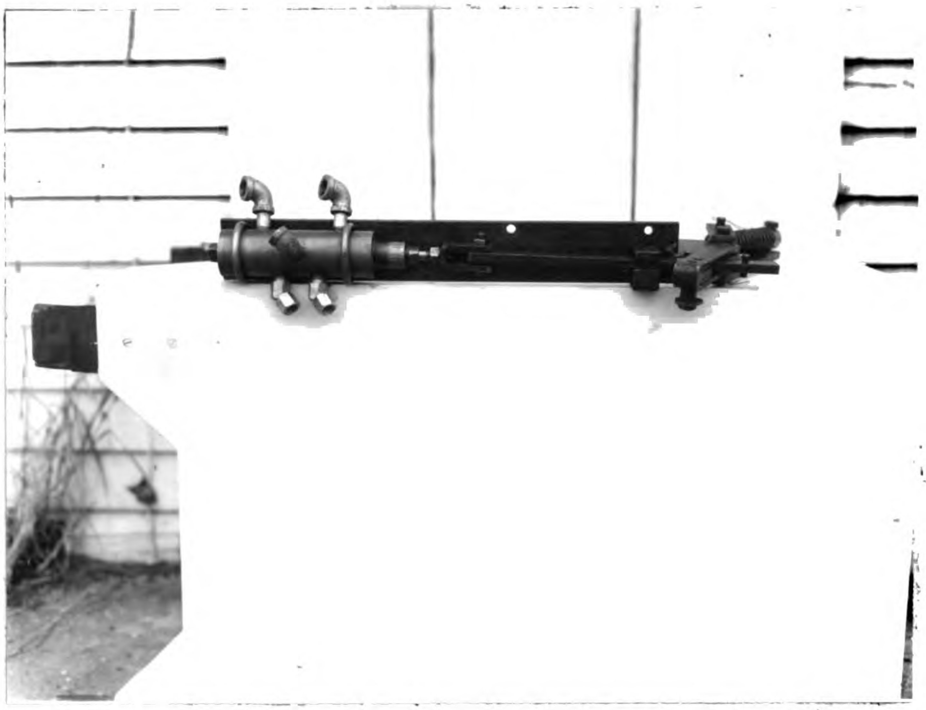

Fig. 25. Four-way spool valve.

Fig. 26. Direction changing mechanism.

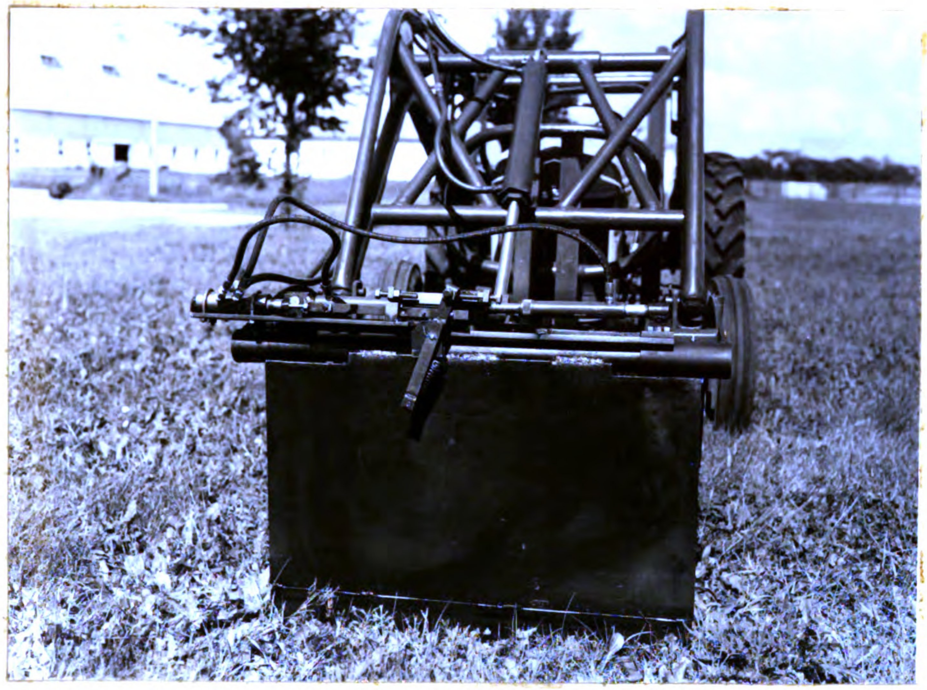

Fig. 27. Direction changing mechanism.

Fig. 28. Three-way valves in position for operating cutter. Quick coupling connections for hydraulic lines are shown.

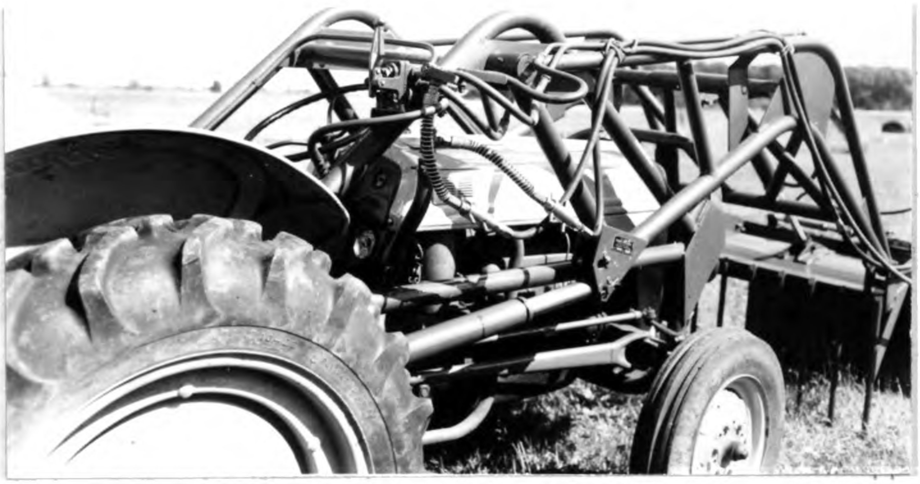

Fig. 29. Three way valves in normal position for operating third cylinder.

Fig. 30. Four-way spool valve with hydraulic lines connected.

The long-grass had all been removed from the trench silo before this set-up was ready to be tried. The first trial was in chopped-grass silage with the mowing machine sections to do the cutting as before.

Results. There was still a tendency for the front of the tractor to move back and forth but not as much as before and at the higher speeds the tendency decreased. The difficulty seemed to be that the material moved with the knife and wedged in the notches between the sections so cutting was not satisfactory.

The mowing machine sections were removed and a straight sharp-edged knife put on in their place. With this change, cutting was improved but it did not seem to be a satisfactory method.

Conclusions. If some type of shear plate could be devised to improve the cutting, it might be a very good method. After the material has been cut, the fork can be rotated by means of the third cylinder and a fork full lifted out without moving the tractor between cutting and lifting (Figure 31). It could then be loaded on a wagon or put into the feed bunks according to the feeding arrangement.

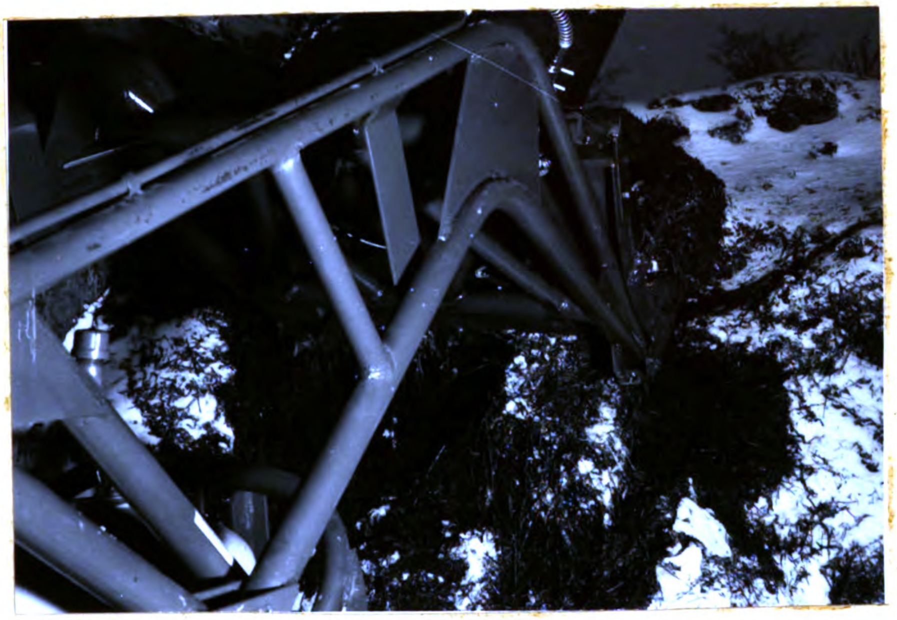

Fig. 31. Lifting load after cutting and rotating fork.

Silage Shear and Density Tests

Shear

__Tests.__ In order to obtain information on how much force would be required to cut the silage without a reciprocating motion, a chisel-like knife was adapted to a soil penetrometer (Figure 32). The spring compresses in proportion to the force applied and the amount of compression is indicated on a chart (Figure 33).

__Results.__ This showed that a force of about one hundred fifty pounds was required to cause it to cut the silage. This

Fig. 32. Chisel-type knife adapted to soil penetrometer.

Fig. 33. Penetrometer chart shows force applied.

would be one hundred pounds for each inch of knife to force it into the material without reciprocation.

Density

Tests. In order to obtain more information about the material, a box one foot square by two feet high was made of three-quarter inch plywood so that the grass silage material could be put in it and compressed to known densities. The box was set in a hydraulic press so that a known force which was indicated on the hydraulic gage could be applied. The silage was added in five pound lots, leveled, and a force of 144 pounds, or one pound per square inch, applied. A total of forty pounds of silage was put in the box before pressure and volume readings were taken.

Force was applied with the hydraulic press so that an added pressure of one pound per square inch was applied and the volume reading taken after the pressure had been maintained for five minutes, and each successive five minutes for three readings (Table, page 40). The volume changed very little during this time in most cases. Volume readings were taken after each additional pound per square inch was added, through seven pounds per square inch, or 1008 pounds per square foot.

Results. With this arrangement it was found that a pressure of 576 pounds per square foot or four pounds per

TABLE

DENSITY DETERMINATION WITH VARYING PRESSURE

Pressure (PSI)	Distance Top of Box to Silage (inches)											
	5 minutes				10 minutes				15 minutes			
	A	B	C	D	A	B	C	D	A	B	C	D
2	4.8	4.8	4.9	4.8	5.1	5.0	5.1	5.1	5.1	5.0	5.1	5.1
3	6.5	6.4	6.5	6.5	6.8	6.6	6.8	6.8	6.9	6.9	6.9	6.9
4	8.6	8.5	8.5	8.5	8.6	8.5	8.6	8.5	8.8	8.6	8.6	8.6
5	10.1	10.0	9.8	9.9	10.1	10.0	9.9	9.9	10.1	10.0	10.0	10.0
6	11.5	11.5	11.3	11.4	11.6	11.8	11.4	11.6	11.8	11.8	11.5	11.8
7	11.9	11.9	11.5	11.9	11.9	11.9	11.6	11.9	12.0	12.0	11.6	12.0

square inch gave a density of 32 pounds per cubic foot. A pressure of 1008 pounds per square foot or seven pounds per square inch gave a density of 40 pounds per cubic foot. This set-up also allowed a check on the force required for cutting. This time a regular one and one-half inch wood chisel was used and it required a very nearly constant 150 pounds to force it into the material full length. The silage continued to compress until the 150-pound force was reached and then cutting began and the force applied remained constant to push the chisel in, even including the handle. Since this checked with the value obtained in the silo using the penetrometer it is felt that the determination is reasonably accurate.

Conclusion

If it is possible to devise a cutter which would give the required force to cut out a bite of the silage it might be the desired arrangement.

Cutting Methods

Hand Cutting

Hay knife. The standard hay knife was used and found to cut satisfactorily if kept sharp. It should not be left driven into the silage as the conditions cause very rapid corrosion.

Broad-axe. The broad-axe worked very satisfactorily and can be used to good advantage in either long-grass or chopped-grass silage to leave a smooth sealed surface. Depth of cut is limited but works very well when a layer of the silage is to be rolled off by hand. A regular axe can be used in the same manner but of course does not cut as much with each blow.

Special cutter. A cutter made by welding a piece of one-inch iron pipe to a plow coulter was made (Figure 34). This type of cutter has been used by several farmers and found to meet their requirements. The weight can be increased by using an old automobile drive shaft or other solid steel bar for a handle. This type cutter may be used either as a broad-axe or in a vertical position. Cutting could be done but it seemed to be hard work.

Chain Saw

A gasoline engine-drive chain saw was tried (Figure 35) to determine if the standard cutting chains would work in the different types of silage. The chipper type chain had a tendency to drag the silage around with it and to fill up between the chain and guard around the drive sprocket but did not plug badly enough to overload the engine during the test. The chain with the chisel type tooth seemed to clear better than the chipper type. The plugging between the chain

Fig. 34. Special cutter made by welding pipe to plow coulter.

and guard over the drive sprocket was about the same. The guard was removed for the purpose of determining if the chain would clear itself by throwing the silage out if the guard did not interfere. In the chopped silage the material was thrown clear. A special guard could be used to cover the side and top of the sprocket. Covering the top would prevent throwing the material on the operator and covering the side would help for safety. The chain saw was tried for

Fig. 35. A chain saw can be used to help in removal of grass silage from the horizontal silo.

cutting in the bundles of peas and oats which were harvested with a grain binder. Some of the long straw followed around with the cutting chain but this did not prevent cutting. If a chain saw is available, it could be used for cutting and would be much faster and easier than the hand cutting method.

The Oregon Chain Company has been developing a special chain for silage cutting to be used with chain saws. This will undoubtedly do a better job than any of the standard chains used for cutting wood.

RECOMMENDATIONS FOR FUTURE STUDY

Future study on the use of the horizontal silo should include:

1. Requirements of structures to preserve properly the silage.
2. Equipment requirements with a complete time study of the different methods of harvest and removal of the silage.
3. Relative feed value of long-grass and chopped-grass silage.
4. Determination of crops best suited to storage in the horizontal silo.
5. Development of mechanical equipment to handle removal of long-grass silage.
6. Determination of cost per ton of good silage with the different storing and handling methods.

SUMMARY

The horizontal silo has proven itself to be one of the outstanding features of many farms. It is an economical method of increasing feed storage as well as being used alone for silage storage. The tenant farmer might not feel justified in constructing vertical silos to meet his needs, whereas a horizontal silo could be used with very little cost.

The removal problem can be handled by many acceptable methods. A mechanical method is to be desired and as soon as a mechanical cutting method is developed, the removal will no longer be a problem.

A mechanical cutter using a chain saw type of cutter mounted on the tractor loader driven by a hydraulic motor is a possibility which should be tried. Another type of device which might solve the problem would be a cutter mounted on the tractor loader so that after the tines of the loader are driven into the pile it could be forced down into the pile to cut out a bite which could be lifted out. For a large operation, equipment is available which will remove the chopped silage so no problem arises. When the small operation becomes properly mechanized, the horizontal silo is doing its duty.

CONCLUSIONS

1. The horizontal silo is a good storage for silage in many situations.
2. The field chopper will be used for harvesting grass-silage on the farms where it is available. The direct-cut field chopper method is probably the fastest of all methods where crew and equipment are available.
3. The buck rake method can be used with the least equipment and crew.
4. The removal problem can be more difficult with long-grass than chopped-grass silage.
5. A completely satisfactory device for removing long-grass silage mechanically from a horizontal silo has not yet been developed, but with information now available it should be possible.

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