UNIVERSITY OF IDAHO

College of Agriculture

Tramp Iron Removal From Livestock Feeds

D. W. WORKS and J. W. MARTIN

IDAHO Agricultural Experiment Station

Bulletin 356
April 1961

Summary

THE prevalence of tramp iron in feeds has increased with the use of wire-tie field balers and choppers. The occurrence of "hardware sickness" varies with locality, but the problem exists wherever cattle are fed. In areas where twine balers are used exclusively or where no baling is done, tramp iron still finds its way into the feed. This points out the fact that conscientious, precautionary measures to prevent the contamination of livestock feeds is the first step in protecting livestock from "hardware disease." This practice will become even more important as greater use is made of nonmagnetic materials, such as aluminum, in farm equipment. These materials cannot be removed with magnetic separators.

The purpose of magnetic separators should be to guard against contamination of feed materials by stray iron which cannot otherwise be prevented through cleanliness and good management. As a final protection, stomach magnets should be used for more valuable livestock such as breeding stock and dairy cows.

Tramp Iron Removal From Livestock Feeds

D. W. WORKS and J. W. MARTIN*

THE growing incidence of tramp iron in livestock feeds is partly due to the machine age in agriculture. Increased mechanization of our farms has introduced many machines to handle feeds in every operation of production and use. Iron has been the most common metal used in constructing the machines; and pieces such as bolts, nuts, screws, cotter pins, pieces of wire, and broken parts often find their way into livestock feeds. Also negligence in handling stray baling wire, staples, nails, and wire tag holders from feed sacks results in thousands of pieces of stray iron contaminating feed during any of the operations from the field to the feed bunk.

The average livestock grower is faced with a tramp iron problem that not only causes damage to grinding and mixing equipment and loss of time, but may cost him many dollars in animal losses. Contaminated feed is usually the source of the small pieces of sharp metal swallowed by livestock causing "hardware disease", known technically as Traumatic Gastritis, one of the most difficult diseases to accurately diagnose. Cattle are particularly subject to "harware disease"; however, sheep and goats may also be affected (9).

A study of records show that 1 cow out of every 20 is afflicted with "hardware disease", while 1 cow out of every 50 dies from it (5). The occurrence of "hardware sickness" will vary with the locality. About 7,000 head of cattle are condemned each year by the Federal Meat Inspection Service as being unfit for human consumption because of this disease (9). Only cattle condemnations made at plants under federal inspection are included. Other losses to livestock growers include animals perished on the farm, poor gains in the feedlot, and loss of milk production.

The eating habits of cattle is probably the primary reason why they swallow so many metal objects. The cow chews her food only briefly at first, but later regurgitates and chews it more thoroughly. For this reason small metallic objects are easily swallowed. Mineral deficiency in feed rations has also been observed as a cause for cattle to eat or lick metallic or leather material (10).

A metallic object that has been swallowed will usually lodge in the bottom of the reticulum or second stomach. Much of this material does little harm; however, sharp pieces such as baling wire

* Assistant Agricultural Engineer and Farm Electrification Project Director; Professor and Head, Department of Agricultural Engineering, respectively.

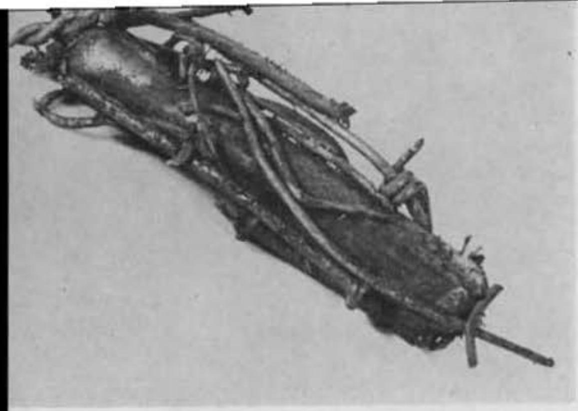

Figure 1 — An Alnico bar magnet covered with tramp iron as recovered from the stomach of a cow by the Department of Veterinary Science, University of Idaho.

and nails may pierce the stomach wall and enter vital organs such as the heart, lungs, and liver or puncture the diaphragm (8). A piece of tramp iron may also only partially penetrate the stomach wall causing pain which temporarily causes the cow to go off feed. However, reoccurrence probably will take place (5). An affected cow may show lameness due to the exertion of moving causing pain. Loss of appetite will follow and eventually death if the metal enters a vital organ (8).

MAGNETIC DEVICES

Fortunately, almost all the metal entering the feed is iron or other ferrous metals that can be removed with magnetic devices. One such device, now in popular use, is an Alnico magnet that is 2½ to 3 inches long and ½ inch in diameter (see Figure 1). When given orally to a cow, the magnet lodges in the reticulum or second stomach and remains to collect small pieces of metal. Gibson (7) and Carroll (1) report the frequency of "hardware disease" in cattle has been greatly reduced by the use of Alnico bar magnets. Gibson estimated the bar magnet is about 70 percent effective in his area, while Carroll reports the use of bar magnets in one instance had reduced the necessity for treatment to 1 percent. In another instance, Carroll found the bar magnets to be about 50 percent effective. Carroll reported that metal objects held by the magnet may be of such a nature and so heavy that occasionally ulceration of the floor of the reticulum may result and removal of the offending material by surgery is necessary. While the bar magnet is quite effective, it should not be considered a cure-all (7) and great care should be used to prevent tramp iron from finding its way into cattle feeds (10). While the cost of the bar magnet may seem to be small, approximate veterinarian fee is $4 per head (7), this expense may become quite an item in large herds.

The ideal solution to the tramp iron problem would be to prevent contamination in the first place by careful handling of baling wire, shipping tag wires, nails, etc. However, the livestock producer seldom has full control over the feeds which he purchases, especially from other farms. Therefore, the most convenient solution seems to be to remove all tramp iron from livestock feed just before it is fed.

Magnetic separators have found acceptance in many industries in removing ferromagnetic objects from nonmagnetic materials being processed. The stray iron not only contaminates the product and causes machine damage, but also may cause sparks during grinding and become a fire hazard. This same principle may be applied to agriculture in removing stray iron from livestock feeds. Improvements in the permanent magnet steels and alloys have made the powerful, highly coercive permanent magnets of today very effective for use on the farm. These magnets are of sufficient strength that an additional source of power is not necessary as is the case with electromagnets. The new alloys have given the magnets a high resistance to demagnetizing.

Some of the more commonly used commercial magnets suitable for farm use are:

Magnetic Pulleys can be effectively used with belt conveyors to remove tramp iron from livestock feeds. These pulleys are readily available in standard widths and diameters. One of the advantages in using magnetic pulleys is its self-cleaning ability. A typical application is shown in Figure 2.

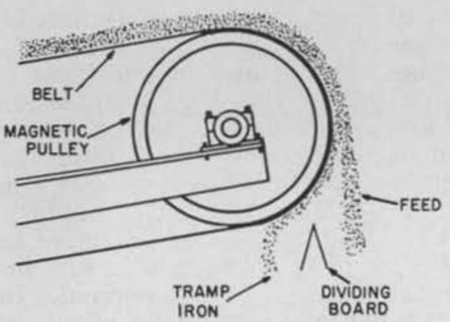

Figure 2 — A magnetic pulley in operation demonstrating the principle of separating tramp iron from granular feeds.

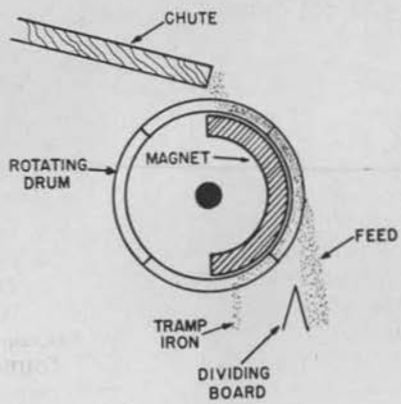

Figure 3 — A cross section of a magnetic drum illustrates the removal of tramp iron from livestock feeds.

Magnetic Drums are designed for use in gravity systems. The flowing material passes over the outer drum causing it to rotate. An inner stationary magnet collects and holds the pieces of iron to the drum until the iron passes out of the magnetic field at the bottom, thus separating the iron particles from the feed, as illustrated in Figure 3.

Magnetic Plates can be installed in feed chutes. As the material passes over the magnet, iron particles are collected and held by the magnet. Also, the plate may be suspended above the material on a conveyor belt. However, since the force of gravity must also

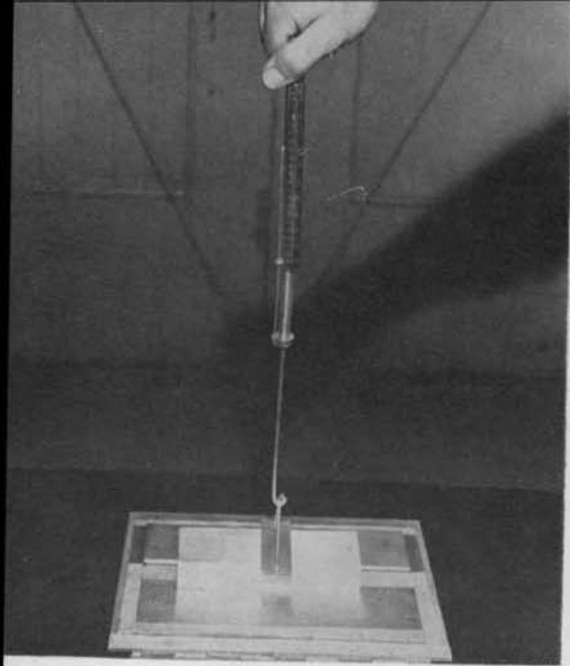

Figure 4 — Measuring the pulling-power of a plate magnet.

be overcome, more powerful magnets are required for this type of installation.

Preliminary work on the problem of removing metallic objects from livestock feeds was conducted by the Idaho Electrification Committee as early as 1932. However, permanent magnets at that time demagnetized with age and soon became ineffective. Electromagnets were found to be bulky, impractical, and expensive. However, by 1952 improvements in magnet steels made the permanent magnet a more desirable method of removing iron pieces from nonmetallic material. In 1952, an Experiment Station Project was inaugurated by the Department of Agricultural Engineering. One of the objectives of this project was to determine the best methods of adapting permanent magnets to remove tramp metal from livestock feeds (2, 3).

In 1957, a Farm Electrification Project was inaugurated in cooperation with the Department of Dairy Science to develop a less expensive magnetic device to remove iron from the ground feed used at the Dairy Barn on the University of Idaho farm.

Experimental Work

DETERMINING THE RELATIVE STRENGTH OF THE PERMANENT MAGNETS

The Eriez Manufacturing Company has pioneered the adoption of standard tests for the purpose of determining the relative strength of magnetic separation equipment (2). Their efforts resulted in the formulation of two standard tests with equipment to perform each test.

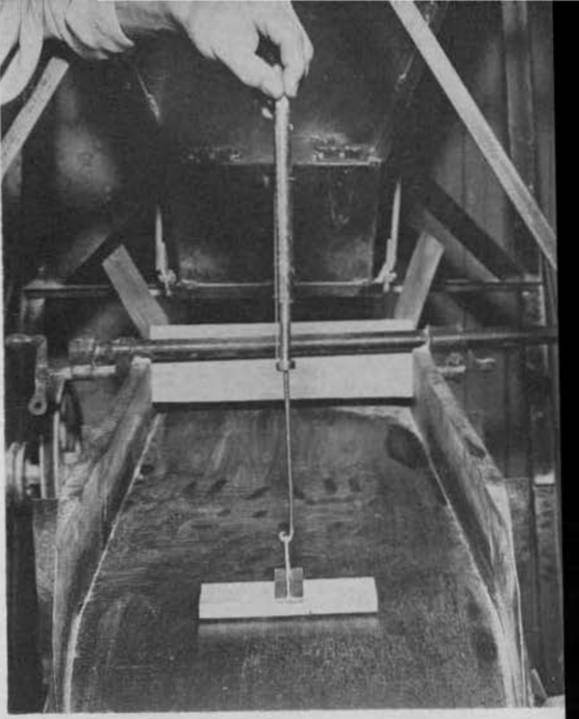

Figure 5 — Measuring the pulling-power of a magnetic pulley.

1. A test which measures the pulling power of the separator. Equipment for this test consists of a spring scale graduated in ounces attached to a standard ⅛″ x 1″ x 3″ steel test piece. This test measures the most important characteristic of a magnetic separator—its ability to reach up through a material stream to remove tramp iron.

2. A test which measures the holding power of the separator. The equipment for this test consists of a spring scale graduated in pounds and a standard 1″ diameter steel ball which is placed in contact with the face of the separator. The results of this test are of secondary importance, since the main requisite of an efficient separator is its ability to throw a powerful magnetic field deep into the material stream. Sufficient holding power is of course necessary to insure the retention of all tramp metal attracted to the magnet; however, a separator designed to supply the ultimate in pulling power usually supplies more than sufficient retention or holding power.

Basically the pull-test scale measures the amount of force necessary to remove the steel test piece from a predetermined position within the magnetic field supplied by the separator. This force measured in ounces is an accurate indication of the magnitude of the magnetic force acting on the test piece. Figures 4 and 5 show the pulling-power being measured for the various type separators that were used in this work. On the plate magnets it is essential that the pull scale be operated so that the steel piece breaks contact evenly. Normally this means that it must be pulled at right angles to the magnet face. For the pulley and plate magnet with the recessed air gap it was necessary to pull the scale at an angle to cause the test piece to break evenly.

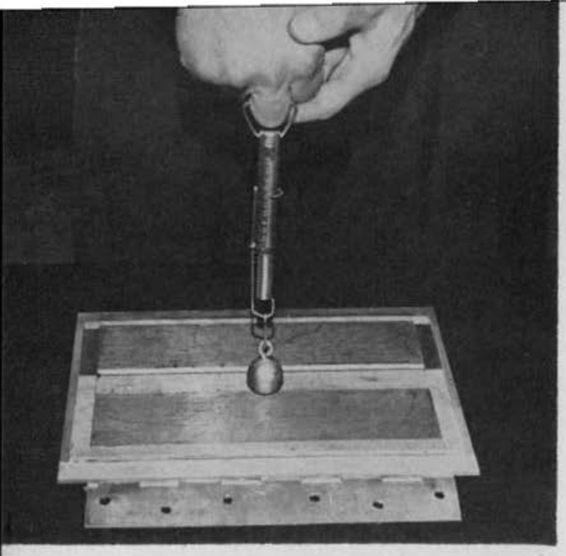

Figure 6 — Measuring the holding-power of a plate magnet.

In order to test the magnetic pulling-power of various positions within the magnetic field, non-magnetic spacers of ¼ inch, ½ inch and 1 inch thickness were stacked together to equal the desired distance from the face of the magnet. Table 1 gives the values of the pulling-power of the magnets used in the experimental work.

Table 1. Pulling-power of magnetic equipment

Type	Size (inches)	Trade-name	Pulling-power (ounces) Distance Away (inches)					
			1¾	1½	1¼	1	¾	½
Plate	7 x 10	Extra-power	8	11	15	23	33	45.5
Plate	7 x 10	Extra-power	9	12	17	22.8	33	45.5
Pulley*	12 x 14	Perma-pulley	5.6	7	11	16	22	32
Pulley	12 x 14	Perma-pulley	7	10	14.5	22	30.5	45
Plate	7 x 16	Ultra-power	12	15	21	29	38	51
Plate**	7 x 10	Ultra-power	11	16	21.5	29	39	52
Plate***	7 x 10	Ultra-power	12.5	18	24.5	33	46	61
Plate	7 x 10	Super-power	17.5	22.5	30	39	57	80

Table 2. Holding-power of magnetic equipment

Type	Size (inches)	Trade-name	Holding power ounces
Plate	7 x 10	Extra-power	208
Plate	7 x 10	Extra-power	208
Pulley*	12 x 14	Perma-pulley	8
Pulley	12 x 14	Perma-pulley	176
Plate	7 x 16	Ultra-power	192
Plate**	7 x 10	Ultra-power	224
Plate***	7 x 10	Ultra-power	224
Plate	7 x 10	Super-power	232

* With 3/16 inch conveyor belt
** With recessed air gap
*** With recessed air gap and slanted pole face

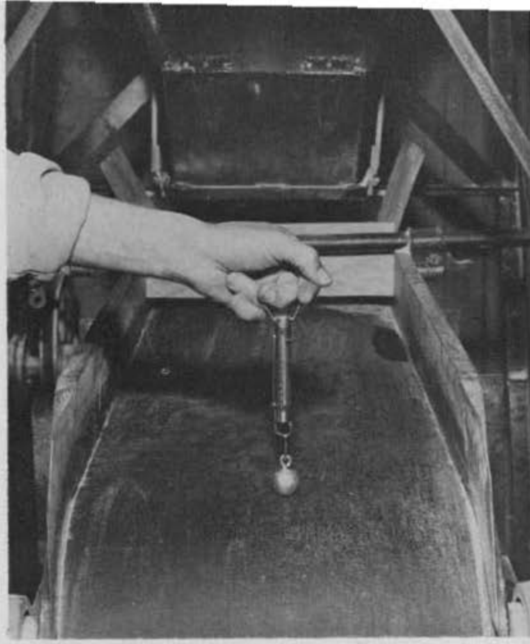

Figure 7—Measuring the holding-power of a magnetic pulley.

The amount of force necessary to pull a 1-inch-diameter steel ball from the pole plate edge bordering the center insulation strip on the magnet is a measure of the holding-power of the magnet. This test is always taken with the ball placed directly on the magnet face. Figures 6 and 7 show the holding power of the various separators being measured. Table 2 gives the results of these determinations.

THE PERFORMANCE OF THE MAGNETIC PULLEY IN REMOVING TRAMP IRON FROM GRANULAR FEEDS

Two types of permanent magnets have been used in the research studies. The first tests were made with a magnetic pulley (2). The objective of this phase of the study was to determine the feasibility of the use of the magnetic pulley as a tramp iron separator for granular livestock feeds.

A magnetic pulley 12 inches in diameter and 14 inches wide was obtained from the Dings Magnetic Separator Company of Milwaukee, Wisconsin. This unit was installed at the discharge end of a conveyor belt; the principle being that a piece of tramp iron would be held to the conveyor belt by the pulley until carried out of the magnetic field by the belt leaving the pulley on the underneath side. The metal piece then dropped into a box beneath the pulley, thus effectively separating tramp iron from granular feeds. Figure 8 shows the apparatus used in this phase of the research work.

The conveyor was driven by an electric motor through a gear reduction to give a belt speed of 150 feet per minute. It was found that the back end of the box must almost touch the belt in order to catch all of the separated tramp iron. Wheat, oats, and barley, both whole and ground, were run over the conveyor at depths of

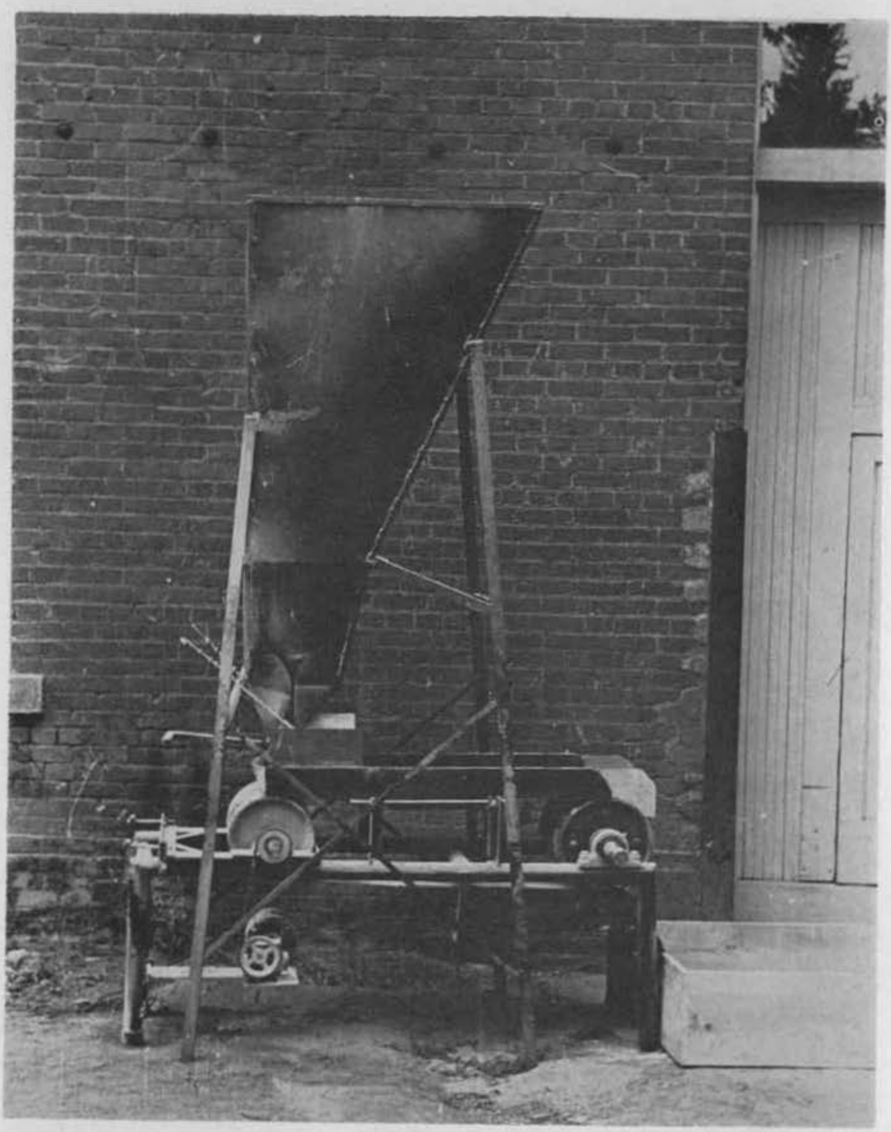

Figure 8 — Research equipment used to determine the performance of a magnetic pulley in removing tramp iron from granular feeds.

2, 2½, and 3 inches. Tramp iron was added to the grain as it was put into the hopper and pieces were checked after the run to see if all were removed by the pulley. Fifty-three assorted pieces of tramp iron were added to about 200 pounds of grain for these tests. The depth of flow was controlled at the discharge of the hopper by a baffle board positioned above the conveyor belt at the desired height.

Table 3. Tramp iron separation with magnetic pulley
Conveyor speed—150 feet per minute

No. of tests	Type of Material	Depth of Flow	Results
5	Whole Wheat	2	Complete removal of metal
8	" "	2½	" "
8	" "	3	" "
5	Whole barley	2	" "
8	" "	2½	" "
8	" "	3	" "
5	Whole oats	2	" "
8	" "	2½	" "
8	" "	3	" "
5	Ground wheat	2	" "
8	" "	2½	" "
8	" "	3	" "

Table 3 shows the results of the tests with constant conveyor speed and varying depth. Because the first misses occurred in testing the ground barley and ground oats the result of the tests with this material are shown separately in Tables 4 and 5 to indicate the type of tramp iron which was missed.

A second series of experiments measured the pulley's performance at various conveyor speeds. The conveyor was driven through a variable-speed V-belt drive. The testing procedure was to start with a speed setting fast enough to cause the pulley to miss a few pieces, then gradually reduce the conveyor speed until complete removal was attained. Repeated tests were run at the first speeds of complete removal to insure that they were slow enough. Table 6 shows the results of these tests.

Table 4. Tramp iron separation from ground oats
Conveyor speed—150 feet per minuate

Tramp metal added	No. of pieces	Depth of ground oats (inches) 2					2½								3							
Test No.		1	2	3	4	5	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Bolts (small)	6																	1*				
Baling wire	16							1							1		1	1			1	
Nuts	3								1								1		1			
Washers	3												1					1		1		
Nails (assorted)	19																			1		
Iron scraps	3																					
Six inch welding rod	1																					
Lag screw (small)	1																					
Wood screws (small)	1																					
Staples (assorted)	3																					
Cotter pin	1																					

* Number indicates the number of pieces not removed.

Table 5. Tramp iron separation from ground barley
Conveyor speed—150 feet per minute

Tramp metal added	No. of pieces	Depth of ground barley (inches) 2					2½								3							
Test No.		1	2	3	4	5	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Bolts (small)	2																					
Baling wire	16																		1*			
Nuts	3														1	1			1			
Washers	3														1							
Nails (assorted)	19																					
Iron scraps	3																					
Six-inch welding rod	1																					
Lag Screw (small)	1																					
Wood screw (small)	1																					
Staples (assorted)	3																					
Cotter pin	1																					

* Number indicates the number of pieces not removed.

CONCLUSIONS

The use of the magnetic pulley as a separator should be considered wherever a conveyor belt is part of the feed handling process. The magnetic pulley can give protection during continuous operations and has all the advantages of a permanent magnetic separator plus the added feature of being self-cleaning. A pulley 8 inches in diameter and about 8 inches wide would have sufficient conveying capacity.

Table 6. Maximum belt speeds giving complete removal of tramp iron from granular feeds.

Material	Depth of flow (inches)	Belt speed (fpm)	Capacity bu./hr.
Whole wheat	1″	425	1988
	2″	385	3590
	3″	235	3240
Whole barley and oats	1″	440	2059
	2″	385	3590
	3″	250	3498
Ground wheat	1″	415	1940
	2″	239	2230
	3″	151	2110
Ground barley	1″	409	1920
	2″	267	2490
	3″	151	2110
Ground oats	1″	405	1890
	2″	318	2970
	3″	151	2110

Tables 1 and 2 show that the presence of the belt reduces the effective pulling and holding power of the pulley. Therefore, the belt should be as thin as possible.

The results of the tests show that certain shapes and sizes of tramp iron are more difficult to separate than others. First pieces to be missed usually were the heavier pieces such as nuts, bolts, and washers. There is a greater inertia to overcome by the magnet to attract these pieces before they are carried on past the pulley. The shape of the piece determines how easily it can be pulled through the material by the magnet. Pieces with a very uneven and rough shape offer more resistance to being drawn through the material.

In testing the ground wheat, oats, and barley, the pieces not removed were sometimes those carried on the very top of the material. The texture of the ground grains offered more resistance to the tramp iron being drawn to the pulley. However, the speed of the conveyor can be controlled to assure complete removal of the tramp iron. Figure 9 shows the conveying capacity of a magnetic pulley at various depths of material.

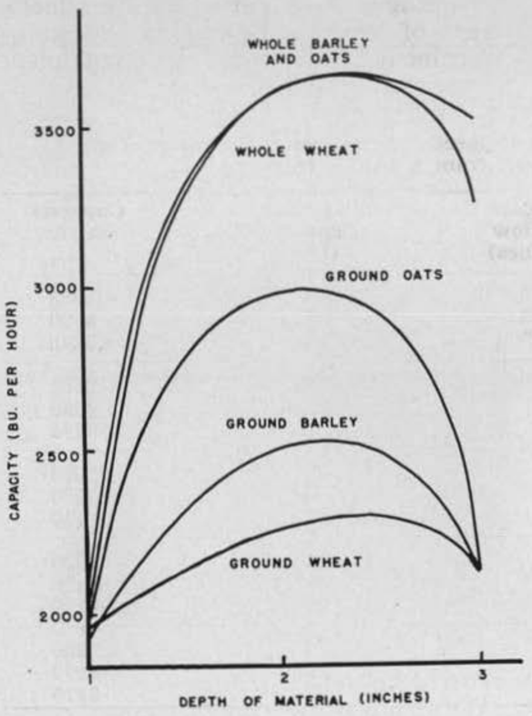

Figure 9 — Conveying capacity of a 12 x 14 magnetic pulley with complete removal of tramp iron.

THE PERFORMANCE OF THE PLATE MAGNET IN REMOVING TRAMP IRON FROM GRANULAR FEEDS

The object of this phase of the research was to determine the feasibility of using a magnetic plate as a tramp iron removal device.

A 10-inch super-power plate magnet was installed in a wooden chute. An overhead hopper supplied the grain through an adjustable slide to control the rate of grain flow. The angle of inclination of the chute was made variable from 0 degrees (horizontal) to 60 degrees incline, as shown in Figure 10.

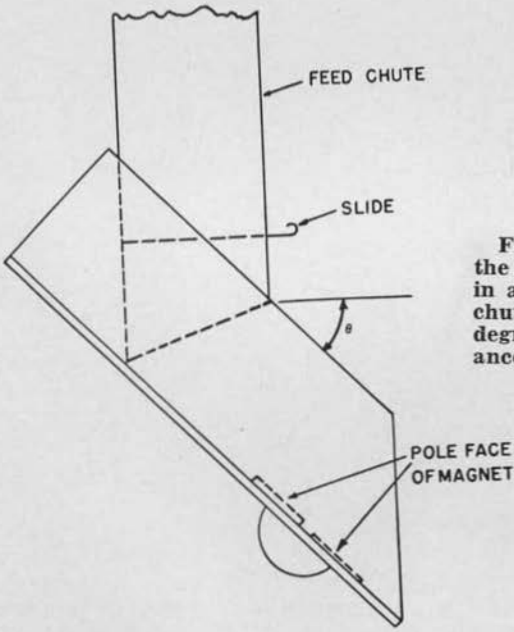

Figure 10 — A sketch showing the installation of a plate magnet in a feed chute. The slope of the chute was adjustable so that the degree of incline for best performance could be determined.

WHOLE GRAIN

The magnet's effectiveness in removing iron was first tested with barley. Tramp iron, consisting of five ¼-inch washers, five 3/16-inch washers, five shingle nails, and 15 pieces of iron wire less than 1 inch in length was added to the barley. The weight of the grain placed in the hopper was 333 pounds. Succeedingly larger slide openings were used to increase the rate of flow to determine the maximum rate at which the magnet would remain effective. The time to discharge the 333 pounds of grain was measured to determine the average grain flow in pounds per minute, which was then converted to bushels per hour as shown in Table 7.

Table 7. Tramp iron separation from barley with plate magnet

Run	Material missed	Angle of incline °	Rate bu. /hr.
1	0	60°	1058
2	0	60°	1330
3	0	60°	2030
4	1 nail	60°	2450
5	0	45°	897
6	0	45°	1310
7	0	45°	1920
8	1 washer	45°	2680
9	1 nail	30°	875

GROUND FEED

The same device was used to determine the effectiveness in removing tramp iron from ground feed. However, due to erratic flow of the ground feed, this device was not suitable. In order to effectively use this method, an additional control device was neces-

Figure 11 — Front view of the machine showing drum and magnet as installed in the chute. Arrows point to the pole faces of the magnet.

sary to regulate the flow and to feed the material evenly over the face of the magnet.

This was accomplished by placing a motor-driven drum between the slide opening and the magnetic plate. Short prongs were welded to the drum to give better control and to prevent the ground material from clinging to the down spout and chute. This device made possible variable control over the rate of flow by adjustments in drum speed, clearance between drum and chute, and length of the prongs (see Figure 11).

Tabulated data of tests made with this device are shown in Table 8.

Table 8. Ground feed capacity with changes in drum speed and clearance.

Cylinder speed (rpm)	Pounds per min.	Length of prongs	Clearance inches
43	236	1½"	1¾"
43	115	¾"	⅞"
43	71.0	⅜"	⅝"
43	51.5	⅜"	½"
21	82.5	¾"	⅞"
21	34.8	⅜"	½"

During the above tests, 20 pieces of iron wire less than 1 inch in length, 20 shingle nails and 10 washers of assorted sizes were used as the tramp iron; all pieces were removed by the magnet. Maximum flow rate tested was 236 pounds per minute which was 3½ times the blower capacity of 67 pounds per minute.

The laboratory test indicated that a positive adjustment for setting the drum to chute clearance with ⅜-inch prongs and a drum speed of 43 rpm would be the most effective and most easily adjusted for the University Dairy Barn installation. The steel drum used during the laboratory tests was mounted in a wooden chute built for installation in the dairy barn. The drum was driven by a ⅓ hp explosion-proof capacitor motor. This device is shown in Figures 11, 12, and 13. Figure 14 shows the tramp iron taken from 7 tons of ground feed.

CONCLUSIONS

A magnetic plate can be installed in a chute to effectively remove tramp iron from whole grains when the angle of incline is 45 to 60 degrees. The 10-inch permanent magnet of super-power quality removed tramp iron from the grain at a rate of flow up to 2,000 bushels per hour.

By using a motor-driven drum to regulate the ground grain flow, this magnet can effectively remove tramp iron with a rate of flow up to 14,000 pounds per hour.

Figure 12 — A slight "Hump" appears (see arrow) in the feed stream as it flows over the magnet. Most of the metal is held in this area. Excessive flow rates prevent this 'Hump" from forming, and pieces of iron pass over the magnet.

TRAMP IRON REMOVAL FROM CHOPPED HAY

The objective of this phase was to develop a method of tramp iron removal from hay (2). It is very difficult to remove tramp metal from hay because of the texture. However, the possibility of removing tramp iron from chopped hay appeared to be greater than from any other form. Although plate magnets and magnetic pulleys have all been used to advantage for removal of iron from liquid, ground, and granular feeds, in the case of hay or silage the plate magnet alone has gained only partial success for these materials.

This work was initiated with the offer of the Fred G. Greaves Company of Seattle, Washington to furnish plate magnets and several pneumatic hump designs for testing at the University of Idaho. The Department of Farm Operations at the University of Idaho furnished the hay, hay chopper, and tractor for the tests.

DESIGN NO 1

The first design is shown in Figure 15. Two Eriez, extra power (7-inch by 10-inch) plate type magnets were installed. The first

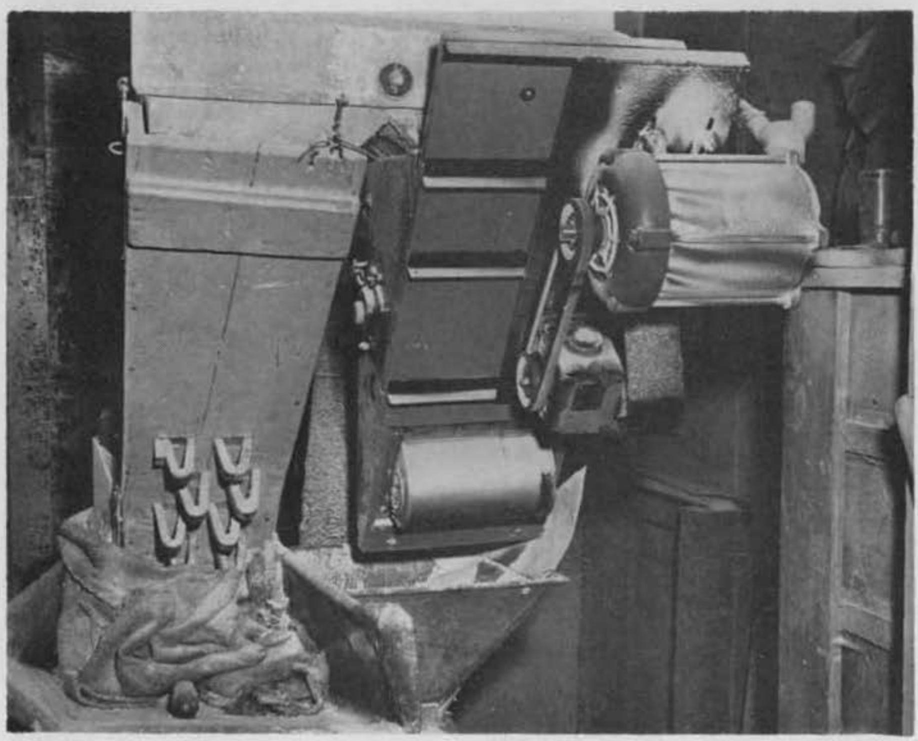

Figure 13 — Rear view of machine showing motor mounting, belt arrangement, and gear reduction unit. The magnet can be seen at the lower part of the chute. The other chute shows an old installation using U-shaped magnets. These have become demagnetized and are of little value.

test runs were made to determine if the hay would pass through without plugging the blower lines. Air velocity through the device was found to be 8,000 feet per minute without hay in the blower. About 2½ tons of string-tied bales were chopped during the first test.

Test runs were also made to determine the ability of magnets to remove tramp iron from the hay. Two tons of wire-tied bales were chopped and tramp iron was added during five separate trials. Table 9 shows the results of these tests. Tests were made at reduced blower speeds to determine the effects of a lower air velocity. The blower was plugged at an air velocity of about 5,000 feet per minute.

The two extra-power magnets were not strong enough, and were replaced by two stronger magnets. An ultra-power (7-inch by 16-inch) magnet was installed lengthwise in position one and a super-power magnet (7-inches by 10-inches) was installed in the second position. This installation is shown in Figure 16.

Table 9. Results of tests with design No.1

Run No.	No. of pieces added	1st position (10″ extra)	2nd position (10″ extra)	No. lost
1	15	4	5	6
2	15	3	5	7
3	15	5	6	4
4	15	4	7	4
5	15	4	6	5
1	15	4	4	7
2	15	5	4	6
3	15	5	7	3
4	15	6	6	3
5	15		(Blower plugged)	
	(16″ Ultra)	(16″ Ultra)	(10″ Super)	
1	15	5	6	4
2	15	3	7	5
3	15	3	8	4
4	15	6	8	1
5	15	7	6	2
Stainless steel strip and baffle (leather)				
1	15	11	4	0
2	15	11	4	0
3	15	13	1	1
4	15	10	5	0
5	15	12	2	1
6	15	9	4	2
7	15	14	0	1
8	15	9	4	2
9	15	11	2	2
10	15	8	5	2
11	15	13	2	0
12	15	10	5	0

Although the percent of tramp iron removed increased with the use of these stronger magnets, the way in which the tramp iron was located at the downstream edge of the magnet indicated that the force of the moving hay was gradually pulling the metal objects loose from the magnet in the first position. To observe this action, glass windows were installed in the sides at the position of the magnets so that with the aid of a strong light, any movement of the wire could be observed. Metal retained by the first magnet was slowly forced to the downstream edge and pulled loose. The downstream edge of the first magnet was fitted with a stainless steel strip about $^3/_8$-inch high to stop the metal at the edge. The second magnet had a raised pole face so no strip was

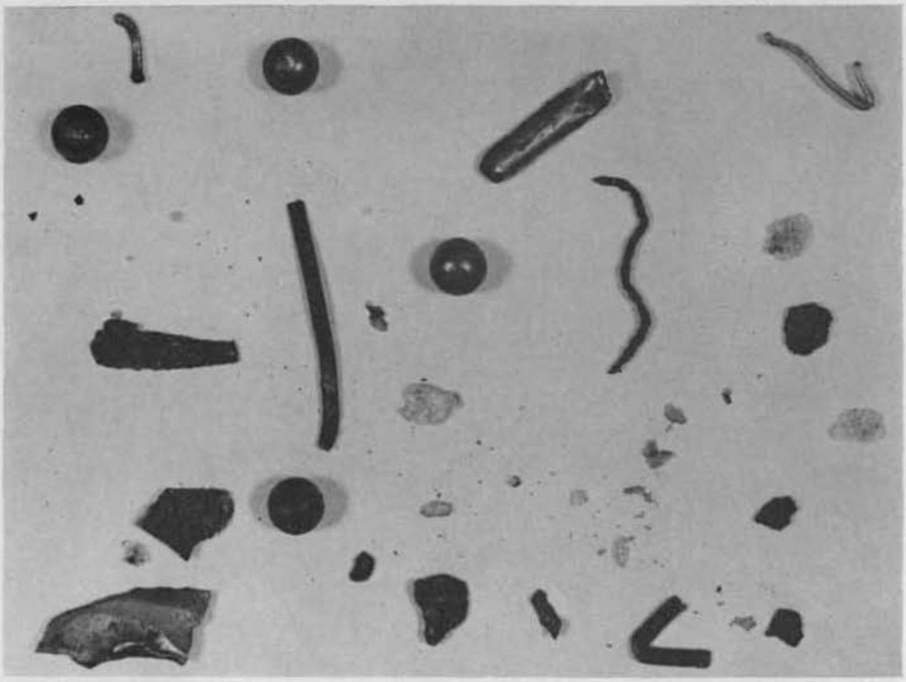

Figure 14 — Tramp iron taken from 7 tons of ground feed.

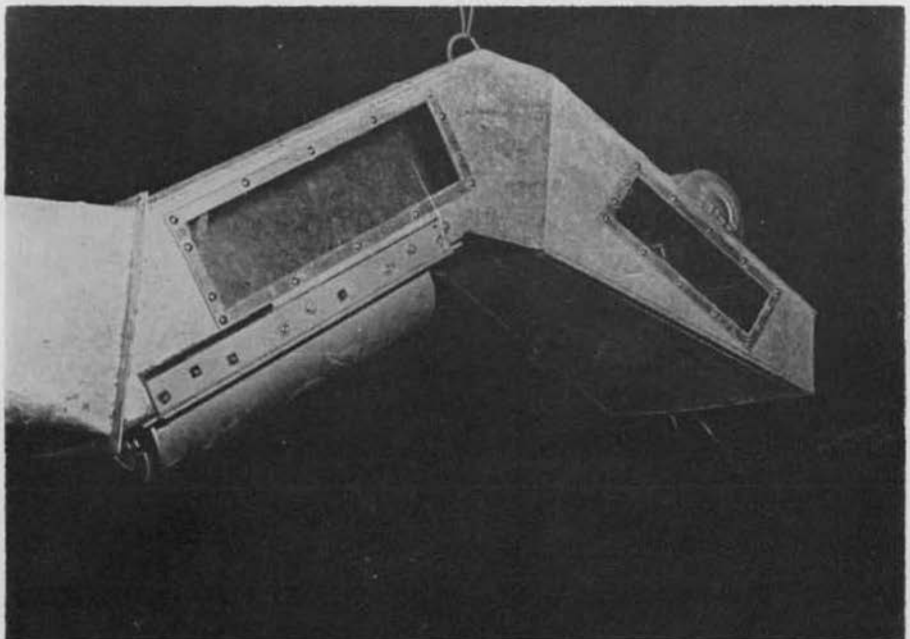

Figure 15 — Design number 1 used in removing tramp iron from chopped hay showing the location of the plate magnets. Windows were installed to observe the movement of tramp iron on the face of the magnet.

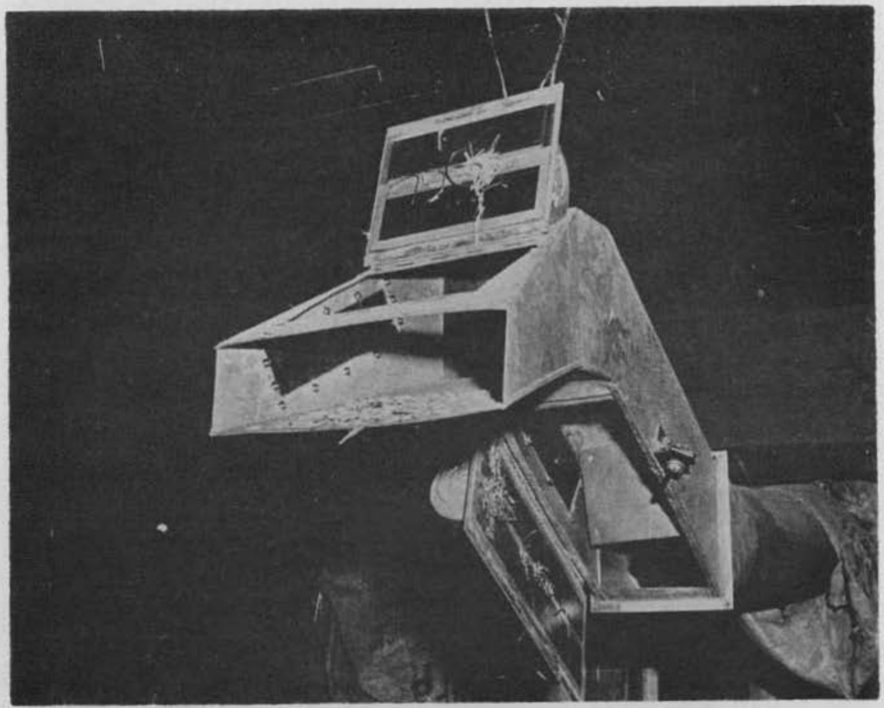

Figure 16—Tramp iron collected during the one trial run of Design Number 1.

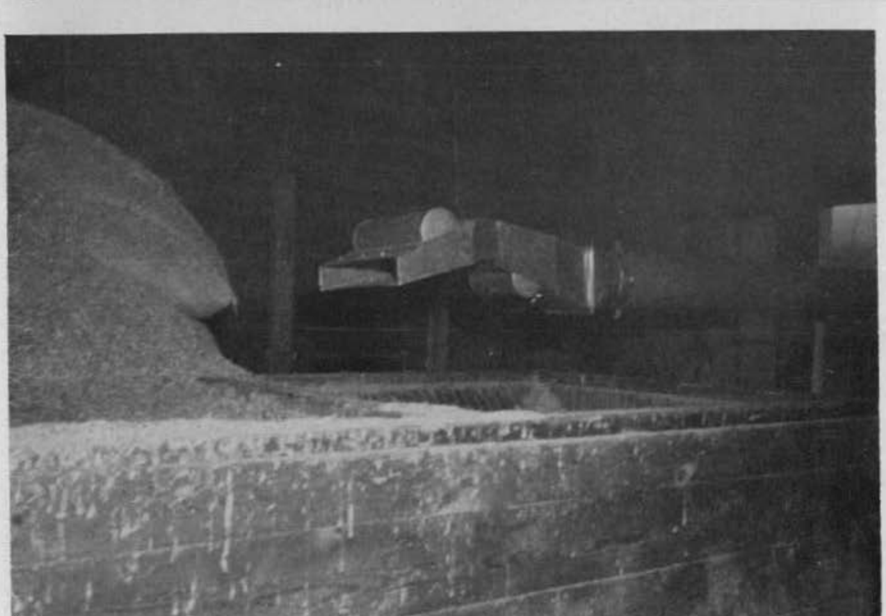

Figure 17 — Design number 2 showing the flatter profile.

Table 10. Results of test with design No. 2

Run No.	No. of pieces added	1st position (16″ extra)	2nd position (10″ super)	No. lost
1	15	4	8	3
2	15	6	7	2
3	15	2	9	4
4	15	5	8	2
5	15	4	6	5
6	15	5	9	1
7	15	4	9	2
	pieces added	(10″ extra)	(10″ super)	
1	15	5	6	4
2	15	3	9	3
3	15	6	6	3
4	15	5	5	5
5	15	4	9	2

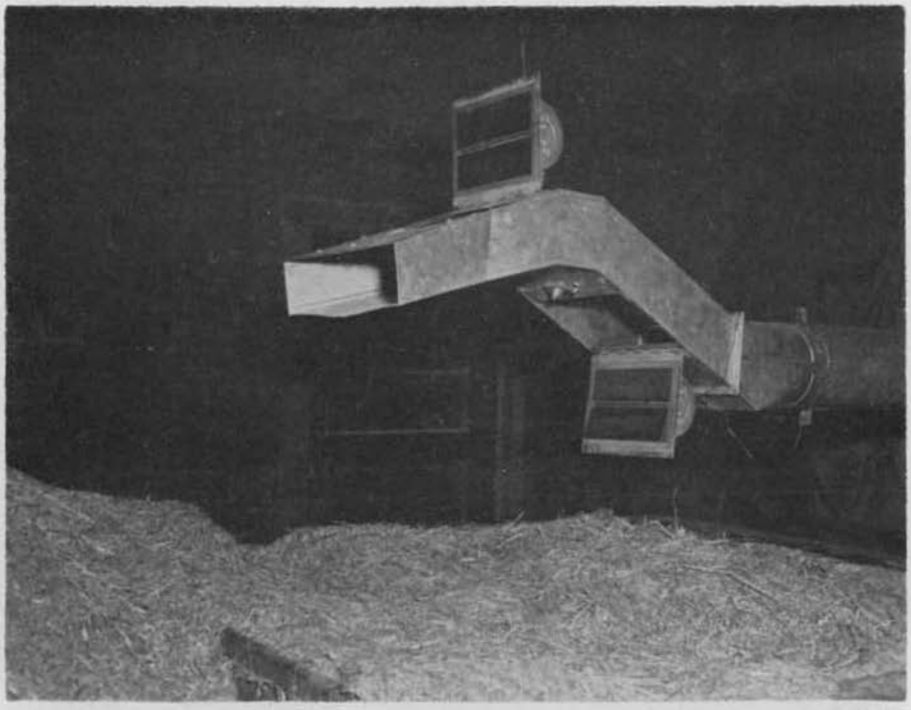

Figure 18 — Design number 3 showing the location of the plate magnets.

Table 11. Test results for design No. 3

Run No.	No. of pieces added	1st position (10″ extra)	2nd position (10″ super)	No. lost
1	15	3	6	6
2	15	1	12	2
3	15	4	6	5
4	15	3	6	6
5	15	1	8	6
With leather baffle.		10″ super)	(10″ extra)	
1	15	10	3	2
2	15	11	3	1
3	15	9	2	4
4	15	12	1	2
5	15	9	3	3
With stainless steel strip on edge of second position magnet				
1	15	7	5	3
2	15	12	2	1
3	15	12	1	2
4	15	9	3	3
5	15	10	2	3
1*	15	11	2	2
2	15	14	1	0
3	15	9	6	0
4	15	14	1	0
5	15	13	2	0
6	15	12	3	0
7	15	15	0	0
8	15	11	3	1
9	15	13	1	1
10	15	12	3	0
		(10″ ultra)	(10″ extra)	
1	15	12	3	0
2	15	8	5	2
3	15	8	6	1
4	15	8	5	2
5	15	14	1	0
6	15	8	7	0
7	15	10	3	2
8	15	12	3	0
9	15	10	4	1
10	15	10	5	0
		(10″ ultra)**	(10″ ultra)***	
1	15	8	7	0
2	15	12	3	0
3	15	14	2	1
4	15	12	3	0
5	15	12	3	0
6	15	8	7	0
7	15	7	8	0
8	15	10	5	0
9	15	11	4	0
10	15	10	5	0

* The extra-power magnet in position No. 2 was moved 4 inches to what seemed to be more in the path of the material and a one-half inch stainless steel strip was installed on the downstream edge.

** Uultra-power magnet with recessed air gap and slanted pole face.

*** Ultra-power magnet with recessed air gap.

necessary. In addition, the original cloth baffle was changed to a leather baffle to force more of the flow on the magnet. As may be seen in Table 9, performance was much improved.

DESIGN NO 2

Although over 95 percent removal was obtained with the first design, a second design was made to utilize less expensive magnets. Figure 17 shows a flatter profile and reduced vertical cross-section. It was hoped that with this flatter profile the device would be less likely to plug the blower at the slower speeds. The reduction in vertical cross-section brought the material closer to the magnet. Trial runs, as shown in Table 10, indicated this design plugged the blower as readily as the first and tended to miss about 10 percent of the tramp iron.

DESIGN NO 3

The third device was designed on the basis of the performances of the first and second designs. Figure 18 shows this design with the same profile of No. 1 and the reduced vertical cross-section of No. 2. The first tests were made with an extra-power magnet in position one and the super-power magnet in the second position. Better performance was obtained with the super-power magnet in the first position and a leather baffle over it. The best results were obtained when the raised pole face on the super-power magnet was downstream, and the extra-power magnet was moved up four inches. A ½-inch stainless steel strip was added to the downstream edge.

Since this design gave the best results, it was decided that possibly the ultra-power magnets might be sufficiently strong if magnets with recessed air gaps were used. Therefore, the tests were made with an ultra-power magnet with a recessed air gap and an inclined pole-face in position one and an extra-power magnet in position two. The extra-power magnet was finally replaced by another ultra-power magnet with a recessed air gap. Final testing resulted in nearly complete tramp iron removal. Air velocity for final testing was about 5,600 feet per minute. Table 11 gives the results of all the tests on this design.

CONCLUSIONS

Examinations of the test results show that a number of things determine the success of a magnetic separator for removing tramp iron from chopped hay. It should be recognized that the unit which gave the best performance in these tests would not necessarily be successful for all situations. However, the third design with the two ultra-power magnets should give good protection.

The air velocity through a tramp iron removal device such as these must be controlled within certain limits. An air velocity greater than 5600 fpm will carry the tramp iron past the magnet; whereas, with an air velocity of 5000 fpm or less, the blower will plug up, especially if a very long horizontal pipe is used. The rise in the stream flow must be high enough for all of the material to change direction against the leading face. The magnet in the second position must be directly in the path of the material.

The purpose of the stainless steel strips was to prevent any tramp metal from being pulled off on the downstream edge; although, where the strips were used, the metal was retained on the entire surface of the magnet. This could be a result of the boundary flow change caused by the presence of the strips. The strips must be of a nonmagnetic material so that the magnetic field will not be affected by installing it at the edge.

Any nonmagnetic material could be used for these strips if it is strong enough. Movement of the tramp iron on the face of the magnet could also be prevented with recessed air gaps between the poles, or some form of raised pole face on the downstream side. The recessed air gap or the raised pole face will trap any piece of tramp iron that is being moved along the face of the magnet.

The merits of the leather baffle are questionable. The tendency was to direct the flow down on the first magnet, but the presence of a baffle offered more resistance to the flow and increased the tendency for the device to clog. These devices were made to operate on an 8-inch blower pipe; however, with a suitable alteration, these same devices would work just as well with smaller pipe provided the desirable air velocity is maintained through the device.

The Eriez Manufacturing Company holds patents on the "Magnetic Hump", but have indicated they will allow the use or manufacture of the "Hump" when Eriez magnets are used.

Acknowledgments

THIS bulletin is a joint contribution of the Department of Agricultural Engineering, University of Idaho, and the Idaho Farm Electrification Committee.

E. S. Craig and W. H. Knight, former members of the Department of Agricultural Engineering, performed the research using the magnetic pulley with whole and ground grain and using the plate magnets with chopped hay.

The authors acknowledge the cooperation of L. G. Williams, Department of Agricultural Engineering, who helped with the testing of the plate magnet with whole and ground grains. Also, the Department of Dairy Science for their cooperation.

The authors express their appreciation to Professor J. W. Bailey, D.V.M., Associate Veterinarian and M. L. Hemstrom, Extension Animal Husbandman, for their review of this material and for their suggestions.

Dings Magnetic Seperator Company of Milwaukee, Wisconsin, and the Fred G. Greaves Company of Seattle, Washington, who provided the magnets.

Bibliography

(1) Carroll, R. E., "Use of Magnets in the Control of Traumatic Gastritis of Cattle" Am. Vet. M. Assn. J. 129:376-8, October 15, 1956.

(2) Craig, E. S., "Some Mechanical Devices for Handling Livestock Feeds", unpublished thesis for Master of Science Degree, Department of Agri. Engr., University of Idaho, 1954.

(3) Craig, E. S., and W. H. Knight, "Tramp Iron in Livestock Feeds", Farm Electrification Leaflet No. 28, University of Idaho, December, 1954.

(4) Dobie, John B., F. C. Jacob, and L. C. Kleist, "Tramp Iron in Chopped Hay", California Agricultural 7:10-11, September, 1953.

(5) Herrick, F., "Cut Down Hardware Disease Problems", Wallace's Farmer 84:50, April 4, 1959.

(6) Knight, W. H., and E. S. Craig, "Magnetic Devices to Remove 'Tramp Metal' from Livestock Feed", mimeograph report presented at the 47th annual meeting, American Society of Agricultural Engineers, University of Minnesota, June 21, 1954.

(7) Mann, David H., "Magnets Inside Cows Prevent Hardware Diseases" Idaho Farmer, pg 33, March 20, 1958.

(8) Newlander, J. A., "Cows are Walking Junk Yards", Hoard's Dairyman 101: 934, September 25, 1956.

(9) Schipper I. A., "Hardware Disease", North Dakota Agri. Exp. Sta., Farm Research Bulletin 20:6, pp 20-1, July, 1958.

(10) Swan, L. C., "Hardware Disease in Dairy Cows", Guernsey Breeders Journal 99:339, February 15, 1957.

THIS BULLETIN is but one of a large number of publications issued by the University of Idaho College of Agriculture to assist dairymen and livestock producers. Included are publications on all phases of feeding and management. All of Idaho's agricultural publications are listed in Ext. Bul. 320, Idaho Farm and Home Bulletins.

A copy of this bulletin list, as well as other University of Idaho agricultural publication, may be obtained from your county agent or by writing to the Mailing Room, College of Agriculture, University of Idaho, Moscow; or to the Agricultural Extension Service, University *of* Idaho, 317½ North 8th St., Boise.