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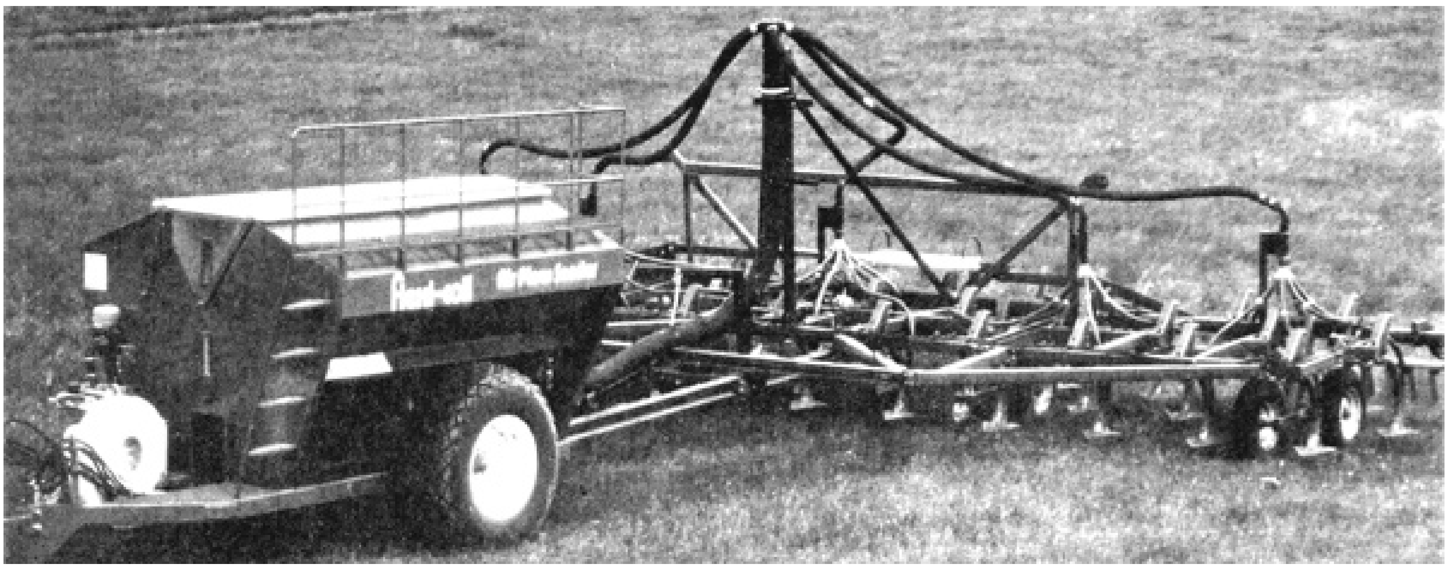

Flexi-coil Air Flow Seeder

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

FLEXI-COIL AIR FLOW SEEDER

MANUFACTURER AND DISTRIBUTOR:

Flexi-coil Ltd.
P.O. Box 1928
Saskatoon, Saskatchewan
S7K 3S5

RETAIL PRICE: (February, 1982, f.o.b. Lethbridge, Alberta).

(a) Flexi-coil air flow seeder complete with seed boots and distribution system to feed 35 shanks.	$23,375.00
(b) John Deere 1610 10.7 m (35 ft) heavy duty cultivator complete with attached harrows.	$21,341.00

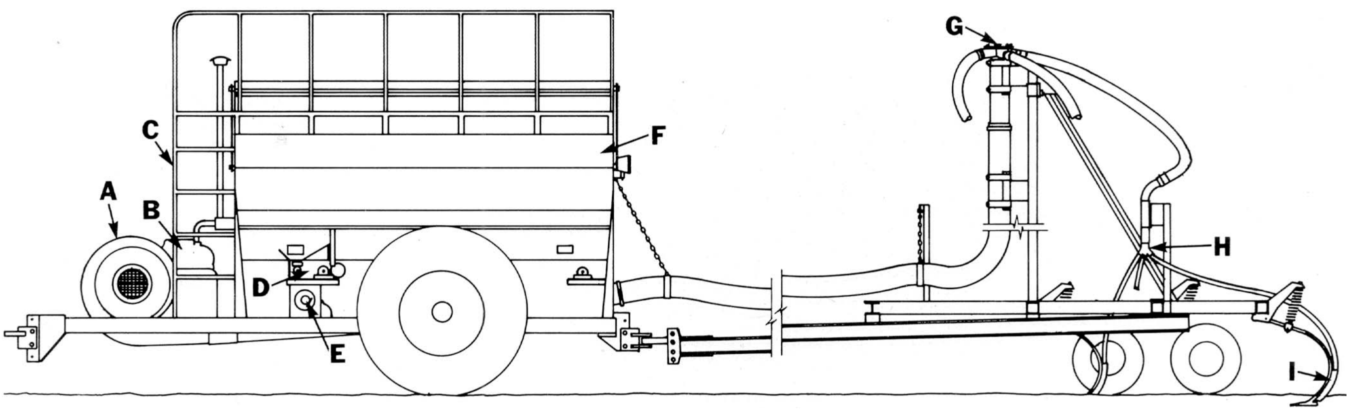

FIGURE 1. Flexi-coil Air Flow Seeder: (A) Fan, (B) Fan Engine, (C) Ladder, (D) Metering System, (E) Air Lock, (F) Tanks, (G) Primary Header, (H) Secondary Header, (I) Seed Boot.

SUMMARY AND CONCLUSIONS

Overall functional performance of the Flexi-coil air flow seeder was *good* in all seeding conditions. Performance was *good* when banding fertilizer. When operated with the 10.7 m (35 ft) John Deere 1610 heavy duty cultivator, the Flexi-coil was suitable for seeding both in primary and secondary field conditions. The Flexi-coil was also suitable for banding fertilizer at application rates up to 365 kg/ha (325 lb/ac) at 9 km/h (5.5 mph). Higher application rates were possible at reduced speeds.

Seed placement was good in most conditions. Variation in seed depth was slightly higher than with a conventional hoe drill when measured in the same fields under the same seeding conditions. Row spacing and seed band width behind each seed boot provided ample stubble for good windrow support. Maintaining good cultivator frame levelling and ensuring a seed depth of at least 50 mm (2 in) were critical in ensuring good emergence.

The manufacturer's metering system calibrations were acceptable in wheat, barley, oats, and fertilizer. The manufacturer's meter calibration was inaccurate for rapeseed.

Distribution uniformity was acceptable in wheat and barley at normal seeding rates and at rates up to 50 kg/ha (45 lb/ac) in oats. Distribution in rapeseed and fertilizer was unacceptable at all application rates.

Field bounce, field slope and ground speed had little effect on metering rates. Distribution uniformity was only slightly affected by field slope.

Seeding rate was easily adjusted. Tank and meter cleanout convenience was fair. Tank filling required the use of a drill fill or auger. Eleven grease fittings and two wheel bearings on the applicator required greasing.

Operator visibility of the cultivator was obstructed by the tanks.

The Flexi-coil with John Deere 1610 heavy duty cultivator could be placed in transport position in less than five minutes.

Rate of work usually ranged from 8.6 to 10.7 ha/hr (21 to 27 ac/hr). About 58 ha (142 ac) could be seeded before refilling both tanks when seeding wheat at a normal seeding rate.

Tractor size depended on soil conditions, seeding depth, ground speed, cultivator width, and soil finishing attachments. In light primary tillage, at 75 mm (3 in) depth and 8 km/h (5 mph), a 107 kW (144 hp) tractor was needed to operate the applicator-cultivator combination. In heavy primary tillage at the same depth and speed, a 128 kW (173 hp) tractor was needed.

The cultivator centre frame tires were slightly overloaded in transport position and the applicator tires were overloaded with full tanks.

The operator's manual contained useful information on safety, adjustment, assembly, maintenance and operation. A detailed parts list was also included.

Only minor mechanical problems occurred during the evaluation.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Improving the front meter calibration for metering rapeseed.
2. Supplying meter calibrations for all grains in SI units.
3. Modifications to the distribution system to improve distribution uniformity in oats, fertilizer and rapeseed.
4. Moving the applicator wheels rearward to reduce applicator hitch bouncing.
5. Modifying the tank lid to reduce the force required to open and close the lid.

6. Providing, as optional equipment, a monitoring system to monitor material flow.
7. Providing an area meter as standard equipment.
8. Providing protection around the fan engine exhaust and shut-off for improved operator safety.

Senior Engineer: E. H. Wiens

Project Engineer: R. K. Allam

THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. Improving the front meter calibration for rapeseed is under study.
2. Meter calibrations in SI units will be supplied with air seeders manufactured in 1982.
3. Testing of modifications to improve the distribution uniformity is presently under way.
4. The axle, on units manufactured in 1982, will be moved rearward. Our tests have shown this eliminates the bounce problem, provides weight transfer to the tractor hitch and maintains good turning ability of the air seeder/cultivator unit.
5. Units manufactured in 1982 will have a crank operated lid.
6. A monitoring system, to be standard on units manufactured in 1982, will monitor material flow, fan speed, feed shaft rotation, bin levels, engine oil, charging rate and area covered. It will also be available, at extra cost, for existing air seeders.
7. See item 6.
8. Air seeders, manufactured in 1982, will have a remote engine control panel with engine tachometer/hourmeter, cable actuated throttle and shut-off, start switch, light switch, and engine indicator lights.

NOTE: This report has been prepared using. SI units of measurement. A conversion table is given in APPENDIX III.

GENERAL DESCRIPTION

The Flexi-coil air flow seeder is a pneumatic seed and fertilizer applicator designed for use with varying makes and models of light, medium and heavy duty cultivators.

The cultivator is attached to the rear of the applicator with the standard cultivator hitch. The applicator is supported by two wheels, each on single axles.

Seed and fertilizer are pneumatically distributed from two tanks through a network of tubes to seed boots attached to the rear of each cultivator shank. The applicator can be used for seeding, for combined seed and fertilizer application, and for fertilizer banding.

Seed or fertilizer are metered from the front tank through an adjustable fluted roll mounted below the tank. Material is metered from the rear tank by varying the gate opening above a conveyor belt. The meters are driven by a series of chains and sprockets from the right applicator wheel. Metered material passes through an air lock before entering the airstream. An air cooled diesel engine powered fan, forces the metered material through the distribution system. The distribution system consists of a five port primary header feedfng five, seven-port secondary headers, all of which are mounted on the cultivator frame. Tubes from the secondary headers connect to the seed boots.

The test machine was used with a John Deere 1610 heavy duty cultivator. This cultivator was 10.7 m (35 ft) wide with a 4.0 m (13.1 ft) centre frame and two 3.3 m (10.8 ft) wing sections. It was equipped with 35 spring cushioned shanks, spaced at 305 mm (12 in), arranged in three rows. The cultivator was equipped with optional three-row mounted harrows. A tractor with three remote hydraulic controls was required to operate the Flexi-coil air flow seeder with the John Deere 1610 cultivator.

Detailed specifications for the pneumatic applicator and cultivator are given in APPENDIX I while FIGURE 1 shows the location of major components.

SCOPE OF TEST

The Flexi-coil was operated in loam and clay soils in the field conditions shown in TABLE 1 for approximately 108 hours while processing about 770 ha (1900 ac). It was evaluated for quality and rate of work, ease of operation and adiustment, power requirements, safety and suitability of the operator's manual.

TABLE 1. Operating Conditions

CROP	FIELD TILLAGE CONDITIONS	STONE CONDITIONS	FIELD AREA (ha)	HOURS
Durum wheat on summerfallow	Secondary	Occasional stones	65	9
Spring wheat on summerfallow	Secondary	Occasional stones	75	10
Spring wheat on stubble	Primary	Occasional stones	115	15
Spring wheat on stubble	Primary	Stone free	365	52
Winter wheat on stubble	Primary	Occasional stones	5	2
Banding fertilizer	Primary	Stone free	145	20
Total			770	108

RESULTS AND DISCUSSION

QUALITY OF WORK

Metering Accuracy: The grain and fertilizer metering system was calibrated in the laboratory[1] and compared with the manufacturer's calibration. Since actual seeding rates for certain settings depended on things such as seed size, density and moisture content, it is not possible for a manufacturer to present charts to include all the varieties of seed. Field calibration checks may be necessary for seed with properties differing from those indicated in the manufacturer's table. Research has, however, shown that small variations in seeding rates will not significantly affect grain crop yields.

Calibration curves for wheat, barley, oats and 11-51-00 fertilizer are given in FIGURES 2 to 5 for the front and rear metering systems. PAMI's calibration curves are compared to the manufacturer's calibration curves. At a seeding rate of 80 kg/ha (70 lb/ac), measured rates agreed with the manufacturer's calibration in wheat for both tanks, were 10 and 14% higher than the manufactuere's rate for barley with the front and rear meters, respectively, were 7% higher than the manufacturers rate and accurate for oats with front and rear meters, respectively, and accurate with 11-51-00 fertilizer for both meters.

The rear metering system was not suitable for seeding rapeseed. FIGURE 6 shows the calibration curves while metering rapeseed with the front meter. At a seeding rate of 7 kg/ha (6.2 lb/ac) in rapeseed, the measured seeding rate was 28% higher than the manufacturer's rate. At a seeding rate of 4 kg/ha (3.6 lb/ac), the measured seeding rate was 65% lower than the manufacturer's rate. It is recommended that the manufacturer's calibration accuracy for rapeseed be improved.

Operating on side slopes and hills had only a minor effect on metering rates. For example, when operating on a 10 degree side slope, metering rates with both wheat and fertilizer could decrease as much as 8%. When going down a hill, the metering rate on the rear meter could increase by as much as 10% for

[1]T773, "Detailed Test Procedures for Grain Drills."

both wheat and fertilizer. An increase in ground speed from 4.8 to 12 km/hr (3 to 7.5 mph) decreased the front metering rate by 7% in wheat and 11% in 11-51-00 fertilizer. Variations in ground speed did not affect the rear meter. Although ground drive wheel slippage in soft fields is common with many ground driven applicators, no ground drive wheel slippage of the large diameter drive wheel was experienced with the Flexi-coil.

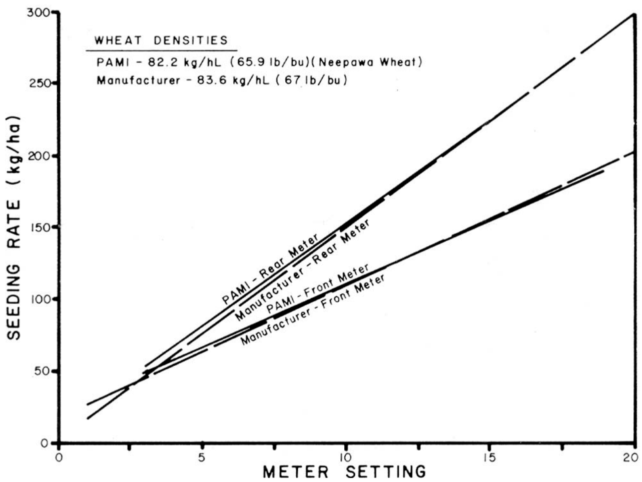

FIGURE 2. Metering Accuracy in Wheat.

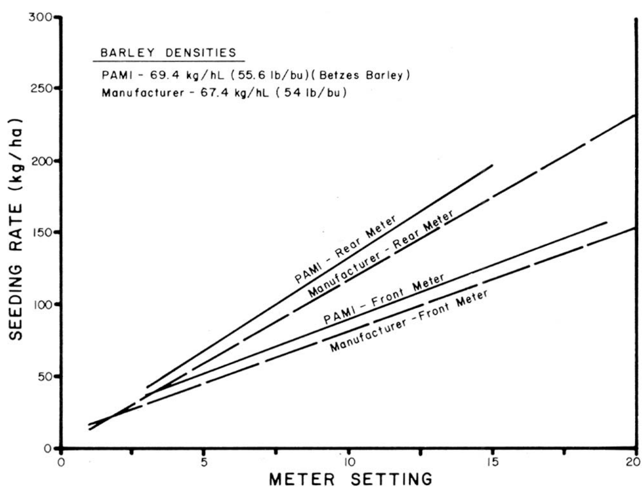

FIGURE 3. Metering Accuracy in Barley.

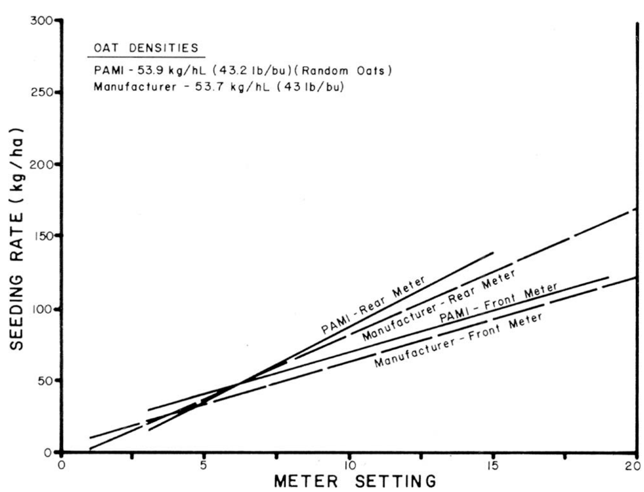

FIGURE 4. Metering Accuracy in Oats.

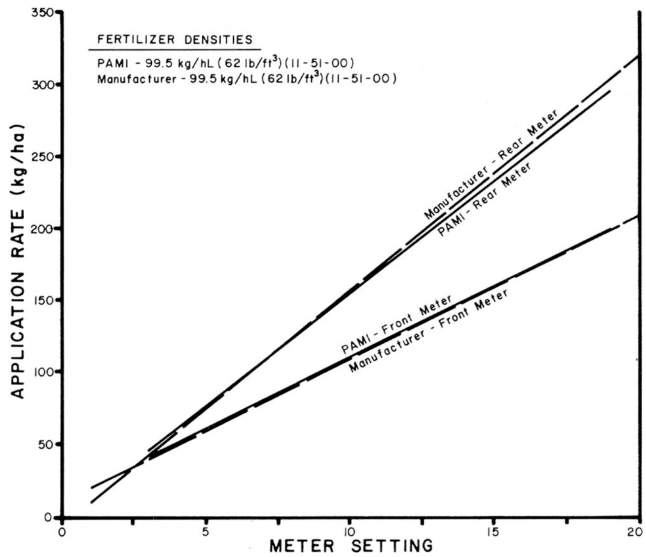

FIGURE 5. Metering Accuracy in Fertilizer.

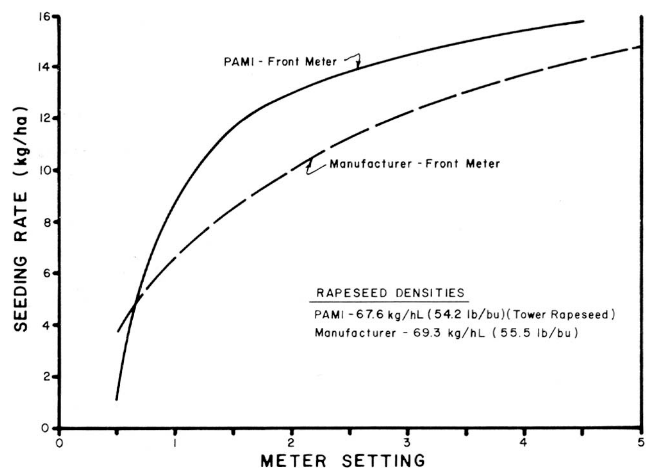

FIGURE 6. Metering Accuracy in Rapeseed.

Distribution Uniformity: FIGURE 7 gives seeding distribution uniformity for the Flexi-coil in wheat, barley and oats at a fan speed of 3000 rpm. Changes in fan speed had very little effect on distribution patterns. For example, in wheat, varying the fan speed from 2500 to 3500 rpm, resulted in coefficients of variation[2] (CV)of 12.2 and 11%, respectively. Distribution was uniform over the normal range of seeding rates for wheat and barley. For example at a seeding rate of 80 kg/ha (70 lb/ac) the CV was 9.8% for both wheat and barley. Distribution uniformity was unacceptable in oats for seeding rates above 50 kg/ha (45 lb/ac).

FIGURE 8 gives seeding distribution uniformity in rapeseed at a fan speed of 2500 rpm. Although decreasing the fan speed from 2500 to 1500 rpm resulted in the CV decreasing from 30.8 to 23.5% respectively, distribution patterns were unacceptable over the full range of fan speeds. FIGURE 8 shows that at a fan speed of 2500 rpm, distribution uniformity is unacceptable over the entire seeding range with CV's varying from 26.4 to 30.8%. FIGURE 9 shows unacceptable distribution uniformity for 11-51-00 fertilizer at all application rates.

It is recommended that modifications be made to the Flexi-Coil distribution system to improve distribution uniformity in oats, fertilizer and rapeseed.

[2]The coefficient of variation (CV) is the standard deviation of seeding rates from individual shanks expressed as a per cent of the average seeding rate. An accepted variation for seeding grain or applying fertilizer is a CV value not greater than 15%. If the CV is less than 15%, distribution is acceptably uniform, whereas if the CV is greater than 15%, the variation in application rate among individual shanks is excessive.

Changes in distribution pattern uniformity could occur at different forward speeds or for different machine widths due to different volumes of material being introduced into the constant volume of air supplied by the fan.

Seeding or fertilizing up or down a 10 degree slope or on a 10 degree sideslope had little effect on distribution uniformity.

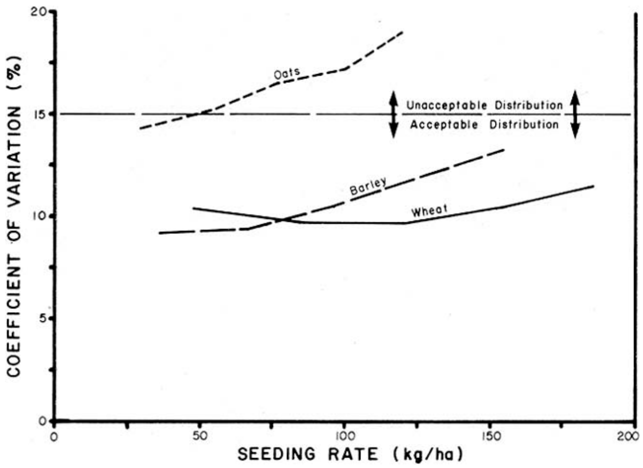

FIGURE 7. Seeding Uniformity in Cereal Grains at 9 km/h and a Fan Speed of 3000 rpm.

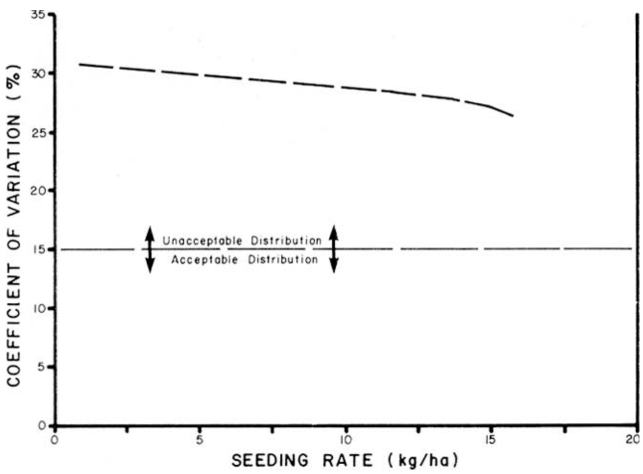

FIGURE 8. Seeding Uniformity in Rapeseed at 9 km/h and a Fan Speed of 2500 rpm.

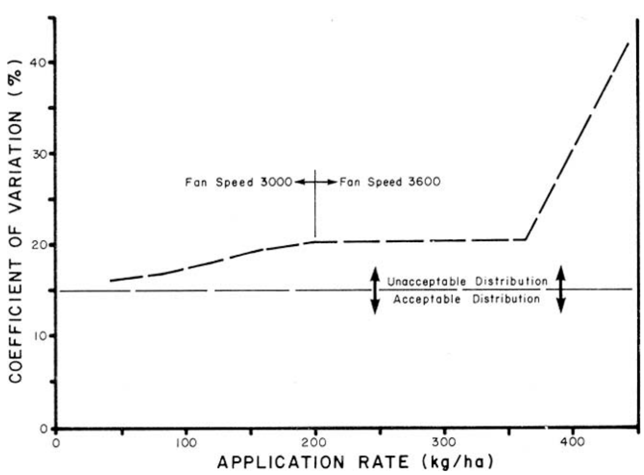

FIGURE 9. Distribution Uniformity in 11-51-00 Fertilizer at 9 km/h and a Fan Speed of 3000 and 3600 rpm.

Grain Damage: Grain damage by the metering and distribution system was within acceptable limits for cereal grains at fan speeds below 3500 rpm. For example, in dry Neepawa wheat at 11.2% moisture content and a fan speed of 3000 rpm, only 0.3% crackage occurred. Wheat crackage at the same moisture content increased to 0.9% at a fan speed of 3500 rpm. In dry rapeseed with a moisture content of 7% crackage at a fan speed of 3000 rpm was 7.6%. Reducing fan speed to 2500 and 2000 rpm reduced rapeseed crackage to 1.6 and 0.6% respectively. Due to excessive rapeseed damage at higher fan speeds, it is suggested that a maximum fan speed of 2500 rpm be recommended for rapeseed.

Seed Placement: Each seed boot was equipped with a V-shaped deflector (FIGURE 10) to spread the seed behind each cultivator sweep. After the spring seeding period the manufacturer supplied alternate seed boots with stronger V-shaped deflectors to replace the original seed boots. Some deflectors on the original seed boots had become deformed by hard soil and rocks. All seed placement measurements taken were in fields seeded with the original seed boots. Although rows were visible when grain first emerged, in most fields, after complete crop emergence, it was difficult to observe distinct plant rows. Therefore, even with 305 mm (12 in) cultivator shank spacing there was sufficient stubble for windrow support at harvest time (FIGURE 11).

Although seeds were usually placed on the furrow bottom at the working depth of each individual cultivator sweep, depth across the width of the machine varied due to cultivator frame geometry and non-uniform field surfaces. On level and gently rolling fields, vertical seed distribution was quite uniform. For example, at an average seed depth of 65 mm (2.5 in), seeding depth across the width of the machine varied from 40 to 95 mm (1.6 to 3.7 in) with most of the seeds being placed within 17 mm (0.7 in) of the average cultivator working depth. This compares to a vertical variation of from 12 to 15 mm (0.45 to 0.6 in) from average seeding depth for a hoe drill in similar conditions.

in fields with sharp hill crests or gullies, seed depth variation became much greater than for a hoe drill, due to the greater distances between shank rows on a heavy duty cultivator than on a hoe drill.

Vertical seed distribution was not adversely affected by field tillage conditions. The shanks on the John Deere 1610 cultivator were sufficiently rigid to maintain a fairly uniform sweep pitch (FIGURE 13) with resultant uniform tillage depth, over a wide range of soil conditions.

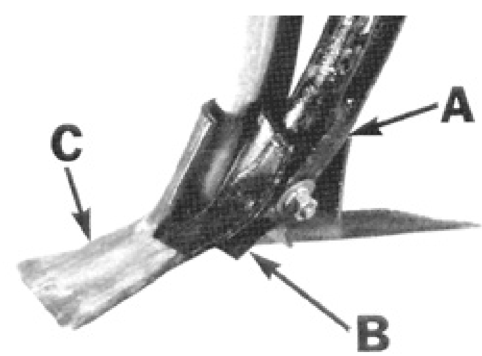

FIGURE 10. Flexi-coil Seed Boot: (A) Seed Boot, (B) V-shaped Deflector, (C) Sweep.

Plant Emergence: As with most seeding implements, time and uniformity of plant emergence depended on seedbed preparation, soil moisture and seed placement. The Flexi-coil was used to seed in a number of fields with different types of seedbed preparation. Uniform emergence resulted as long as machine settings were carefully adjusted to place seed in moist soil at the correct depth and providing loose seedbeds were packed after seeding. FIGURE 11 shows good wheat emergence when wheat was seeded directly into summerfallow as the first spring operation.

Careful cultivator frame levelling was important in obtaining uniform emergence across the cultivator width. Due to the rigidity of heavy duty cultivator frames, improper sideways levelling and fore-and-aft levelling can both result in rows of shanks operating at different depths.

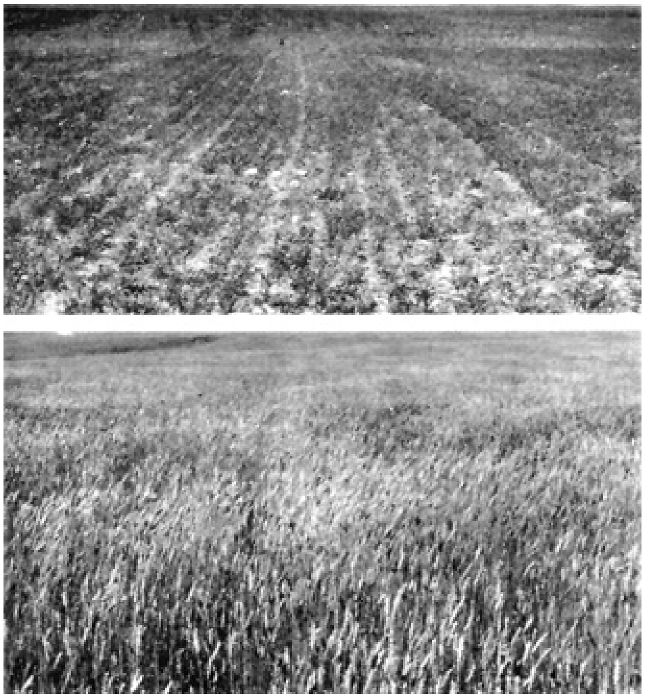

FIGURE 11. Uniform Wheat Emergence in Summerfallow (Upper: 30 Days after seeding, Lower: At Harvest).

Seeding Depth: It is very important to seed deep enough to obtain uniform seed coverage. Correct cultivator adjustment for pneumatic seeding were best obtained by comparing the depth of seeds placed by several shanks across the cultivator width and from both the front and rear shank rows. This permitted accurate frame levelling to obtain uniform seed coverage. Seeding shallower than 50 mm (2 in) is not recommended for a heavy duty cultivator, due to poor seed coverage and generally poor cultivator performance at shallow tillage depths.

Frame levelling had to be checked and appropriate depth adjustments made when changing fields to ensure adequate, uniform seed coverage.

Soil Finishing: For this evaluation, the John Deere 1610 cultivator was equipped with optional three-row mounted harrows. The mounted harrows were effective in smoothing the soil surface and in breaking soil lumps when adjusted to maximum ground pressure. The harrows also increased weed kill by loosening weeds.

The Flexi-coil with John Deere 1610 cultivator was not equipped with packers. Since it was considered essential to pack most fields seeded with the Flexi-coil, a harrow-packer drawbar[3] equipped with five bar tine harrows and trailing steel coil packers was used as a follow-up operation. The harrow-packer combination served to further smooth and pack the seedbed, leaving packer ridges from 25 to 30 mm (1 to 1.2 in). To obtain a smooth, firm seedbed in dry conditions required packer drawbar operations in two directions. Care had to be used in moist conditions to avoid over-packing the seedbed. FIGURE 12 shows a typical seedbed after seeding into stubble both before and after use of the packer drawbar.

Shank Characteristics: The John Deere 1610 cultivator was equipped with adjustable spring cushioned shank holders. During the evaluation, it was used with 406 mm (16 in) wide Edwards sweeps with a 50 degree stem angle, giving a no-load sweep pitch of 2 degrees. These shanks were very suitable for seeding since sweep pitch (FIGURE 13) varied only 3 degrees over the full range of draft normally expected for a heavy duty cultivator. This resulted in uniform tillage depth and a smooth furrow bottom over a wide range of soil conditions.

Cushioning spring preload, with new shanks, was exceeded at drafts greater than 7.3 kN/m (500 lb/ft), occurring just beyond the normal primary tillage draft range, indicating the John Deere 1610 was suited for heavy primary tillage.

The shanks performed well in stony fields. Maximum lift height to clear obstructions was 210 mm (8.3 in).

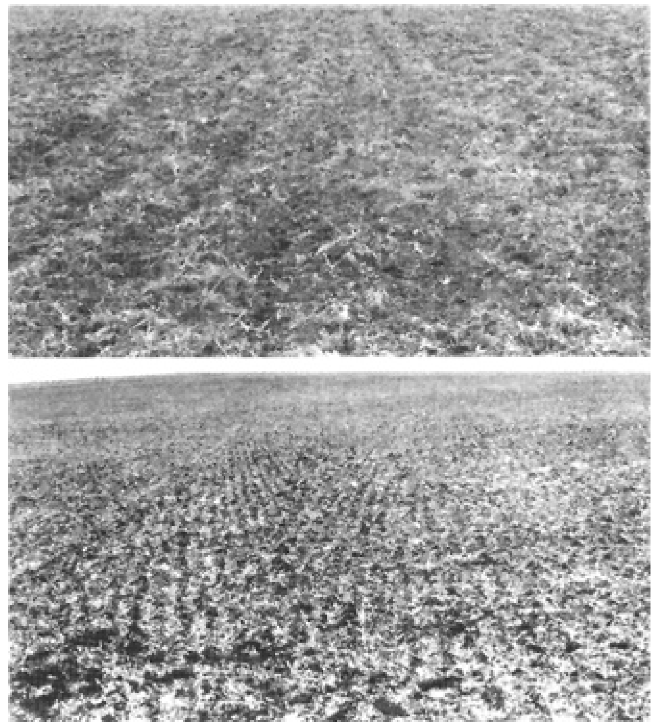

FIGURE 12. Flexi-coil Seedbed (Upper: Before Packing, Lower: After Packing).

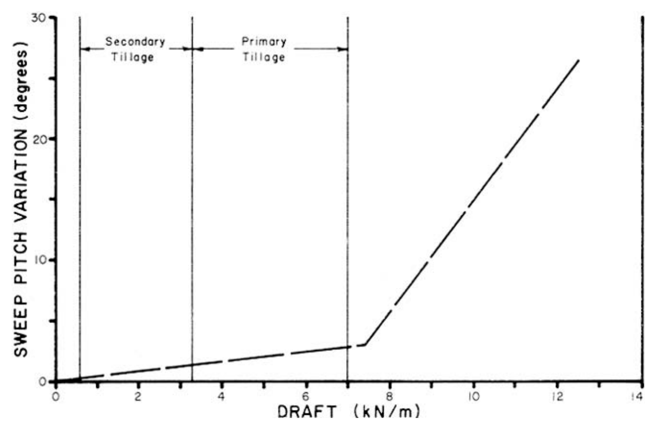

FIGURE 13. Sweep Pitch Variation over a Normal Range of Draft (305 mm Shank Spacing).

Penetration: When equipped with 50 degree, 406 mm (16 in) sweeps, penetration was good in most field conditions and it was easy to obtain correct seeding depth. Correct seeding depth could not be obtained in hard conditions such as dry, baked slough bottoms or in fields with abnormally hard furrow bottoms. Penetration was uniform across the cultivator width provided all depth control linkages and hitch height were kept properly adjusted.

The cultivator wheels were positioned so that each centre wheel supported about 16% of the total cultivator weight while each wing wheel supported about 9%. In addition, each center wheel supported about 13% of the total suction force while each wing wheel supported about 12%. Cultivator or pneumatic seeder sinking was not a problem in moderately soft soils. Since the pneumatic seeder was not supported by the cultivator wheels, but was carried on its own wheels, it did not contribute to cultivator sinking in soft soils.

[3]See Machinery Institute Evaluation Report 277.

Trash Clearance: The John Deere 1610 cultivator had excellent trash clearance. The John Deere mounted harrows had to be raised to clear heavy loose trash.

With the harrows properly adjusted it was possible to operate in fields with a heavier trash cover than was possible with a conventional hoe drill.

Skewing and Stability: The John Deere 1610 cultivator and Flexi-coil applicator combination were very stable and sideways skewing occurred only in very hilly conditions. The cultivator shank pattern was symmetrical and did not impose any side forces on the cultivator during normal tillage. When equipped with 406 mm (16 in) sweeps, the cultivator had to skew more than 3 degrees to miss weeds. Throughout the evaluation period, in normal seeding conditions, skewing was never serious enough to cause weeds to be missed. Reasonable care had to be observed on steep hillsides, due to the high centre of gravity of the applicator, especially with full grain and fertilizer tanks.

Whenever the material level in the front tank was lower than the rear tank, the Flexi-coil hitch weight would become negative, causing the applicator hitch to bounce up and down on the tractor drawbar. This motion was undesirable as it alternately raised and lowered the cultivator hitch by as much as 50 mm (2 in). It is recommended that the manufacturer consider moving the applicator wheels rearward to reduce applicator hitch bouncing.

Weed Kill: Weed kill was very good when equipped with 406 mm (16 in) sweeps. The 305 mm (12 in) shank spacing resulted in 100 mm (4 in) sweep overlap. Considerable sweep wear could occur before weeds were missed. However, to ensure adequate sweep lift is maintained for proper seed placement, sweeps should be replaced before significant wear is evident.

Fertilizer Banding: The Flexi-coil could be used for two types of fertilizer applications. It could be used for normal fertilizer application at seeding time by metering fertilizer from one tank and grain from the other and applying both through the same seed boots. When equipped with chisel points, and alternate banding boots (FIGURE 14), it could also be used for fertilizer banding.

Banding is a relatively new method of fertilizer application on the Prairies. Experimental results suggest that placing fertilizer in compact bands from 35 mm (1.5 in) below seed depth to twice seeding depth is desirable for fall fertilizer application. This requires the use of chisel points to obtain sufficient depth and minimize soil disturbance and special boots to minimize fertilizer spreading.

The Flexi-coil worked well for fertilizer banding. Fertilizer granules were placed in a band about 25 mm (1 in) wide. Vertical fertilizer distribution generally ranged from chisel tip depth to 10 mm (0.4 in) above chisel tip depth. Wider fertilizer bands were obtained as the chisel points became worn.

The fan did not provide adequate air to allow both meters to be fully opened while distributing 11-51-00 fertilizer. When using both tanks, the air supply at a maximum fan speed of 3600 rpm, was adequate to apply 440 kg/ha (392 lb/ac) with the 10.7 m (35 ft) cultivator at 9 km/h (5.5 mph). At higher application rates, plugging occurred in the hoses between the secondary header and seed boots. When using the rear or front tank only, fertilizer rates of 300 and 200 kg/ha (270 and 180 lb/ac), respectively, were possible.

Banding suitability at 9 km/h (5.5 mph) was reduced for application rates greater than 365 kg/ha (325 lb/ac) due to the rapid deterioration of the distribution uniformity (FIGURE 9) at higher rates. Higher application rates with suitable distribution uniformity could be obtained by reducing forward speed. For example, the application rate could be increased to about 410 kg/ha (365 lb/ac) at 8 km/h (5 mph).

When exposed to driving rain, some moisture entered the metering compartment. The metering system should be checked after rainfall for any caking of fertilizer to avoid errors in application rates. The Flexi-coil tanks were coated inside with an epoxy paint for corrosion protection. All unprotected metal surfaces such as the meter adjustment lock bolts should be cleaned and oiled periodically when applying fertilizer, to prevent corrosion.

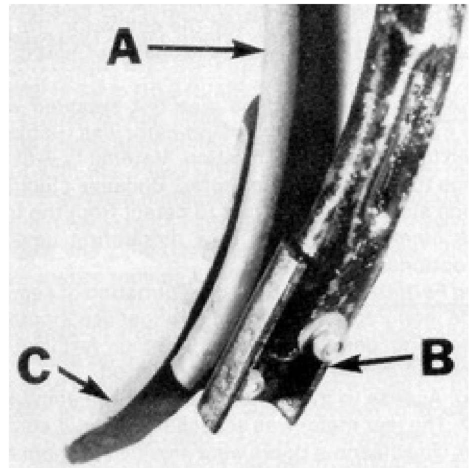

FIGURE 14. Flexi-coil Banding Boot: (A) Cultivator Shank, (B) Banding Boot, (C) Chisel Point.

EASE OF OPERATION

Dual Purpose Operation: The Flexi-coil could be detached from the cultivator by two men in about one hour. A hoist or front end loader was required to remove the primary header stand from the cultivator. The secondary headers and hoses also had to be removed from the cultivator, allowing the cultivator to be used as a dual purpose machine, both for seeding and seasonal tillage.

Hitching: The Flexi-coil air flow seeder was easily hitched to a tractor. Hitching convenience was increased by the fact that the hitch link remained horizontal when unhitched from the tractor. Hitching also required hook-up of six hydraulic lines with quick couplers.

Filling: A drill fill or grain auger was needed to fill the applicator tanks. Because the filler openings were located 2.4 m (8 ft) above the ground, hand filling was difficult as it necessitated carrying the grain or fertilizer up the access ladder. The large 1260 x 890 mm (50 x 35 in) filler openings gave ample room for auger filling. The filler lid was mounted on over-centre hinges (FIGURE 15), requiring a force of about 445 N (100 lb) to push the lid open (over centre) and about 550 N (125 lb) to close the lid. The considerable force required to open the filler lid was inconvenient for some operators. The lids were not equipped with weather stripping to prevent moisture entry. It is recommended that the tank lid opening and closing force requirement be reduced.

The front tank held 3200 L (88 bu) while the rear tank held 3318 L (92 bu).

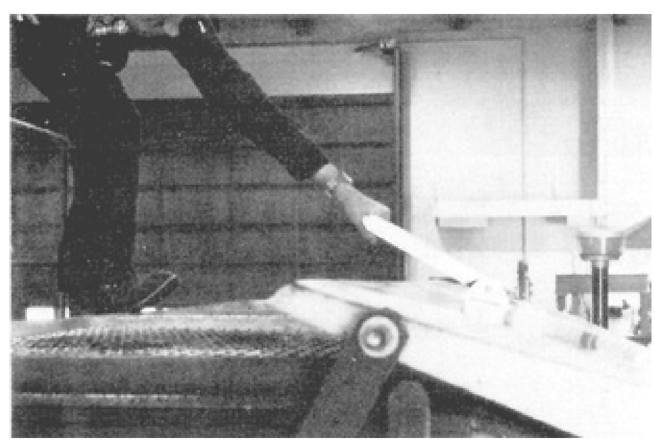

FIGURE 15. Operator Closing Tank Lid.

Visibility: Visibility of the cultivator mainframe section was obstructed by the tanks. Care had to be observed when operating the Flexi-coil to detect possible problems such as mainframe plugging.

Maneuverability: Because of the additional pivot point at the hitch between the applicator and the cultivator, the Flexi-coil air flow seeder, when attached to the cultivator, was difficult to maneuver while backing up.

Monitoring: The test machine was not supplied with a material flow monitoring system. An indicator was visible from the tractor cab to monitor meter rotation. Material flow through the distribution tubes was not monitored. Because plugging of the distribution system was difficult to detect from the tractor seat, it is recommended that a flow monitoring device be provided as optional equipment.

Seed and Fertilizer Boots: Due to deformation of seed boot deflectors, the manufacturer supplied stronger seedboots after the spring seeding period. No seed boot or fertilizer boot plugging occurred during the evaluation period.

Cleaning: Access to the front meter required emptying of the front tank. The rear meter was accessible without emptying the tank. Tank side cieanout doors were provided for both tanks. However, the rear tank did not empty by gravity and required the material to be moved to the cleanout door. Because the cleanout doors were located about 100 mm (4 in) above the meters, a vacuum cleaner was required for thorough cleaning. Access to the tanks was possible through the tank filler openings by removal of the tank opening screens. The screens could be removed without tools.

Area Meter: No area meter was supplied with the Flexi-coil. It is recommended that the manufacturer consider supplying a land area meter as standard equipment.

Transporting: A distinct advantage of cultivator mounted pneumatic seeders over conventional drills is the ease with which relatively wide machines can be transported. The Flexi-Coil applicator and John Deere cultivator were easily placed in transport position (FIGURE 16) in less than five minutes. Dual hydraulic cylinders raised the cultivator wings to the upright position. The meter drive was conveniently engaged and disengaged hydraulically from the tractor seat. For extended transport at high speeds, the meter drive chain on the right hand applicator wheel should be removed. Access for chain removal was good.

The assembly towed well in transport position. Overall transport height and width were 4.3 m (14.1 ft) and 6.2 m (20.3 ft) respectively, requiring care when travelling on public roads.

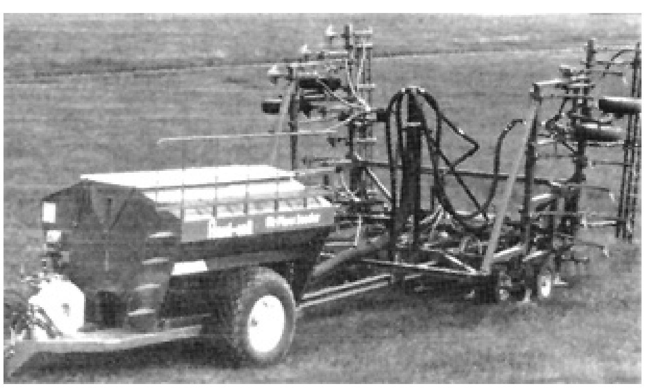

FIGURE 16. Transport Position.

EASE OF ADJUSTMENT

Lubrication: Lubrication was convenient with good access to all grease fittings. Eleven fittings on the applicator and seven on the cultivator required servicing. Two wheels on the applicator and eight on the cultivator required servicing. A servicing schedule was supplied in the operator's manual.

Engine Servicing: The engine was positioned for convenient access. The recommended oil change interval for the engine was 100 hours. Engine fuel consumption was about 2.5 L/hr (0.55 gal/hr). The engine could run about 24 hours on one filling of the 60 L (13 gal) tank.

Application Rate: Application rate for the front tank was easily changed by loosening a lock bolt and moving the adjustment slide controlling the amount of meter flute exposure (FIGURE 17). Moving the slide to the right from zero, along the fine scale, adjusted the meter for small grains in increments of 0.5 from 0 to 5. Moving the slide to the left, along the coarse scale, adjusted the meter for cereals in increments of 1, from 0 to 20.

Application rate for the rear meter was changed by loosening a lock bolt and adjusting a lever for the amount of gate opening above the conveyor belt in increments of 1, from 0 to 20.

Calibration charts in pounds per acre were shown in both the operator's manual and a decal on the applicator.

Adjusting for precise seeding rates was difficult due to relatively large scale divisions. For example, in Tower rapeseed, each 0.5 scale increment changed the seeding rate by up to 6 kg/ha (5.3 lb/ac).

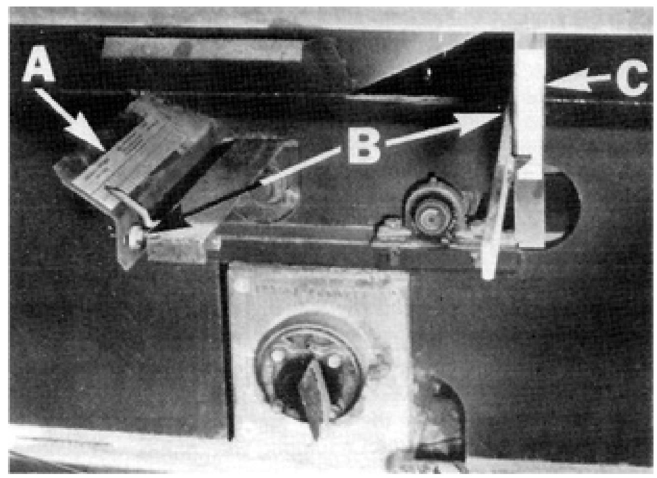

FIGURE 17. Application Rate Adjustment: (A) Flute Exposure Indicator, (B) Lock Bolts, (C) Gate Opening Indicator.

Depth Adjustment: Seeding Depth was conveniently adjusted with dual mainframe cylinders connected in series to a cylinder on each wing in a master-slave arrangement. All four tandem wheel sets were on walking beam axles, a feature which was considered desirable for keeping the frame level in the fore and aft direction. An adjustable sleeve on one of the dual mainframe depth cylinders could be used to set maximum depth. A wrench was needed to position the depth stop. As is common with series hydraulic systems, to maintain the centre and wing frame at the same height, periodic synchronization of the cylinders, by completely extending them to the fully raised position was necessary.

The John Deere cultivator hitch was levelled by positioning the hitch stop bolts in one of six positions. The cultivator hitch on the rear of the applicator could also be placed in one of two positions. The applicator hitch height could be adjusted by placing the hitch link in one of six positions. Cultivator wing levelling was accomplished, using two wrenches, by turning threaded connectors on each wing depth cylinder. Levelling adjustments were adequate to suit all field conditions encountered throughout the evaluation.

RATE OF WORK

The Flexi-coil was operated at speeds ranging from 5 to 10 km/h (3 to 6 mph). Overall best performance in terms of weed kill and seed placement was obtained at speeds of 8 to 10 km/h (5 to 6 mph) resulting in field work rates for the 10.7 m (35 ft) unit ranging from 8.6 to 10.7 ha/hr (21 to 27 ac/hr). Using both tanks, when seeding wheat at a rate of 85 kg/ha (75 lb/ac), about 58 ha (142 ac) could be seeded before refilling. Using only the rear tank, about 30 ha (73 ac) could be seeded before refilling. This compares to 15 to 25 ha (40 to 60 ac) between refills for most conventional drills of similar widths.

POWER REQUIREMENTS

Draft Characteristics: Attempting to compare draft requirements of different makes of heavy duty cultivators usually is unrealistic. Draft requirements for the same cultivator, in the same field, may vary by as much as 30% in two different years, due to changes in soil conditions. Variations in soil conditions affect draft much more than variation in machine make, usually making it impossible to measure any significant draft difference between makes of heavy duty cultivators. The power requirements given in TABLES 2 and 3 are based on average draft requirements of 15 makes of heavy duty cultivators in 56 different field conditions. Additional draft due to the Flexi-coil applicator with full tanks and the mounted harrows has been included.

Tractor Size: TABLES 2 and 3 show tractor sizes needed to operate the Flexi-coil applicator and John Deere 1610 heavy duty cultivator, in light and heavy primary tillage. Tractor sizes have been adjusted to include tractive efficiency and represent a tractor operating at 80% of maximum power on a level field. The sizes presented in the tables are the maximum power take-off rating as determined by Nebraska tests or as presented by the tractor manufacturer. Selected tractor sizes will have ample power reserve to operate in the stated conditions.

Tractor size may be determined by selecting the desired tillage depth and speed from the appropriate table. For example, in light primary tillage at 75 mm (3 in) depth and 8 km/h (5 mph), a 107 kW (144 hp) tractor is required to operate the seeding unit. In heavy tillage at the same depth and speed a 129 kW (173 hp) tractor is needed. Power tests with cultivators equipped with chisel points indicated that tractors suited for seeding in heavy primary tillage conditions will have ample power for banding fertilizer at depths up to 50 mm (2 in) greater than seeding depths.

TABLE 2. Tractor Size (Maximum Power Take-Off Rating, kW) to Operate the Flexi-Coil Applicator, with 10.7 m John Deere 1610 Cultivator in Light Primary Tillage.

DEPTH	SPEED (km/h)					
(mm)	7	8	9	10	11	12
50	65	79	93	108	125	141
75	90	107	124	142	163	183
100	113	135	155	178	201	225
125	138	163	186	212	239	266

TABLE 3. Tractor Size (Maximum Power Take-Off Rating, kW) to Operate the Flexi-Coil Applicator, with 10.7 m John Deere 1610 Cultivator in Heavy Primary Tillage.

DEPTH	SPEED (km/h)					
(mm)	7	8	9	10	11	12
50	61	73	86	101	114	131
75	109	129	149	170	192	214
100	158	184	211	240	269	297
125	207	240	274	309	345	381

OPERATOR SAFETY

The Flexi-coil tank access ladder was convenient and safe. A safety handrail was provided beside the access ladder and along the upper walkway.

The fan engine fuel shut-off was located on the side of the engine. After prolonged periods of use, the shut-off became very hot and difficult to shut off without some form of insulation between the operator's hand and the engine. The engine ignition and electrical warning indicators, originally located on the engine, were relocated above the engine in a manufacturer's modification (FIGURE 18). The engine exhaust system was located so that the operator had to reach over the exhaust to operate the ignition. It is recommended that modifications be made to insulate or protect both the engine shut-off and engine exhaust for improved operator safety.

Extreme caution is needed in transporting most folding cultivators to avoid contacting power lines. Minimum power line heights vary in the three prairie provinces. In Saskatchewan, the energized line may be as low as 5.2 m (17 ft) over farm land or over secondary roads. In Alberta and Manitoba, the neutral ground wire may be as low as 4.8 m (15.7 ft) over farm land. In all three provinces, feeder lines in farmyards may be as low as 4.6 m (15 ft).

The Flexi-coil applicator with John Deere 10.7 m (35 ft) cultivator was 4.3 m (14.1 ft) high in transport position, permitting safe transport under prairie power lines. On the other hand, transport height with the 11.9 m (39 ft) wide model of the same cultivator is 4.9 m (16.2 ft) which is high enough for contact with many prairie power lines. The legal responsibility for safe passage under utility lines rests with the machinery operator and not with the power utility or the machinery manufacturer. All provinces have regulations governing maximum permissible equipment heights on various public roads. If height limits are exceeded, the operator must contact power and telephone utilities before moving.

The Flexi-coil with John Deere 1610 cultivator was 6.2 m (20.3 ft) wide in transport position. This necessitated caution when towing on public roads, over bridges and through gates.

A slow moving vehicle sign was provided on the rear of the applicator for transport. Pins were provided to lock the cultivator wings in transport position. The depth cylinder could be locked in the raised position with the depth adjusting sleeve.

The Flexi-coil applicator, with John Deere 1610 cultivator, towed well at speeds up to 28 km/h (17 mph).

Centre section tire loads on the cultivator in transport position exceeded the Tire and Rim Association maximum load rating for 7.60 x 15, 6-ply tires by about 13 per cent.

Applicator wheels exceeded the Tire and Rim Association maximum load rating for 18.4 x 26, 10-ply tires by about 45 per cent. This tire load could be unsafe at high transport speeds and therefore prolonged transport with full applicator tanks should be avoided.

Total engine and fan noise level at the tractor hitch point was about 99 dbA. This increased the operator station noise level in most modern tractor cabs by only 2.3 dbA. For example, in one tractor cab, operator station noise level was 77.8 dbA with only the tractor operating and 80.1 dba with the tractor and pneumatic applicator operating. Suitable ear protectors should be worn if the tractor is not equipped with an appropriate cab.

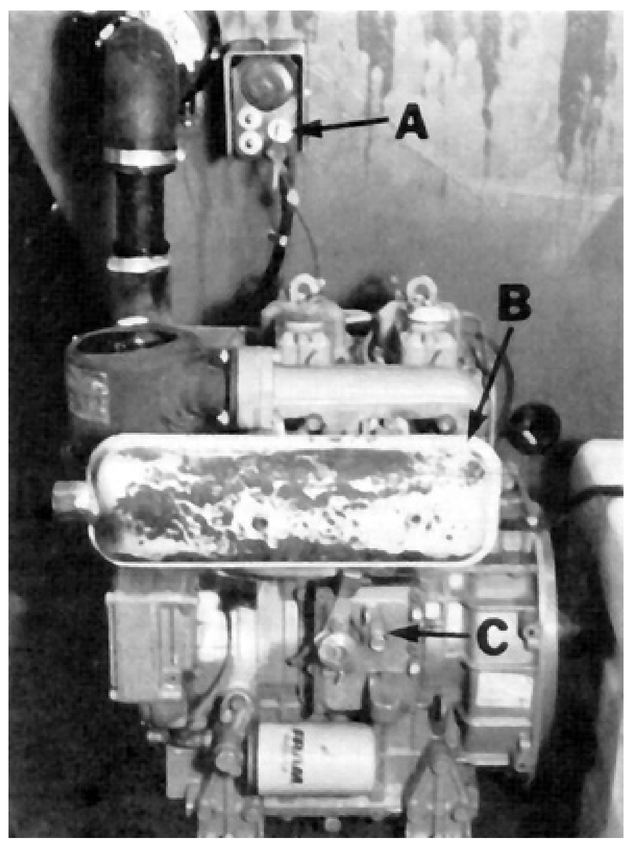

FIGURE 18. (A) Engine Ignition, (B) Engine Exhaust. (C) Engine Fuel Shut-Off.

OPERATOR'S MANUAL

The operator's manual for the Flexi-coil air flow seeder contained useful information on safety adjustments, maintenance, specifications, assembly and operation. A detailed parts list was also included. Metering calibration charts for various cultivator widths, calibrated in Imperial units, were included in the operator's manual. Calibration charts were also printed on decals which could be placed on the seeder for convenient field reference. A metric meter calibration was not included. It is recommended that the manufacturer consider supplying meter calibrations for all grains in SI units.

DURABILITY RESULTS

TABLE 4 outlines the mechanical history of the Flexi-coil air flow seeder with 1610 John Deere cultivator during 108 hours of field operation while processing about 770 ha (1900 ac). The intent of the test was evaluation of functional performance. An extended durability evaluation was not conducted.

TABLE 4. MeChanical History.

ITEM	OPERATING HOURS	EQUIVALENT FIELD AREA (ha)
APPLICATOR		
- The meter operation indicator bulb filament broke and was replaced at	13, 27, 62	90, 190, 440
- The engine generator light vibrated out of the control box and was replaced at	34	240
- The gauge indicating fan static pressure became inoperative at	41	290
- Manufacturer's modifications were made at	58, 82	415, 585
- The rear metering conveyor belt was adjusted at	82	585
- Two distribution hose ends pulled out of the fertilizer boots and were reinstalled at	105	750
- The front metering barrel was removed and the flutes were straightened and rewetded at	108	770
- The primary and secondary headers were cleaned at	108	770
CULTIVATOR		
- The sweeps working in applicator and cultivator wheels tracks were replaced at	54	385
- The depth stop adjustment bolt was replaced at	77	550
- All sweeps were replaced at	83	590
- Fertilizer banding boots and chisel points were installed at	88	628
- The right wing depth cylinder pin fell out and was replaced at	105	750

DISCUSSION OF MECHANICAL PROBLEMS

APPLICATOR

Manufacturer's Modifications: Manufacturer modifications performed during the evaluation period included modified fan engine mounting, relocation of fan engine electrical control box, exchange of fan pressure gauge with fan tachometer, heavier seed boots, altered fan drive shield and improved fan engine air cleaner.

Metering Flutes: The front metering flutes were damaged due to small rocks lodging between the rotating meter flutes and the meter body. The flutes were straightened and repaired and no further problems were encountered.

Headers: Moisture in the distribution system resulted in a build-up of material inside both the primary and secondary headers (FIGURE 19). A small amount of material build-up did not affect material distribution adversely. However, continued build-up of material could have an effect. Operating the fan for a few minutes before seeding to remove the moisture should reduce material build-up.

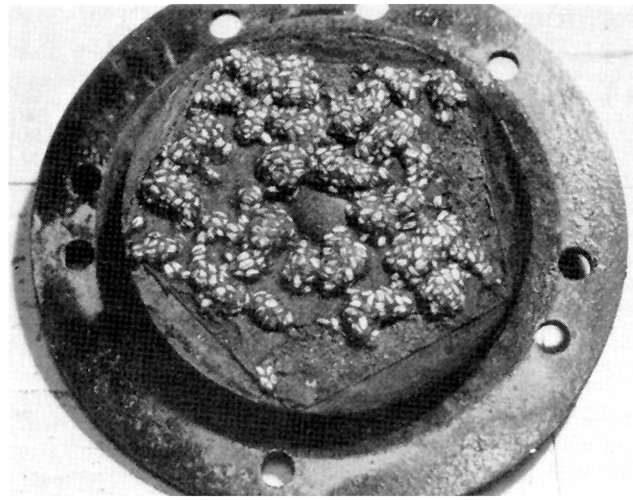

FIGURE 19. Moist Soil Build-up: (Upper: Primary Header, Lower: Secondary Header).

APPENDIX I
SPECIFICATIONS

(A) AIR FLOW SEEDER

MAKE:	Flexi-coil Air Flow Seeder
MODEL:	AS
SERIAL NUMBER:	193L1
MANUFACTURER:	Flexi-coil Ltd. P.O. Box 1928 Saskatoon, Saskatchewan S7K 3S5
DIMENSIONS:	
- width	2780 mm
- length	5290 mm
- height	3100 mm
- maximum ground clearance	210 mm
- wheel tread	2245 mm
METERING SYSTEM:	
- type	
- front	externally fluted feed wheel
- rear	slide door over conveyor belt
- number of meters	2
- drive	chain drive from right applicator wheel
- adjustment	
- front	
- coarse	slide for exposure area over coarse flutes
- fine	slide for exposure area over fine flutes
- rear	vary gate opening above conveyor belt
- transfer to openers	pneumatic conveyance through divider headers and hoses
TANK CAPACITIES:	
- front	3208 L (88 bu)
- rear	3318 L (92 bu)
Total	6526 L (180 bu)
FAN:	
- type	straight blade centrifugal
- maximum operating speed	3600 rpm
- drive	triple V-belt
ENGINE:	
- make	Lombordini Air Cooled 4-Stroke Diesel
- model	904
- serial number	2033608
- power rating	15.4 kW at 2540 rpm
- starting system	12-volt electric
- fuel tank capacity	60 L
WHEELS:	
- single wheels	18.4 x 26, 10-ply
NUMBER OF LUBRICATION POINTS:	11 grease fittings 2 wheel bearings
HITCH:	
- vertical adjustment range	
- applicator	235 mm in 6 positions
- cultivator	205 mm in 2 positions

(B) CULTIVATOR

MAKE:	John Deere Heavy Duty Cultivator
MODEL:	1610
SERIAL NUMBER:	005242N
MANUFACTURER:	John Deere Des Moines Works Des Moines, Iowa 50306 U.S.A.
SHANKS:	
- number	35
- lateral spacing	305 mm
- trash clearance (sweep to frame)	735 mm
- number of shank rows	3
- distance between rows	840, 990 mm
- shank cross section	32 x 50 mm
- shank stem angle	52 degrees
- sweep hole spacing	57 mm
- sweep bolt size	11 mm
HITCH:	
- vertical adjustment range	155 mm in 6 positions
DEPTH CONTROL:	hydraulic
FRAME:	
- cross section	100 mm square tubing, 6.4 mm thickness
TIRES:	8, 7.60L x 15, 6-ply implement
NUMBER OF LUBRICATION POINTS:	7 grease fittings 8 wheel bearings 6 oiling points
HYDRAULIC CYLINDERS:	
- main depth control	2, 108 x 203 mm
- wing depth control	1, 102 x 203 mm 1, 95 x 203mm
- wing lift	2, 102 x 813 mm

OPTIONAL EQUIPMENT:
- 10 width options ranging from 7.0 to 12.5 m
- frame mounted 3-row spring tine harrows

(C) OVERALL SPECIFICATIONS FOR APPLICATOR-CULTIVATOR ASSEMBLY

DIMENSIONS:	**FIELD POSITION**	**TRANSPORT POSITION**
- width	10,375 mm	6240 mm
- length	12,340 mm	12,340 mm
- height	3560 mm	4290 mm
- maximum ground clearance	175 mm	175 mm
- wheel tread	8800 mm	3280 mm
- effective seeding width	10,670 mm	
WEIGHTS:	**TANKS EMPTY**	**TANKS FULL OF WHEAT**
APPLICATOR		
- hitch	100 kg	230 kg
- left wheel	1320 kg	3810 kg
- right wheel	1370 kg	3740 kg
CULTIVATOR (WITH ATTACHED HARROWS)	**FIELD POSITION**	**TRANSPORT POSITION**
- left centre tandem wheels	1220 kg	2010 kg
- right centre tandem wheels	1300 kg	2090 kg
- left wing tandem wheels	800 kg	
- right wing tandem wheels	780 kg	
Total, Tanks Empty	6890 kg	
Total, Tanks Full of Wheat		11,880 kg

APPENDIX II

MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

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

APPENDIX III

CONVERSION TABLE

1 hectare (ha)	= 2.5 acres (ac)
1 kilometre/hour (km/h)	= 0.6 miles/hour (mph)
1 meter (m)	= 3.3 feet (ft)
1 millimetre (mm)	= 0.04 inches (in)
1 kilowatt (kW)	= 1.3 horsepower (hp)
1 kilogram (kg)	= 2.2 pounds mass (lb)
1 newton (N)	= 0.22 pounds force (lb)
1 litre (L)	= 0.03 bushels (bu)
1 kilogram/hectare (kg/ha)	= 0.9 pounds/acre (lb/ac)
1 kilogram/hectolitre (kg/hL)	= 0.8 pounds/bushel (lb/bu)
1 kilonewton/metre (kN/m)	= 70 pounds force/foot (lb/ft)

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