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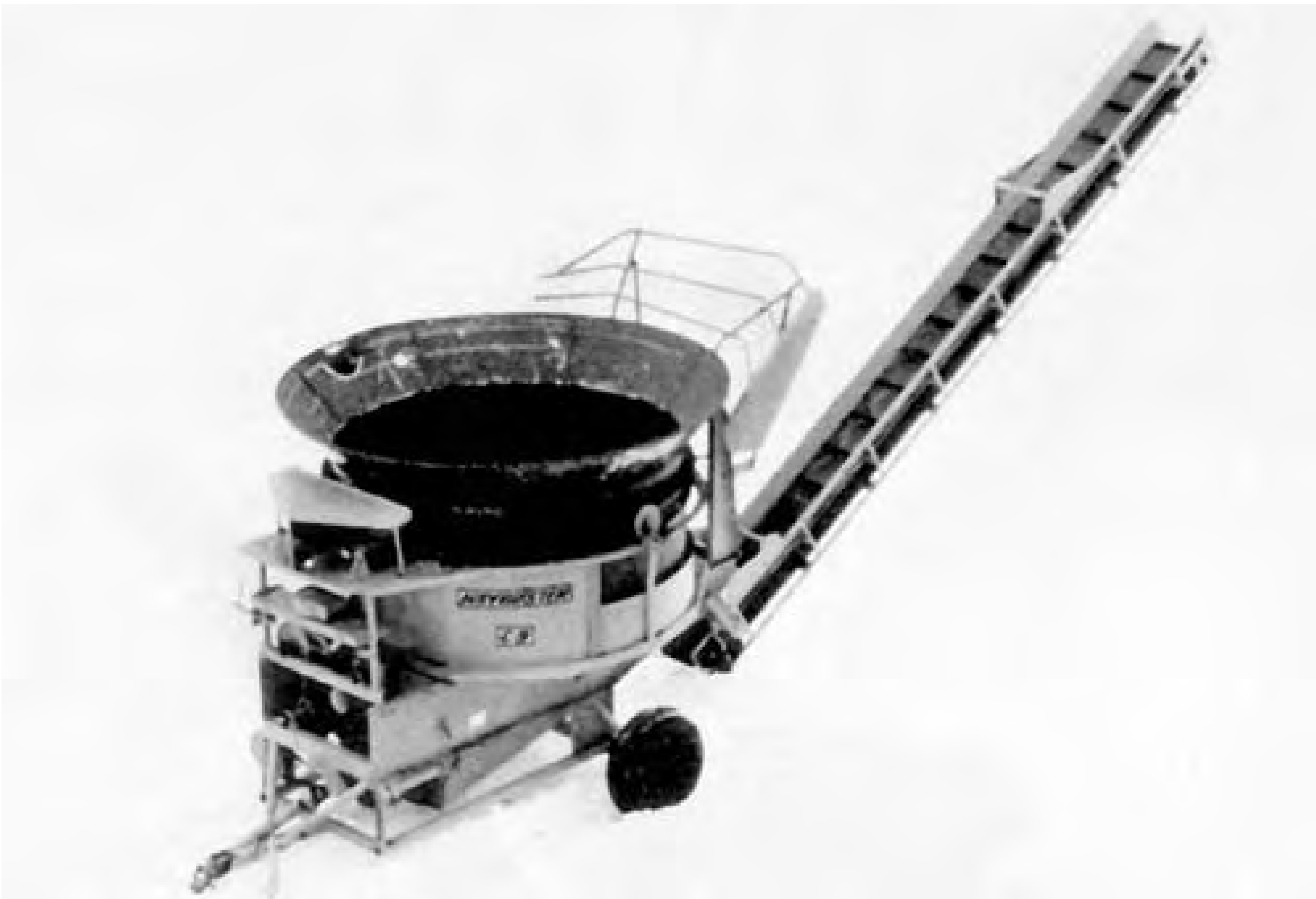
Evaluation Report 13



Haybuster Model C-9 Tub Grinder

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

HAYBUSTER MODEL C-9 TUB GRINDER

MANUFACTURER:
Haybuster Manufacturing Inc.
Box 1008
Jamestown, North Dakota 58401

DISTRIBUTOR:
Agrifuture Equipment Ltd.
Lloydminster, Saskatchewan
S9V 1C1

RETAIL PRICE:
$7,013.00 (December 1, 1975, f.o.b. Humboldt, with 51 mm (2 in) and 76 mm (3 in) screens).

FIGURE 1. Haybuster C-9 Tub Grinder.

SUMMARY AND CONCLUSIONS

Overall functional performance of the Haybuster C-9 was fair in both baled and stacked hay and straw. Ease of operation was poor.

Maximum grinding rates with a 51 mm (2 in) screen were about 4.5 t/h (5.0 ton/h) in baled alfalfa, 4.8 t/h (5.3 ton/h) in stacked alfalfa, 5.7 t/h (6.3 ton/h) in stacked barley straw and 7.9 t/h (8.7 ton/h) in baled barley straw. Maximum grinding rates with a 25 mm (1 in) screen were about one-half as large as those with a 51 mm (2 in) screen. With most tractors, grinding rates were usually limited by feeding, poor selection of tub speeds and slippage of drive belts.

As with most tub grinders, power consumption was high and specific capacity was low. Specific capacity varied from 0.37 t/kW•h (0.30 ton/hp•h) in stacked alfalfa hay to 0.15 t/kW•h (0.12 ton/hp•h) in round barley straw bales, when using a two inch screen. Specific capacities were reduced by about 50% when using a one inch screen.

As with most tub grinders, the method of feeding the hammer mill imposed heavy shock loads on the power train and resulted in wide power fluctuations. For example, at the maximum feedrate of 7.9 t/h (8.7 ton/h), with a 51 mm (2 in) screen in round barley straw bales, the average power input was 54 kW (72 hp), however, a tractor with a maximum power take-off output of at least 86 kW (116 hp) was needed to prevent tractor stalling due to the wide power fluctuations. By adjusting the tub governor, smaller tractors could be used at reduced grinding rates.

The Haybuster C-9 had several potential safety hazards. No conveyor safety support straps were provided for transport and the conveyor winch was potentially dangerous as it did not use a friction drag clutch. No ladder or inspection platform was provided for tub access or servicing. Tub support rollers and several belt pulleys were not shielded. If the tub speed was not properly adjusted, the centrifugal clutch on the tub drive could overheat and present a fire hazard.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Redesigning entire tub drive system to improve ease of operation, functional performance and safety.
2. Installing access ladder and/or inspection platform to improve access to tub for servicing.
3. Installing friction drag winch on conveyor.
4. Providing conveyor safety straps for transport.
5. Providing adjustable baffles on tub wall.
6. Providing shields for the tub support rollers.
7. Investigating the possibility of installing a suitable flywheel on the hammer mill to reduce drive train shock loads.

Chief Engineer - E. O. Nyborg

Senior Engineer - L. G. Smith

THE MANUFACTURER STATES THAT

With regard to recommendation number:

The Model C-9 has been discontinued. It has been completely redesigned to include a hydraulic tub drive, similar to all other models presently being manufactured by Haybuster.

GENERAL DESCRIPTION

The Haybuster Model C-9 Tub Grinder (FIGURE 1) is a portable power take-off driven hammer mill with rotary feed tub, designed to grind loose stacked or baled straw and hay.

The Manufacturer recommends use with tractors up to 187 kW (250 hp) at 1000 rpm power take-off speed.

The Haybuster C-9 is designed to be batch fed with a suitably equipped front end loader. The mechanically driven tub has four speed settings to regulate feed to a belt driven hammer mill. A centrifugal clutch automatically stops tub rotation when the tractor speed drops below a preset level.

Fineness of grind is determined by the size of screen used below the hammer mill. Ground material falls through the screen onto two chain driven, screw conveyors which deliver it to an adjustable, slatted rubber belt conveyor.

Detailed specifications are given in APPENDIX I.

SCOPE OF TEST

The Haybuster C-9 was operated for 41 hours while processing about 186 t (205 ton) of hay and straw. It was used to process small square bales, large round bales, and stacked hay.

It was evaluated for ease of operation, rate of work, power consumption, quality of work, operator safety and suitability of the operator's manual.

RESULTS AND DISCUSSION

EASE OF OPERATION

Hitching: The Haybuster C-9 was easily hitched to a tractor. The hitch jack was safe and convenient to use. The 1000 rpm power take-off shaft was attached with a spring-loaded pin.

Tub Control: Tub speed was selected from a combination of two sets of V-belt drives each containing four sheaves (FIGURE 2) providing a total of four different tub speeds.

This tub drive was inconvenient and unsafe as the tub grinder must be shut down in order to change tub speeds and the many belts and pulleys were not properly shielded.

This speed selection system was driven by a centrifugal clutch, which would disengage if hammer mill speed dropped below 1700 rpm and engage when speed returned to normal. A tub speed should be chosen to attain steady tub rotation or the clutch may overheat, and become a potential fire hazard.

Complete redesign of this tub drive system is recommended.

Loading the Tub: The tub (FIGURE 3) had straight sides with a flare top and a rear guide rack to facilitate loading large round bales. Height to the top of the tub was 2620 mm (8.6 ft). When loading loose hay with grapple forks, hay often caught on the flare top if large loads were used. The most effective feeding was obtained by taking small loads, which would easily drop within the flare top.

Occasionally, a large round bale placed in the centre of the tub would not contact the tub fins and no grinding would occur. Loading a second bale on top would force the first bale against the tub wall and initiate grinding. It is recommended that an adjustable fin be placed on the side of the tub to correct this problem.

FIGURE 2. Sheaves for Tub Speed Control.

FIGURE 3. Tub and Guide Rack.

Screen Removal: Eight screen sizes from 6 mm (1/4 in) to 76 mm (3 in) were available. Changing the two piece screen required the removal of two clamping rods and three bolts (FIGURE 4). Using a prybar, the screens could be pried up and around mill until free. Changing the screens could be carried out by one man in about 20 minutes.

FIGURE 4. Hammer Mill.

Hammer Mill: The hammer mill contained eight rows of swinging hammers; four rows had eight hammers and four rows had seven hammers. When worn, the hammers could be reversed or rotated end-for-end to present new wear surfaces. This could be accomplished from within the tub by removing each pivot shaft. Reversing or rotating a complete set of hammers took two men about two hours.

Discharge Chamber: The hammer mill discharged ground material into two belly pan augers (FIGURE 5) beneath the screen. The augers effectively removed the ground material and delivered it to the elevating conveyor. Auger blockage never occurred. Doors on each side of the belly pan gave access to the screen and permitted screen unplugging if hammer blockage occurred.

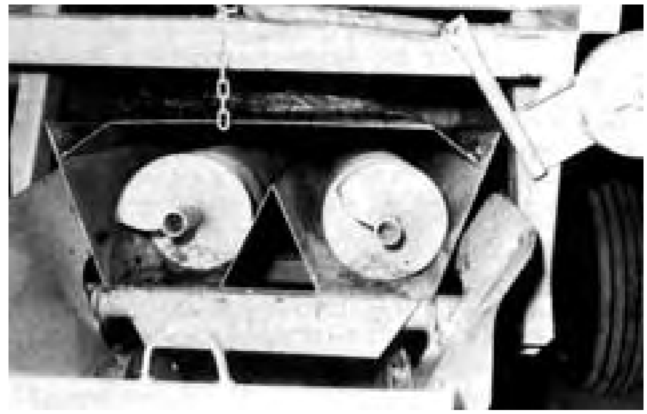


FIGURE 5. Belly Pan Augers.

Elevating Conveyor: The slatted belt conveyor had ample conveying capacity at lift angles up to 25°. In most materials, at lift angles greater than 25°, the material slipped and tumbled on the belt. At a 25° angle, the conveyor had a discharge height of 2780 mm (9.1 ft) and a corresponding reach of 5280 mm (17.3 ft).

The conveyor was equipped with self-cleaning pulleys, which effectively reduced the buildup of fines between the conveyor belt and the belt trough. The conveyor sides reduced losses of fines in moderate winds.

No safety straps were provided for supporting the conveyor while transporting. This imposed severe shock loads on the winch and lifting cable, especially when transporting on rough roads. Although conveyor height was easy to adjust, the lift winch had an over-centre ratchet lock and would free-wheel if accidentally released when lowering the conveyor. It is recommended that a friction drag winch and transport safety straps both be installed to correct these potential safety hazards.

Winter Operation: All evaluation was conducted in winter conditions, typical of most tub grinder use in the prairie provinces. All components worked well, even at temperatures of -30° C.

During winter operation, accumulated snow should be removed from the tub and rotating parts checked for ice accumulation before starting. It is also recommended to start the grinder with the tub control in neutral position.

As is common with all tub grinders, excessive snow mixed with ground hay can result in heating problems. If ground hay is to be stockpiled, the moisture content must be low enough to ensure that the stockpile will not heat and spoil.

Transporting: The Haybuster C-9 had a fixed single axle with no spring suspension. As a result, it was not suited for high speed transport. Due to the large overhang of the conveyor behind the rear wheels and the lack of a conveyor transport safety lock, extreme care had to be exercised in turning corners and on rough roads. It is unsafe to tow the C-9 behind a light truck; a tractor or large truck is needed.

RATE OF WORK

Maximum Grinding Rate: The maximum grinding rate for a tub grinder depends on the type of hay being ground, whether the hay is baled or loose, its moisture content and temperature, the screen size used, and the available tractor power. In general, grinding rates are higher at very low temperatures as hay becomes more brittle at reduced temperatures.

Maximum grinding rates obtained with the Haybuster C-9, when equipped with a 51 mm (2 in) screen were 4.5 t/h (5.0 ton/h) in baled alfalfa, 4.8 t/h (5.3 ton/h) in stacked alfalfa, 5.7 t/h (6.3 ton/h) in stacked barley straw and 7.9 t/h (8.7 ton/h) in baled barley straw.

POWER CONSUMPTION

Power Take-off Requirements: FIGURE 6 shows the average power take-off input for the Haybuster C-9 in alfalfa and barley straw. The power input is plotted against grinding rate up to the maximum rate reached for each test. The average power input, at maximum grinding rate, with a 51 mm (2 in) screen varied from 13 kW (17 hp) in stacked alfalfa hay to 54 kW (72 hp) in round barley straw bales.

The power consumption at reduced grinding rates, corresponding to smaller tractors, may be read from FIGURE 6.

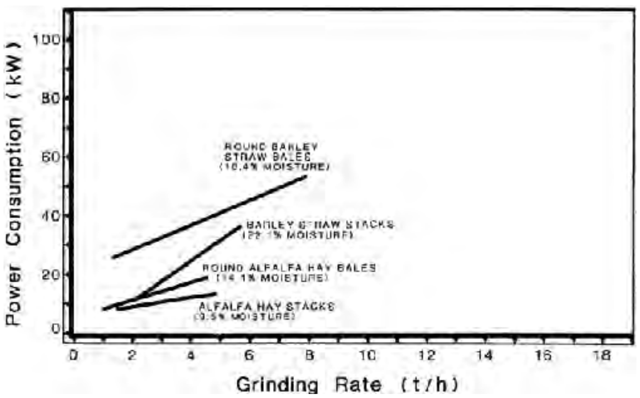


FIGURE 6. Power Consumption of the Haybuster C-9 at Various Grinding Rates, when Equipped with a 51 mm (2 in) Screen.

Specific Capacity: Specific capacity is a measure of how efficiently a machine performs a task. A high specific capacity indicates efficient energy use while a low specific capacity indicates inefficient operation. Tub grinders, in general, are inefficient machines.

The specific capacity of the Haybuster C-9, with a 51 mm (2 in) screen, varied from 0.37 t/kW•h (0.30 ton/hp•h) in stacked alfalfa hay to 0.15 t/kW•h (0.12 ton/hp•h) in round barley straw bales. These values represent average operating values and not peak outputs. These values would be reduced to about 0.19 t/kW•h (0.15 ton/hp•h) in alfalfa and 0.08 t/kW•h (0.06 ton/hp•h) in straw, when equipped with 25 mm (1 in) screen.

Instantaneous Power Requirements: FIGURE 6 shows the average power consumption at various feedrates. Instantaneous power input fluctuates rapidly due to non-uniform feeding to the hammer mill and governor sensitivity. Peak power requirements are much greater than those shown in FIGURE 6. A typical one-minute long instantaneous record of power input while grinding baled alfalfa hay is shown in FIGURE 7. As can be seen, input power fluctuated rapidly during one minute of operation at a fixed governor setting. These wide power fluctuations represent shock loads to the tractor and grinder drive train and indicate the amount of reserve power needed to prevent tractor stalling.

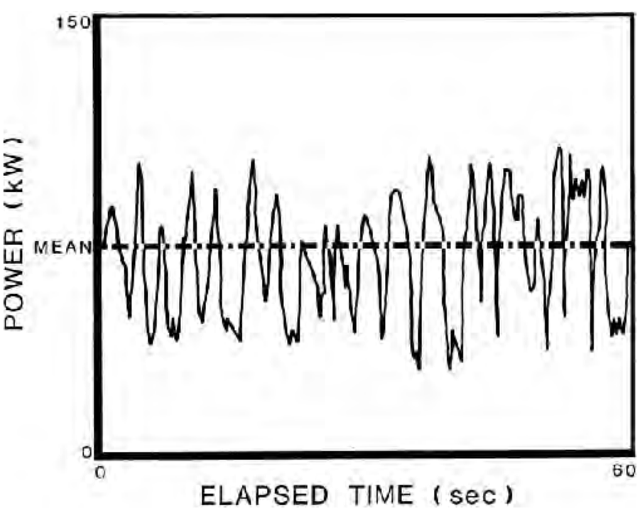


FIGURE 7. Typical Instantaneous Power Requirements for a Tub Grinder.

The coefficient of variation[1] (TABLE 1) may be used to compare the power train shock loads and to show the possibility of tractor stalling when grinding various materials. The larger the coefficient of variation, the higher the shock loads and the greater the possibility of tractor stalling. Large variations in power requirements may be partially controlled with the tub governor. Most of the variation, which is beyond operator control, is due to the erratic nature of feeding in most tub grinders. In general, smaller variations in power requirement occurred with loose hay or straw than with bales, due to more uniform feeding. It is recommended that the manufacturer investigate the possibility of installing a suitable flywheel on the hammer mill to reduce drive train shock loads.

TABLE 1. Coefficients of Variation of Input Power for the Haybuster C-9 with 51 mm (2 in) Screen

Straw Bales	Alfalfa Bales	Alfalfa Stacks
30%	18%	8.0%

Determining Expected Grinding Rate for Certain Tractor Size: FIGURE 8[2] may be used to estimate the average grinding rate, which may be expected for a certain tractor size in a certain type of material when using a 51 mm (2 in) screen. FIGURE 8 presents the same data as given in FIGURE 6, but has been corrected to include the peak power fluctuations shown in TABLE 1. For example, a tractor with maximum power take-off output of 70 kW (94 hp) at 1000 rpm expected maximum grinding rates without tractor installing are 5.6 t/h (6.2 ton/h) in round straw bales. As previously discussed, changing to 25 mm (1 in) screen would reduce the expected grinding rates to about one-half of those shown in FIGURE 8, for the same power output.

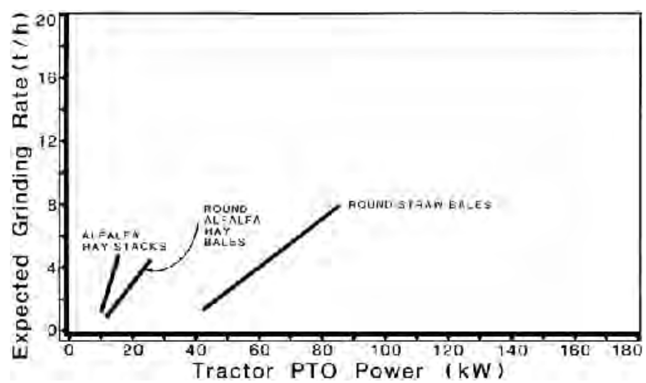


FIGURE 8. Determining Expected Average Grinding Rates With the Haybuster C-9 for Various Tractor Sizes when Using a 51 mm (2 in) Screen.

QUALITY OF WORK

Length of Cut: For a certain screen size, tub grinders produce chopped hay of varying particle lengths. FIGURE 9 shows a typical particle size distribution for the Haybuster C-9 when grinding stacked alfalfa hay with a 51 mm (2 in) screen. TABLE 2 shows the percent by weight of each of the particle sizes shown in FIGURE 9, when grinding various materials with a 51 mm (2 in) screen.

TABLE 2. Size Distribution of Ground Material when using a 51 mm (2 in) Screen

Length of Particle	Percent of Total Sample Weight				
	Stacked Barley	Round Barley	Stacked Alfalfa	Round Alfalfa	Stacked Sweet Clover
Less than 3 mm long (FIG. 9a)	6.0	18.9	20.1	12.9	34.3
3 to 10 mm (FIG. 9b)	23.9	41.1	34.1	42.3	34.7
10 to 18 mm (FIG. 9c)	20.3	18.0	12.5	13.1	10.3
18 to 25 mm (FIG. 9d)	13.6	11.0	11.2	14.9	9.4
25 to 38 mm (FIG. 9e)	28.0	9.4	17.5	14.5	6.2
Greater than 38 mm (FIG. 9f)	8.2	1.6	4.6	2.3	5.1

[1]*The coefficient of variation is the standard deviation of the power fluctuation expressed as a percent of the mean power at one feedrate setting. The coefficients of variations given in TABLE 1 are the average of the coefficients of variation for at least five different feedrates in each material.*

[2]*FIGURE 8 is a plot of the mean power requirements plus twice the standard deviation of the power fluctuations. Instantaneous power requirements should fall below the line 98% of the time.*

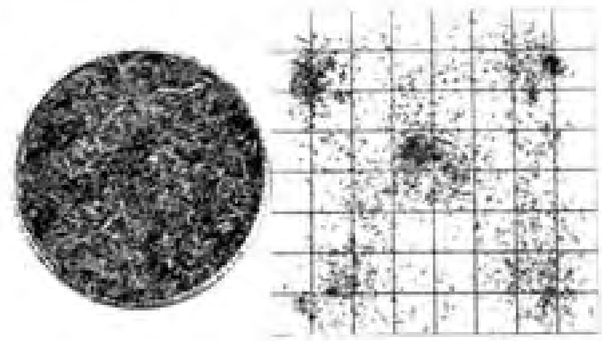


FIGURE 9a. Less than 3 mm long.

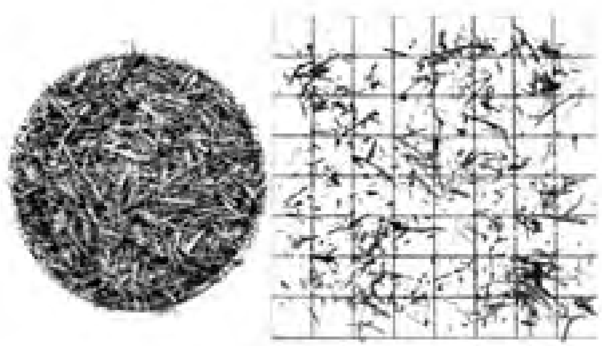


FIGURE 9b. 3 to 10 mm.

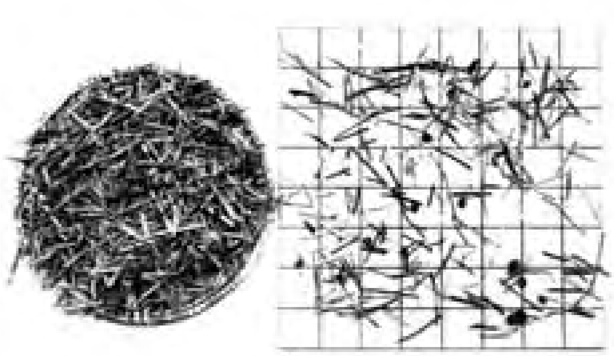


FIGURE 9c. 10 to 18 mm.

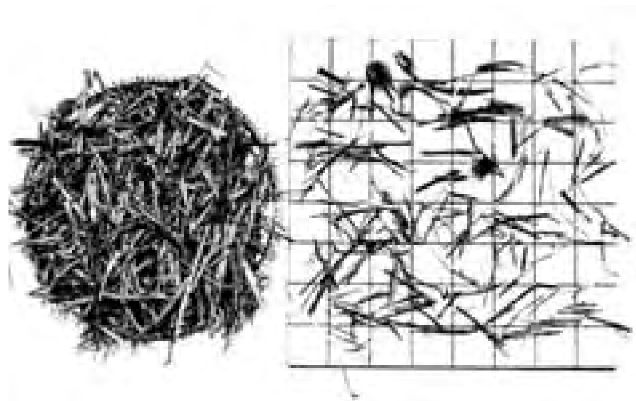


FIGURE 9d. 18 to 25 mm.

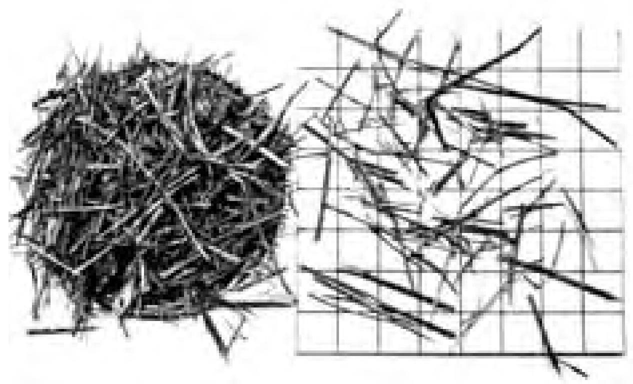


FIGURE 9e. 25 to 38 mm.

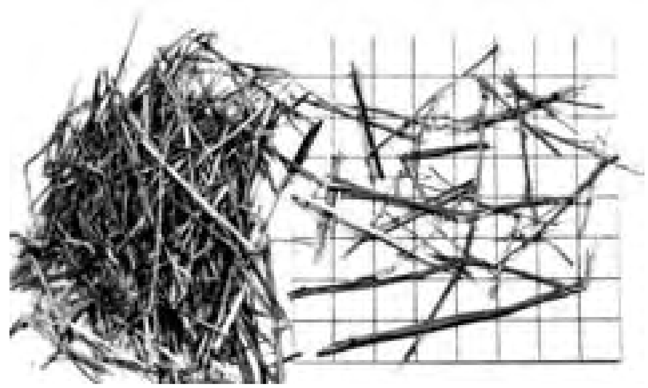


FIGURE 9f. Greater than 38 mm.

FIGURE 9. Distribution of Particle Lengths when Grinding Stacked Alfalfa Hay with a 51 mm (2 in) Screen. (Pictures were taken on a 2 cm grid.)

OPERATOR SAFETY

The Haybuster C-9 had several potential safety hazards, which required additional caution when servicing, operating and transporting the machine.

Several safety improvements are recommended. The total weight of the conveyor, in transport position, was supported on the winch cable. It is recommended that safety transport straps be provided for the conveyor. The conveyor lift winch was an over-centre ratchet winch, which free-wheeled if released in the unlocked position. It is recommended that a friction drag winch be used to eliminate this potential hazard. It is also recommended that a ladder and inspection platform be installed for tub access and servicing as climbing into the tub is both difficult and hazardous. It is recommended that shields be provided for the tub support rollers to eliminate the possibility of hands or clothing being caught. The tub drive system had several exposed belts and pulleys (FIGURE 10) and the centrifugal clutch would overheat if tub speed was not properly set. Complete redesign of the tub drive is recommended.

GENERAL SAFETY COMMENTS

The operator is cautioned that a tub grinder is potentially very dangerous. The following precautions should be observed when operating any tub grinder:

Never stand on the inspection platform or look into the tub while the grinder is in operation as dangerous objects may be thrown out of the tub by the hammer mill.

Never grasp loose baler twine that is hanging over the tub wall as it may be instantaneously reeled into the hammer mill causing injury.

Periodically remove twine buildup from the hammer mill rotor to reduce fire hazard and carry a fire extinguisher on the grinder at all times.

Tow the grinder behind a tractor or suitably sized truck at low speed. A light pickup truck is not suitable. Be especially careful of conveyor height and overhang when turning corners or passing under power lines.

Disengage the power take-off and stop the tractor to clear blockages or to make adjustments. The manufacturer can only go to certain limits in providing shielding and safety devices and must rely on the operator's common sense in following established safety procedures.

As is common with all tub grinders, great care must be taken to ensure that hay is free of foreign material such as barbed wire or baling wire. This is especially true when processing large round bales. Although wire presents no problem to the tub grinder, the short pieces formed after grinding are a potential source of "hardware disease" in cattle.

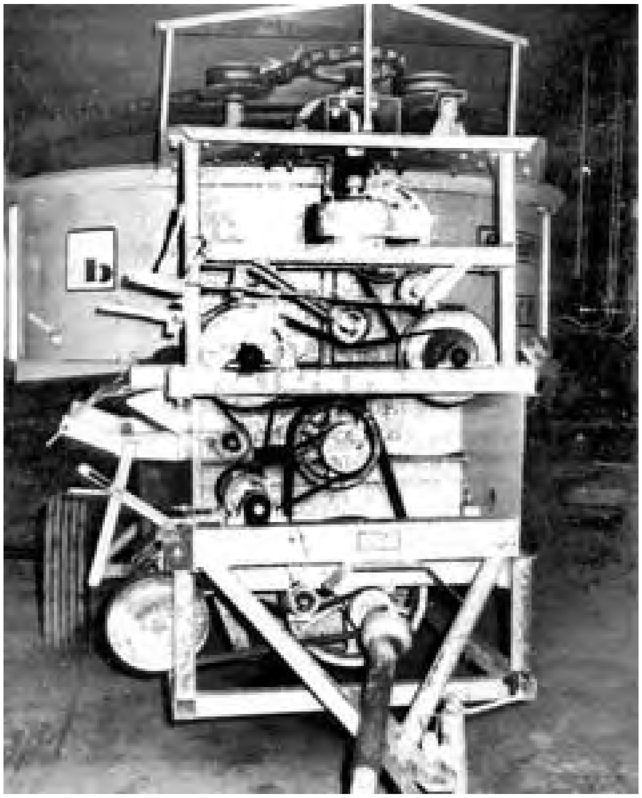


FIGURE 10. Lack of Shields on Belts and Pulleys.

OPERATOR'S MANUAL

The operator's manual was brief and poorly written. Further information should be provided on operation and safety.

DURABILITY RESULTS

The Haybuster C-9 was operated for 41 hours while processing about 186 t (205 ton) of hay and straw. The intent of the test was to evaluate functional performance and an extended durability evaluation was not conducted. No significant mechanical problems occurred during functional testing.

APPENDIX I
SPECIFICATIONS

MAKE:	Haybuster Tub Grinder
MODEL:	C-9
SERIAL NUMBER:	75-10-335
MANUFACTURER:	Haybuster Manufacturing Inc. Box 1008 Jamestown, North Dakota U.S.A. 58401
OVERALL DIMENSIONS:	
-- width	2710 mm (108 in)
-- height	3120 mm (123 in)
-- length (with conveyor at 25°)	9300 mm (366 in)
-- ground clearance	190 mm (8 in)
WEIGHT:	
-- hitch	168 kg (370 lb)
-- left wheels	876 kg (1931 lb)
-- right wheels	920 kg (2028 lb)
TOTAL	1964 kg (4329 lb)
SUSPENSION:	Solid
TIRES:	
-- size	2 - 7.60 x 15, 6-ply rating
TUB:	
-- top diameter	2710 mm (107 in)
-- bottom diameter	2200 mm (87 in)
-- depth of top flare	370 mm (15 in)
-- depth	1340 mm (53 in)
-- loading height	2620 mm (103 in)
-- type of governor	Mechanical Clutch
-- tub speed range	1.7 to 8 rpm
-- drive	Mechanical drive to chain around tub
HAMMER MILL:	
-- length	1000 mm (39.4 in)
-- diameter (hammers extended)	635 mm (25 in)
-- shaft diameter	55.5 in (2.2 in)
-- hammers	
-length	194 mm (7.8 in)
-thickness	7.9 mm (0.31 in)
-type	Reversible, 4 corners
-number of rows	8
-hammers per row	4 with 8, 4 with 7
-total number of hammers	60
-pin size	23.8 mm (0.94 in)
-drive train	Belt driven from PTO shaft
-- hammer mill rpm at 1000 rpm PTO	1653 rpm
-- speed when governor engages tub	1165 rpm
-- speed when governor disengages tub	1120 rpm
HAMMER MILL CONVEYOR:	
-- type	2229 mm (9 in) diameter augers
-- length	2440 mm (96 in)
-- width	711 mm (28 in)
-- minimum clearance to screen	51 mm (2 in)
-- drive	Chain driven by belts off PTO shaft
-- speed	270 rpm
ELEVATING CONVEYOR:	
-- type	Rubber conveyor belt
-- length	5830 mm (230 in)
-- height at 25° incline	2780 mm (109 in)
-- width	405 mm (15.9 in)
-- drive train	Chain drive by belts off PTO shaft
-- speed	2.4 m/s (469 ft/min)
SCREENS:	
-- type	Two-piece
-- length	1065 mm (41.9 in)
-- circumferential length of each screen	720 mm (28.3 in)
-- thickness	6 mm (0.25 in)
-- screened area	1.53 m² (2372 in²)
MANUFACTURER'S MAXIMUM RECOMMENDED TRACTOR SIZE AT 1000 RPM	187 kW (250 hp)

APPENDIX II
MACHINE RATINGS

The following rating scale is used in Prairie Agricultural Machinery Institute Evaluation Reports:

(a) excellent	(d) fair
(b) very good	(e) poor
(c) good	(f) unsatisfactory

APPENDIX III
METRIC UNITS

In keeping with the Canadian metric conversion program, this report has been prepared in SI Units. For comparative purposes, the following conversions may be used:

1 kilometre/hour (km/h)	= 0.62 miles/hour (mph)
1 hectare (ha)	= 2.47 acres (ac)
1 kilogram (kg)	= 2.2 pounds (lb)
1 tonne (t)	= 2204.6 pounds (lb)
1 tonne/hectare (t/ha)	= 0.45 ton/acre (ton/ac)
1 tonne/hour (t/h)	= 1.10 ton/hour (ton/h)
1000 millimetres (mm) = 1 metre (m)	= 39.37 inches (in)
1 kilowatt (kW)	= 1.34 horsepower (hp)
1 litre/hour (L/h)	= 0.22 Imperial gallons/hour (gal/h)

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