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Group 4a

Evaluation Report 677

John Deere 535 Round Baler

A Co-operative Program Between
ALBERTA FARM MACHINERY RESEARCH CENTRE
PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

JOHN DEERE 535 ROUND BALER

MANUFACTURER:

John Deere Ottumwa Works
928 East Vine St.
Ottumwa, Iowa
52501
(515) 684-4641

DISTRIBUTOR:

John Deere Ltd.
Box 1000
Grimsby, ON
L3M 4H5
(416) 945-9281

RETAIL PRICE:

$33,748.00 (March, 1992 f.o.b. Portage la Prairie, MB) with pickup gage wheels, converging wheels, hi-flotation tires, bale push bar, surface wrap bundle (net wrap), silage bundle, Bale-Trak monitor, bale counter, safety chain, and warning light kit

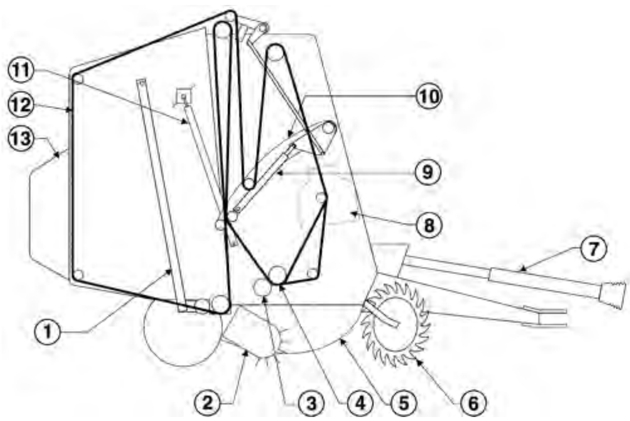

FIGURE 1. John Deere 535 Round Baler. (1) Pushbar, (2) Pickup, (3) Starting Roller, (4) Drive Roller, (5) Windguard, (6) Converging Wheels, (7) Drive Shaft, (8) Twine Box, (9) Belt Tension Cylinder, (10) Belt Tension Arm, (11) Gate Cylinder, (12) Forming Belts, (13) Net Wrap Box.

SUMMARY

Rate of Work: Typical throughput of the John Deere 535 varied from 5.4 ton/h (4.9 t/h) in mixed grasses wrapped with twine to 18.0 ton/h (16.3 t/h) in alfalfa wrapped with net wrap. Throughput was limited by pickup and feeding performance rather than by the bale chamber capacity.

Quality of Work: Bale quality was excellent, with well formed and durable bales in all crops. Hay bales weighed from 1000 to 1500 lb (450 to 680 kg) and straw bales weighed from 800 to 1000 lb (360 to 450 kg). Net wrapped bales were observed to be more durable than twine wrapped bales.

Resistance to bale moisture penetration and spoilage was very good. Minimal spoilage had occurred during the 100 day weathering period. Leaf loss was rated very good. Total leaf toss at 12% MC was 2.5% for twine wrapped bales and 1.8% for net wrapped bales. Net wrap accounted for a 27% reduction in leaf loss.

Ease of Operation and Adjustment: Ease of forming a bale was very good. The bale shape indicators helped the operator produce a well formed bale. In hot dry conditions it was sometimes necessary to reduce the PTO speed. Ease of feeding the bale chamber was excellent. The baler's feeding system was positive and aggressive in all crops. Ease of twine and net wrapping was good and ease of bate discharging was very good. The wrapping cycle was automatically activated when the bale had reached the preset size. Bale wrapping and bale discharging were automatically sequenced and were completed in about 40 to 45 seconds and 15 to 20 seconds for twine and net wrap respectively.

Ease of transporting was good. The baler was easily manoeuvred but required care when backing up due to poor rear visibility. Ease of hitching the baler to a tractor was very good. Hitching components included a draw-pin, PTO driveline, one hydraulic remote circuit and an electrical connection to the baler's monitor. Twine threading was good and net wrap threading was very good. Twine was easily threaded through the front twine arm but threading the inner twine arm was less convenient.

Ease of adjustment was good. Adjustments were simple but reference positions and decals were not included on the baler. This often made adjustments a trial and error process. Ease of lubricating was good. Complete daily servicing took about 20 minutes.

Power Consumption: Peak power requirements were about 50 hp (38 kW) in hay on level fields at high workrates. A 75 hp (56 kW) tractor was suggested by the manufacturer to fully utilize baler capacity on soft and hilly fields. The specific capacity of the John Deere 535 was 0.53 ton/hp-h (0.65 t/kW-h) in alfalfa at an instantaneous workrate of 17.8 ton/h (16.1 t/h) with twine wrapped high density bales. The specific capacity was 0.62 ton/hp-h (0.76 t/kW-h) in alfalfa at an instantaneous workrate of 20.4 ton/h (18.5 t/h) with net wrapped high density bales.

Operator Safety: Operator safety of the John Deere 535 was very good if normal safety precautions were observed.

Operator's Manual: The operator's manual was very good. It was well written and clearly illustrated.

Mechanical History: A twine guide rod bent and the mechanism that holds the twine arms apart bent during the test.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifications to improve the baler's ability to crowd hay at the edges of the bate chamber.
2. Modifications to the wrapping system to reduce the inconveniences associated with servicing and inspecting the baler.
3. Supplying a safety chain as standard equipment.
4. Adding a bale size reference scale to aid the operator in setting the bale size.
5. Adding reference points to the twine and net wrap flow control valves to aid the operator in setting the number of twine and net wraps.
6. Adjustable twine guides that would allow the operator to select the distance from the outside twine wraps to the ends of the bale.
7. Increasing the strength of the mechanism used to adjust the spacing between the twine arms.

Station Manager: B.H. Allen

Project Engineer: R. W. Schott

THE MANUFACTURER STATES THAT

With regard to the recommendations:

1. No action is planned at this time.
2. No design action is planned at this time, however we will consider adding a note to the Operator's Manual explaining how to prevent unwanted twine arm cycling.
3. A safety chain is supplied as standard equipment with the baler. We do allow the customer to buy the baler less safety chain to satisfy those operators who prefer to have the safety chain on the tractor instead of one chain on each implement.
4. We will add a bale size scale to the linkage for our next model year update.
5. No change is planned at this time.
6. An adjustable twine guide is available for the left hand end of the bale. When the baler is operated according to procedure in the Operator's Manual, an adjustable RH guide has not been necessary.
7. We will consider this change for our next model year update.

GENERAL DESCRIPTION

The John Deere 535 is a pull-type, 540 rpm PTO driven baler with a variable cylindrical chamber and a drum pickup. The 535 baler produces hard core bales measuring 5.1 ft (1.6 m) wide and up to 6.0 ft (1.8 m) in diameter. Bale diameter is adjustable and the desired size is manually set on the baler. The baler can wrap the bales with either twine or net wrap, which is selected manually on the baler. The automatic twine wrap system uses a double tube twine arm. The amount of twine or surface wrap and the density of the bale are variable and are also manually set on the baler. The baler requires a 12 volt power source to operate the monitor and one tractor hydraulic remote circuit to operate the gate. The wrapping system uses a self contained hydraulic system on the baler.

Crop is fed directly into the vertical throat of the bale chamber by the drum pickup. Eight, 7.0 in (178 mm) wide forming belts form the bale. The baler's belt tension arm and hydraulic circuitry control the pressure exerted by the forming belts onto the bale. With this system, the density of the bale is infinitely adjustable within a certain range. A 5.5 in (140 mm) diameter starting roller with 0.375 in (9.5 mm) thick steel bats ensure crop feeds properly around the perimeter of the forming bale.

When the preset bale diameter has been reached the selected wrapping system is automatically activated. When wrapping is complete the operator opens the rear gate hydraulically and discharges the bale. A bale push bar pushes the bale back clear of the gate.

The baler is equipped with a monitor that displays the various operating statuses. The monitor includes lights to indicate when the rear gate is closed, when the bale is near its finished size, when the twine arms are cycling and when the baler is filled to its maximum capacity. A buzzer also sounds when the wrapping system begins to cycle. In addition, the monitor has two bale shape indicators that help the operator to feed the baler uniformly across the bale's width and produce well shaped bales.

The test machine was equipped with the following optional equipment: pickup gage wheels, converging wheels, hi-flotation tires, bale push bar, surface wrap bundle (net wrap), silage bundle, Bale-Trak monitor, bale counter, safety chain, and warning light kit. The baler was equipped with an updated pickup part way through the test. Other attachments available on the John Deere 535 but not tested, include adjustable left-hand twine guide, hydraulic pickup lift, PTO conversion parts - 1000 rpm, belt lacing tool, and a rear-view mirror extension.

Detailed specifications are given in APPENDIX I. FIGURE 1 shows the location of major components and Figure 2 shows the monitor.

FIGURE 2. John Deere 535 Monitor.

SCOPE OF TEST

The machine evaluated by PAMI was configured as described in the General Description, FIGURE 1 and Specifications section of this report. The manufacturer may have built different configurations of this machine before or after PAMI tests. Therefore, when using this report, check that the machine under consideration is the same as the one reported here. If differences exist, assistance can be obtained from PAMI or the manufacturer to determine changes in performance.

The John Deere 535 was operated in a variety of crops (TABLE 1) for 101 hours, while producing 1644 bales. It was evaluated for rate of work, quality of work, ease of operation, ease of adjustment, power requirements, operator safety, and suitability of the operator's manual. In addition, mechanical problems were monitored throughout the evaluation.

TABLE 1. Operating Conditions

Crop	Operating Hours	Number of Bales		Equivalent Field Area	
		Twine Wrapped	Net Wrapped	ac	ha
Alfalfa	36	285	295	387	155
Alfalfa/Bromegrass	17	207	135	156	62
Mixed Grasses	4	–	36	30	12
Oat Greenfeed	7	80	39	73	29
Alfalfa Silage	15	181	–	137	55
Barley Straw	4	–	50	23	8
Wheat Straw	18	246	90	145	58
Total	101	999	645	951	380

RESULTS AND DISCUSSION

RATE OF WORK

Throughput depended on windrow size, uniformity of crop conditions, field surface, available tractor speeds, operator skill, and the bale wrapping system used. Typical throughputs for the John Deere 535 (TABLE 2) varied from 5.4 ton/h (4.9 t/h) in mixed grasses wrapped with twine to 18.0 ton/h (16.3 t/h) in alfalfa wrapped with net wrap. The values in TABLE 2 are based on typical workrates for daily field operation. Peak workrates during any one day were generally 10% to 20% higher.

TABLE 2. Typical Throughput

Crop	Crop Yield		Typical Daily Throughput	
	ton/ac	t/ha	ton/h	t/h
Alfalfa/Twine Wrapped				
Field A	1.3	2.9	12.8	11.6
Field B	0.6	1.4	5.7	5.2
Alfalfa/Net Wrapped				
Field A	1.1	2.5	14.5	13.2
Field B	1.0	2.3	9.0	8.2
Alfalfa Brome/Twine Wrapped	1.5	3.4	13.9	12.6
Alfalfa Brome/Net Wrapped	1.7	3.9	18.0	16.3
Mixed Grasses	0.7	1.6	5.4	4.9
Oat Greenfeed	1.2	2.7	11.6	10.5
Alfalfa Silage	1.0	2.3	10.3	9.3
Barley Straw	1.2	2.7	6.9	6.3
Wheat Straw	1.0	2.3	11.1	10.0

Net wrap increased the work rate by 23%, on average, when compared with twine wrap. This was attributed to less time spent wrapping the bale. The net wrap system only required one to two turns of the bale. However, the dual tube twine wrapping system required 8 to 12 turns of the bale depending on operator preference. The extent of this advantage depended on the feedrate and the number of twine wraps and net wraps of the bales being compared. In most crops, the feed rate was primarily limited by windrow size and pickup/feeding performance. In lighter crops, the ground speed was normally limited to about 8 mph (13 km/h) due to rough ground and pickup performance.

QUALITY OF WORK

Bale Quality: Bale quality was generally excellent. The John Deere 535 produced firm, durable bales with flat ends and uniform diameter in all hay and straw crops (FIGURE 3) with both twine and net wrap. The net wrapped bales were observed to be more durable when handled a number of times. It also permitted durable bales to be formed from short, dry straw discharged from rotary combines. Farmers generally found the net wrap easier to remove than the twine wrap. An occasional tear was observed in the net wrapped bales.

The overall bale quality depended greatly on the operator's skill. Failure of the operator to evenly feed both sides of the baler resulted in barrel or cone-shaped bales. The bale shape gauges aided the operator in uniformly feeding the width of the baler.

Baling windrows with a width greater than half the baler pickup, but less than the entire pickup, resulted in barrel-shaped bales. This is typical of round balers. Proper windrow preparation, consisting of windrows with widths less than half the baler pickup width or slightly wider than the baler pickup, ensured proper bale formation.

A typical hay or straw bale averaged 5.1 ft (1.6 m) in width, and could be made any diameter up to 6.0 ft (1.8 m). Bales tested settled to about 97% of their original height after 100 days. Typical 5.5 ft

(1.7 m) diameter hay bales weighed from 1000 to 1500 lb (450 to 680 kg) with average densities ranging from 8.2 to 12.2 lb/ft³ (130 to 195 kg/m³). Typical 5.5 ft (1.7 m) diameter straw bales weighed from 800 to 1000 lb (360 to 450 kg) with densities ranging from 6.6 to 8.2 lb/ft³ (105 to 130 kg/m³). The bale density control allowed a wide range of densities. Variation in feed rate and uniformity of feed rate also affected bale density.

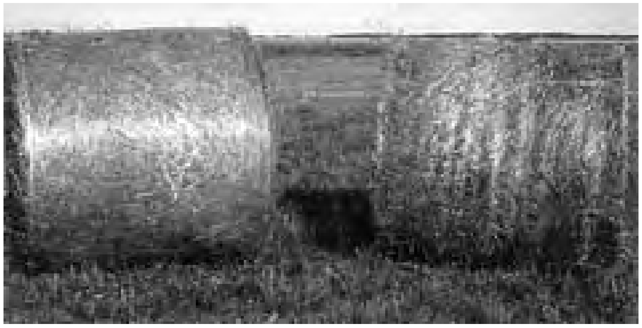

FIGURE 3. Typical Twine Wrapped and Net Wrapped Bales.

Bale Weathering: Resistance to bale weathering was very good. During a period of 100 days, over which 4 in (100 mm) of total rainfall was measured, spoilage was observed to a depth of 1 in (25 mm). The net wrapped bales had a smoother surface, which may repel moisture better. However, the limited scope of this test did not permit a conclusive comparison of the spoilage between twine and net wrapped bales.

Leaf Loss: Leaf and stem loss on the John Deere 535 using the twine wrap system averaged 2.5% at a 12% moisture content. The corresponding results for net wrapped bales was 1.8%. These results were considered very good. The tests were conducted in a moderate crop of alfalfa, which had been cut with a 15 ft (4.6 m) windrower. Average crop yield was about 1.3 ton/acre (2.9 t/ha). Instantaneous workrates ranged from 13.4 to 18.9 ton/h (12.2 to 17.4 t/h).

The net wrapped bales accounted for a 27% reduction in leaf loss compared with twine wrapped bales. The net wrap system reduced the number of turns the bale made while being wrapped which reduced the leaf loss.

The importance of baling at a high moisture content on losses can be noted in FIGURE 4. This figure represents an accumulation of previous data for several round balers showing the total measured leaf and stem loss over a range of moisture contents in fields of mixed alfalfa, crested wheatgrass and bromegrass. Although the John Deere 535 was tested in a different crop, its total measured leaf loss was less than that presented in the figure.

FIGURE 4 does not include the relative effects of baling unconditioned or light windrows. Heavy, conditioned windrows are important to minimize losses. Lowering the PTO speed is effective in reducing the number of times the bale turns in the chamber, and consequently reduces leaf loss.

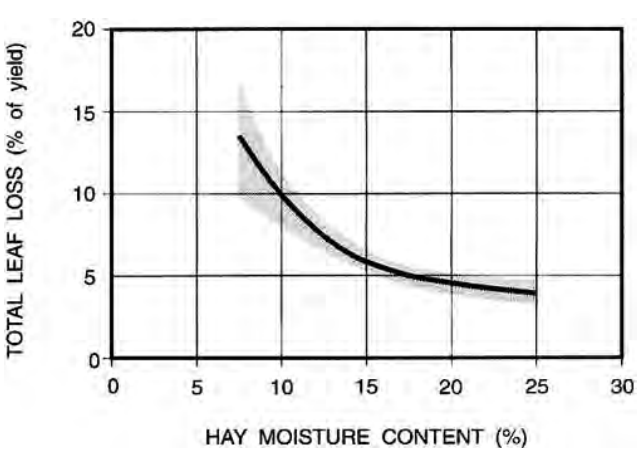

FIGURE 4. Typical Round Baler Leaf and Stem Loss in Mixed Alfalfa, Crested Wheatgrass and Bromegrass.

EASE OF OPERATION AND ADJUSTMENT

Bale Forming: Ease of bale formation was very good. The forming belts aggressively conveyed the crop into the bale chamber from the pickup creating a positive feeding and forming action. The core was formed by initially feeding the centre of the baler followed by two quick left and right swings of the baler to feed the edges of the bale chamber. Further bale formation consisted of feeding one side of the baler and holding there for a short period of time and then quickly steering the baler over to the other side and holding for about the same time. The bale shape gauges could be used to determine when to weave the baler from side to side. This technique fed the width of the bale chamber evenly and produced bales of uniform diameter. Improper bale forming techniques such as the operator weaving too frequently or too slowly from one side of the baler to the other produced barrel-shaped bales. FIGURE 5 shows the stages of bale formation in the John Deere 535.

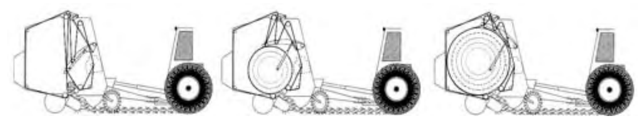

FIGURE 5. Stages of Bale Formation: (Left) Starting Bale, (Centre) Partially Completed Bale, (Right) Completed Bale.

The bale shape gauges showed the shape of the bale by measuring the tension in the left and right outside belts. When the belt tension dropped the gauge fell into the red, which indicated that side of the baler needed crop. The operator moved the baler over to fill the appropriate side of the baler. The gauge read green when an adequate amount of crop was present in the respective side of the baler.

Because the bale shape indicators worked off the two outside belts it was important that the operator crowd the edges of the baler well. Otherwise, the outside belts would slacken off relative to the inner belts and cause the bale shape indicators to read low. When this occurred, the operator would often weave too frequently which fed more material into the centre of the bale chamber than the outside edges. Barrel-shaped bales were often produced as a result.

The John Deere 535 was supplied with ground driven converging wheels. They were intended to help the operator pack the edges of the bale by crowding crop at the edges of the bale chamber. It was essential that the edges of the bales were well packed in order to obtain effective operation of the bale shape gauges and to produce durable bales. However, they were not aggressive and often rode over the windrow but did work well in fluffy windrows that were recently turned with a rake. The rubber teeth frequently worked part way out of the wheel assembly and caused interference with the converging wheel arm. It is recommended that the manufacturer consider modifications to improve the baler's ability to crowd hay at the edges of the bale chamber.

Feeding: Feeding performance was excellent. Feeding was positive and aggressive in all crops with only infrequent plugging. Any excessive blockages or plugging activated the main drive slip clutch. This clutch disengaged all feeding and bale forming mechanisms and thus prevented damage to the baler.

The baler frequently plugged when baling short, dry crops in hot weather and using normal operating techniques. It was found that decreasing the PTO speed, maintaining normal ground speeds, reducing the bale density and baling during late evening or early morning improved the performance. An improved pickup recently released by John Deere was installed partway through PAMI's test. The new pickup seemed to improve performance in these conditions as well. With this new pickup and following the procedures listed above the John Deere was able to bale straw that had been discharged from a rotary combine.

The John Deere was installed with a silage bundle and operated in silage crops with moisture contents up to 65%. The silage bundle helped to reduce crop build up on the rollers and as a result no feeding or forming problems occurred in silage crops.

Twine Wrapping: Ease of twine wrapping was good. A flashing light on the monitor alerted the operator when the bale was near its preset size. This allowed time to even up the bale before the automatic wrap cycle began. When the bale reached the preset size this light turned solid, a buzzer sounded and the wrapping system started automatically. The operator stopped forward travel of the baler once twine was feeding onto the bale. Two twine moving indicators turned as twine passed through them and indicated to the operator when twine was feeding into the baler. The dual twine arms quickly swung out to the right side of the baler and returned at a speed set by the operator. This speed governed the number of twine wraps across the width of the bale. The twine was cut on the left side of the baler with a twine knife assembly. To start the wrap cycle manually the operator tripped the wrapping mechanism by pulling on a rope.

Most operators preferred a wrapping sequence of 30 to 35 seconds consisting of 20 wraps, which corresponded to a twine consumption of 460 ft/ton (155 m/t). This produced a durable bale in both hay and straw that could be handled several times. Typical twine consumption for small square balers is about 670 ft/ton (225 m/t).

The twine knife performed well in most conditions. When baling dry short straw, crop back fed as it entered the bale chamber and collected on the knife assembly. When this occurred the knife had trouble cutting the twine.

In heavy crop conditions, the high swath occasionally dragged the twine out of the inner twine arm and had to be rethreaded before wrapping the bale. The outer twine arm was supplied with a shield to guard against this.

Every time the rear gate was opened the twine arms cycled. This proved to be inconvenient. Further, to observe the wrapping cycle the operator had to lock the rear gate, raise the tension arm and trip the wrapping system. This was also inconvenient. It is recommended that the manufacturer consider modifications to the wrapping system to reduce inconveniences associated with servicing and inspecting the baler.

Because the wrapping system started automatically once the preset bale size was reached, it was sometimes difficult to finish feeding the bale evenly across its width. The flashing light that indicated the bale formation cycle was nearly complete was helpful but it still was a little difficult to ensure a uniform bale diameter. If the operator could trigger the wrap cycle manually then the operator could finish off the bale evenly before wrapping.

Net Wrapping: Ease of net wrapping was good. The operation of the net wrap system was similar to the twine wrap system. When the preset bale size was reached a yellow light illuminated on the monitor and a buzzer sounded to alert the operator. The forward travel of the baler was stopped immediately to ensure crop was not fed in over the net wrap. This was not always possible at higher ground speeds. When wrapping was complete a second buzzer sounded and a red light on the monitor flashed to indicate to the operator that the net wrap was fed onto the bale properly and it was ready to be discharged. Switching from twine to net wrap was done simply by opening a hydraulic valve.

A double wrap of net was recommended by the manufacturer. It took about 10 seconds to wrap a bale. This produced a durable bale in both hay and straw that could be handled several times with minimal feed loss.

During net wrapping both the twine and net wrapping mechanisms operated simultaneously. The net wrap was applied when the twine arms swung out and the net was cut off when the twine arms reversed their direction. Twine was tied back from the ends of the twine arms to prevent it from feeding into the baler. In heavy crops the swath occasionally pulled the twine out of the twine arms, which allowed it to feed into the baler. Because the twine wrapping system was in operation when applying net wrap the same inconveniences and difficulties noted in the previous section were also prevalent with the net wrap system.

I n short dry crops the net wrap sometimes protruded out into the throat of the baler as the bale was being wrapped. When this happened the pick up teeth tore some of the net wrap. This problem was related more to the feeding difficulties associated with baling short dry crops than to the net wrap system.

Tearing occurred at either end of the net wrap when the roll was nearly consumed. Near completion, the roll's diameter was smaller and it dug into its outer supports.

Bale Discharging: Ease of bale discharging was very good. Once the wrapping sequence was completed the operator opened the rear gate hydraulically. The bale push bar operated mechanically with the rear gate and pushed the bales back clear of the gate. As a result, the operator did not have to move the baler ahead before closing the rear gate. Further, the operator did not need to reduce the PTO drive speed when discharging a bale. When the operator had fully closed the gate, the baler was ready to make the next bale. A light on the monitor indicated to the operator when the tailgate was fully closed.

The bale could be wrapped and discharged in about 40 to 45 seconds and 15 to 20 seconds for the twine and net wrap systems respectively.

Adequate hydraulic flow from the tractor was necessary to avoid problems when discharging a bale. When the gate opened too slowly the starting roller damaged the net wrap. When the gate was closed with inadequate hydraulic flow, the tension arm did not fall fast enough relative to the gate and left the forming belts loose. These belts became pinched when the gate was fully closed.

Transporting: Ease of transporting the John Deere 535 was good. Ground clearance was adequate and there was adequate hitch clearance for turning sharp corners provided dual tractor tires were not used. Care was necessary when backing up or transporting on roadways due to obstructed visibility to the rear. The baler could easily be towed behind a tractor or a suitably sized truck. The load on the baler floatation tires with a full bale chamber did not exceed the Tire and Rim Association maximum load ratings at transport speeds of 25 mph (40 km/h). The operator had to dismount from the tractor to lift the pickup. An optional hydraulic pickup lift was available. A safety chain was not standard equipment but was available as an option. It is recommended that the manufacturer consider supplying a safety chain as standard equipment.

Hitching: Ease of hitching the John Deere 535 to a tractor was very good. The hitch jack was convenient for raising and lowering the A-frame hitch. After hitching, the jack was raised off the ground, then removed and stored along the hitch frame. The baler monitor required a 12 volt electrical power source. One set of remote hydraulics was required. The constant velocity joint on the PTO driveline was effective in minimizing driveline chatter.

Twine Threading: Ease of twine threading was good. For each twine arm the twine was routed through a tension plate on the baler frame, around a twine moving indicator, through a number of guides and finally through the twine arm. A leaf spring mounted in the twine arm allowed the arm to have one open side. This made twine threading much easier. Routing the twine was very easy for the front twine arm but the inner twine arm was more difficult. Mechanisms near the inner twine arm and the need to move the front twine arm forward out of the way made it less convenient.

Net Wrap Threading: Ease of threading the net wrap was very good. Procedures involved gathering the loose end of the net wrap together and threading up to one inch (25 mm) of net between two rubber rollers. If too much net was threaded between the rubber rollers the net sometimes plugged in the rollers.

During wrapping the rubber rollers fed the net wrap onto the surface wrap guide and pan. At this point, the forming belts were in contact with the net and pulled the net along the guide and pan to the bale chamber. Once in the bale chamber, the net clung to the bale and wrapped around it as it turned in the chamber.

Adjustment: Ease of adjustment was good. The pickup was adjusted to the desired position with a hand crank. The operator was required to visually check the operating position of the pickup each time the pickup was lowered from its transport position. The optional gauge wheels made this adjustment easier to perform because they acted as a reference point. However, the gauge wheels were not designed to be in constant contact with the ground. John Deere also supplies an optional hydraulic pickup lift. In this case the hand crank acts as a stop controlling the pickup height. This would greatly improve the ease of adjusting the pickup height.

Bale size was adjusted by setting the bale size knob as pictured in FIGURE 6. No reference scale was provided. As a result, trial and error was necessary to set the knob properly for the desired size. It is recommended that the manufacturer consider adding a bale size reference scale to aid the operator in setting the bale size.

Bale density was controlled by the belt tension roller (FIGURE 1).

As the bale grew, it pushed up on this roller. The roller was mounted to a belt tension arm. The baler's hydraulic circuitry provided resistance to tension arm rotation, which in turn provided pressure to the forming bale. The bale density was controlled by adjusting the relief valve pressure setting. Turning the control knob clockwise increased the bale pressure.

FIGURE 6. Bale Settings: (1) Bale Size Control Knob, (2) Twine Wrap Control Valve, (3) Net Wrap Control Valve.

The twine wrap spacing was easily set but required some trial and error for varying conditions. The distance between the dual twine arms governed the desired twine spacing. The desired distance between adjacent dual twine wraps was then set equal to the spacing between the twine arms. This was done by adjusting the speed that the twine arm moved across from the right hand side of the bale to its home position. This speed was controlled by a hydraulic flow control valve (valve as shown at (2) in FIGURE 6). Rotating the valve clockwise decreased the twine arm speed, which decreased the space between adjacent dual twine wraps. Bale size, PTO speed and hydraulic oil temperature affected the spacing between adjacent dual twine wraps at any given valve setting. As a result, the valve setting was readjusted when any of the above variables changed.

Net wrap was fed onto the bale as the twine arms travelled from their home position to the right hand side of the baler. When the twine arms reached their right hand position a valve tripped that terminated the net wrapping. The amount of net wrap fed around the bale was controlled by the time taken for the twine arms to move from their home to right hand position. The speed that the twine arms moved outward was controlled by the hydraulic flow control valve (3) as shown in FIGURE 6. Rotating it clockwise decreased the twine arm speed, which in-creased the amount of net wrap fed onto the bale before wrapping was stopped. Trial and error was necessary to set the valve for the appropriate number of wraps. Bale size, PTO speed and hydraulic oil temperature affected the number of wraps fed onto a bale at any given valve setting. As a result, the valve setting was readjusted when any of the above variables changed. It is recommended that the manufacturer consider adding reference points to the twine and net wrap flow control valves to aid the operator in setting the number of twine and net wraps.

The distance between the end wraps of twine and the end of the bale could not be adjusted on the John Deere 535. In conditions such as straw, the edge twines often pulled off the bale. If the twine could have been placed further in from the edge of the bale this problem would have been reduced. It is recommended that the manufacturer consider adjustable twine guides that would allow the operator to select the distance from the outside twine wraps to the ends of the bale.

Lubricating: Ease of lubricating the John Deere was good. It had 4 drive chains, 3 drive belts, 42 grease fittings, one gearbox, and one hydraulic oil reservoir. The operator's manual recommended lubricating the roller drive chains every 10 hours, servicing 24 grease fittings every 10 hours, 16 grease fittings every 30 hours, and two grease fittings every 50 hours. A number of decals indicating grease fitting locations were omitted on the baler. Complete daily servicing took one person about 20 minutes.

POWER CONSUMPTION

Power Requirements: FIGURE 7 shows typical PTO and drawbar power requirements for the John Deere 535 at a workrate of 17.8 ton/h (16.1 t/h) and 15.2 ton/h (13.8 t/h) for a high and low density twine wrapped bale respectively. The power input is plotted against the bale weight to show the power requirements while each bale is formed. The curves are an average of the highly fluctuating measured PTO data, which varied from 7 to 11 hp (5 to 8 kW) at no load to a maximum of 42 hp (32 kW) in alfalfa for full sized bales. PTO power requirements are highly dependent on workrate. The high power consumption measured from the John Deere is a result, in part, of the high workrate it was tested at.

Drawbar requirements at 7.2 mph (11.5 km/h) were about 8 hp (6 kW) when the bale reached full size for high density bales. Although maximum horsepower requirements did not exceed 50 hp (38 kW), additional power was required to suit other field conditions such as soft and hilly fields. The manufacturer suggested a 75 hp (56 kW) tractor to fully utilize baler capacity.

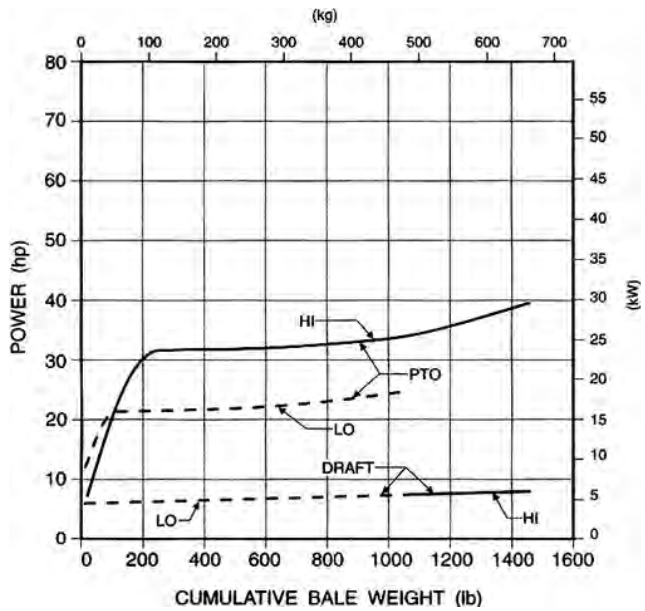

FIGURE 7. Typical Power Consumption During Bale Formation in Alfalfa (HI) High Density Bale, (LO) Low Density Bale.

Specific Capacity: Specific capacity is a measure of how efficiently a machine performs a task. A large specific capacity indicates efficient energy use. Specific capacity is dependent on the power consumed and the workrate of a task.

The specific capacity of the John Deere 535 was 0.53 ton/hp-h (0.65 t/kW-h) in alfalfa at an instantaneous workrate of 17.8 ton/h (16.1 t/h) producing high density twine wrapped bales. The specific capacity with high density, net wrapped bales was 0.62 ton/hp-h (0.76 t/kW-h) in alfalfa at an instantaneous workrate of 20.4 ton/h (18.5 t/h). Net wrap increased the specific capacity by about 17%. The typical range of specific capacities for small square balers in alfalfa is 0.6 to 1.2 ton/hp-h (0.7 to 1.4 t/kW-h).

OPERATOR SAFETY

Overall operator safety of the John Deere was very good if normal safety precautions were observed. The operator is cautioned that a round baler is potentially a very dangerous farm implement. The operator must disengage the PTO and stop the tractor engine before clearing blockages or making adjustments. Many serious and fatal accidents have occurred with round balers. Most of these are caused by operators dismounting from the tractor while leaving the baler running.

The John Deere 535 was safe to operate and service as long as common sense was used and the manufacturer's safety recommendations were followed. Rotating parts were well shielded. The pickup and feeding area were well guarded to discourage operators from attempting to clear blockages with the baler in operation. The safety shields were conveniently hinged so they did not have to be completely removed. Safety decals were prominently displayed at hazardous locations on the baler.

A tailgate lock valve provided safe servicing when working around the baler with the tailgate in a raised position. This valve closed the hydraulic lines to the tailgate, which prevented anyone from lowering the tailgate with the tractor controls. A slow moving vehicle sign was provided with the baler. Other safety equipment available on the John Deere included a warning light kit for safe transporting on roads and highways.

OPERATOR'S MANUAL

The operator's manual was very good. The manual was well written and clearly illustrated. It contained useful information on warranty, operation, servicing, adjustments, optional equipment and safety procedures.

MECHANICAL HISTORY

The John Deere 535 was operated for 101 hours while baling 1644 bales. The intent of the test was an evaluation of functional performance and an extended durability evaluation was not conducted. TABLE 3 outlines those problems, which occurred during functional testing.

TABLE 3. Mechanical History

Item	Operating Hours	Number of Bales
-Twine guide rod bent & repaired at	52	833
-Twine arm spacer bent & repaired at	62	1015

DISCUSSION OF MECHANICAL PROBLEMS

Twine Guide Rod: The twine guide rod bent when a forming belt inadvertently slipped underneath the rod and pulled up on it when tension returned to the belts. The forming belts had been slack in the throat of the baler and the twine arms caught the outside belt and slipped it underneath the twine rod as they swung over.

Twine Arm Spacer: The steel strap of the mechanism that adjusted the spacing between the twine arms bent during the test. It was straightened well enough to allow for proper operation. However some permanent deformation remained and the part likely was weakened by it. It is recommended that the manufacturer consider increasing the strength of the mechanism used to adjust the spacing between the twine arms.

APPENDIX I
SPECIFICATIONS

MAKE:	John Deere
MODEL:	535
SERIAL NUMBER:	E00535 X 888147
DIMENSIONS:	
-- width	9.6 ft (2.9 m)
-- height, with gate closed	9.5 ft (2.9 m)
-- length, with gate closed	13.6 ft (4.2 m)
-- ground clearance	9.0 in (230 mm)
TIRES:	Two, 31 x 13.5 - 15NHS
WEIGHT:	
-- left wheel	2315 lb (1050 kg)
-- right wheel	2298 lb (1042 kg)
-- hitch point	1027 lb 1466 kg)
TOTAL	5640 lb (2558 kg)
BALE CHAMBER:	
-- width	5.1 ft (1.6 m)
-- maximum diameter	6.0 ft (1.8 m)
-- bale density control	Hydraulic relief valve system
-- bale peripheral speed at 540 rpm	7.6 mph (12.2 km/h)
FORMING BELTS:	
-- type	3-ply combination nylon polyester, diamond tread
-- number of belts	Eight
-- belt width	7.0 (178 mm)
-- thickness	3/16 in (5 mm)
-- spacing (centre to centre)	7.5 in (191 mm)
-- belt speed (at 540 PTO rpm)	670 ft/min (204 m/min)
-- belt length	(4) - 43.8 ft (13.3 m) (4) - 44.3 ft (13.5 m)
ROLLERS:	
-- Driving Rollers	
-number	Two
-roller surface	Steel with 0.15 in (3.8 mm) thick grip pads
-length	5.1 ft (1.6 m)
-diameter	5.5 in (140 mm)
-speed	325 rpm
-- Starting Roller	
-roller surface	steel with 3/8 x 1 in (9.5 x 25.4 mm) steel bats
-length	5.1 ft (1.6 m)
-diameter	5.5 in (140 mm)
-speed	320 rpm
PICKUP:	
-- type	cylindrical drum with spring teeth
-- height adjustment	hand crank
-- width	5.1 ft (1.6 mm)
-- diameter	10.4 in (265 mm)
-- number of tooth bars	four, 12 double teeth per bar
-- speed	150 rpm
-- tooth tip speed (at 540 rpm)	8.8 mph (14.3 km/h)
TWINE WRAP SYSTEM:	
-- capacity	six bails
-- type	self activating hydraulic at preset bale size
-- recommended twine	sisal or plastic
-- twine feed	dual twine arm
-- twine cutter	pivoting knife against twine
NET WRAP SYSTEM:	
-- capacity	one, 5 ft (1.5 m) x 1 ft (0.3 m) diameter roll
-- type	self activating hydraulic at preset bale size
-- net cutter	pivoting knife against net
DRIVES:	
-- number of belt drives	three
-- number of chain drives	four
-- number of gear drives	one
-- number of universal joints	one
-- number of constant velocity joints	one
SAFETY DEVICES:	
-- main drive slip clutch	
-- tailgate hydraulic lockout valve	
-- hinged safety shields	
-- tailgate down indicator	
-- oversize bale indicator	

SERVICING:	10 hr	30 hr	50
-- grease	24	16	2
-- oil chains every	10 hours		
-- gearbox	check oil level routinely		
-- hydraulic reservoir	check oil level routinely		

TRACTOR HOOK-UP:	
-- connections	PTO electrical connection for monitor one tractor hydraulic remote circuit
-- hitch height	13.5 to 29 in (343 to 737 mm)

APPENDIX II
MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

Excellent	Fair
Very Good	Poor
Good	Unsatisfactory

SUMMARY CHART
JOHN DEERE 535 ROUND BALER

RETAIL PRICE:	$33,748.00 (March, 1992 f.o.b. Portage la Prairie, MB)
RATE OF WORK:	5.4 ton/h (4.9 t/h) in mixed grasses wrapped with twine to 18.0 ton/h (16.3 t/h) in alfalfa wrapped with net.
QUALITY OF WORK:	
Bale Quality	**Excellent;** tight wrap
Weatherability	**Very Good;** about 1 in (25 mm) spoilage
Leaf Loss	**Very Good;** 2.5% & 1.8% for twine and net wrapped bales respectively
EASE OF OPERATION AND ADJUSTMENT	
Bale Forming	**Very Good;** bale shape indicators aided operator
Feeding	**Excellent;** positive and aggressive in all crops
Twine Wrapping	**Good;** automatic start, inconvenient servicing
Net Wrapping	**Good;** easy operation, required quick response from operator
Bale Discharging	**Very Good;** fast and simple
Transporting	**Good;** easy to manoeuvre, poor rear visibility
Hitching	**Very Good;** convenient
Twine Threading	**Good;** easy to thread front arm, inner arm less convenient to thread
Net Wrap Threading	**Very Good;** simple
Adjustments	**Good;** simple but few reference positions or decals
Lubricating	**Good;** about 20 minutes for daily service
POWER CONSUMPTION:	
Power Requirements	75 hp (56 kW) suggested by manufacturer
Specific Capacity	0.53 ton/hp-h (0.65 t/kW-h) at a work rate of 17.8 ton/h (16.1 t/h) for twine wrapped bales; 0.62 ton/hp-h (0.76 t/kW-h) at a work rate of 20.4 ton/h (18.5 t/h) for net wrapped bales.
OPERATOR SAFETY:	**Very Good;** well shielded and visible decals
OPERATOR'S MANUAL:	**Very Good;** well written
MECHANICAL HISTORY:	Twine guide rod bent, twine arm spacer bent

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