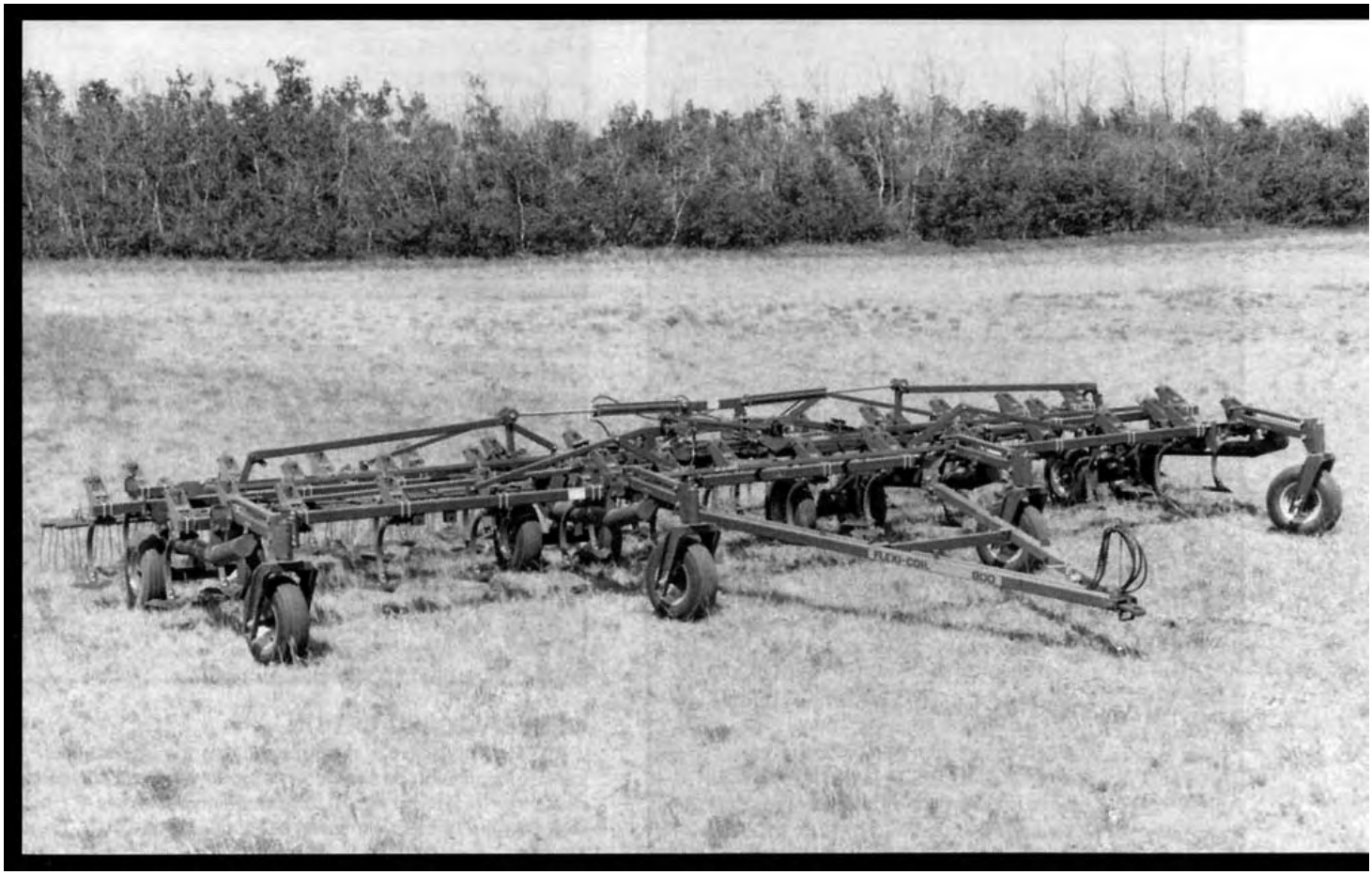
Printed: April, 1989
Tested at: Humboldt
ISSN 0383-3445Group 10d

Evaluation Report 547



Flexi-coil 800 Chisel Plow

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

FLEXI-COIL 800 CHISEL PLOW

MANUFACTURER AND DISTRIBUTOR:

Flexi-coil Ltd.
1000 - 71 Street East
P.O. Box 1928
Saskatoon, Saskatchewan
S7K 3S5
Telephone: (306) 934-3500

RETAIL PRICE:

$31,749.00 (March. 1989, f.o.b. Humboldt, Saskatchewan, 41.3 ft (12.6 m) width and 650 lb (2.9 kN) trips with optional three row harrows, McKay sweeps and mud scrapers.)

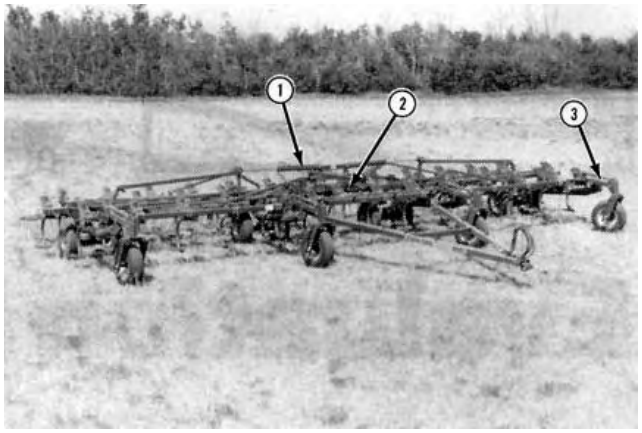


FIGURE 1. Flexi-coil 800: (1) Wing Lift Cylinders, (2) Depth Control Cylinder, (3) Outrigger Wheels.

SUMMARY AND CONCLUSIONS

Quality of Work: The Flexi-coil 800 Chisel Plow was suitable for all primary and secondary tillage. Penetration was very good in most conditions. Uniformity of tillage depth was very good in primary tillage and excellent in secondary tillage. The floating hitch and the flexibility built into the frame sections allowed the Flexi-coil 800 to follow rolling field contours very well. Shank force at the trip point was 660 lb (2.9 kN) and at the sweep pitch limit of 7° was 730 lb (3.3 kN). Common tillage tools at normal depths were held in the proper position.

The trip height of 12 in (305 mm) provided very good stone protection. Trip height was slightly lower under wheel rockshafts. Trash clearance was very good. Similar to other chisel plows, the 12 in (305 mm) spacing of the Flexi-coil 800 cleared low and moderate amounts of trash without plugging. In heavy or damp trash, the Flexi-coil 800 occasionally plugged along the back row of shanks and under wheel rockshafts. Surface finish was good and similar to other chisel plows. The harrows left bunches, typical of all mounted harrows, on the field surface in heavy trash.

The Flexi-coil 800 was stable. Skewing was minimal even on hillsides or where soil hardness varied across machine width.

Ease of Operation and Adjustment: Ease of maintenance was good with easy access to grease fittings. There were many grease fittings but most only required lubrication every 50 hours. Ease of hitching was very good. The rigid hitch link and hitch jack made one-man hitching easy. Ease of transporting was very good. The center frame transport lock was automatically positioned. Transport height of the 41.3 ft (12.6 m) chisel plow was 17.5 ft (5.3 m). Maneuverability was very good. The tractor tires did not contact the hitch on turns.

Ease of adjusting depth was very good. The hydraulic stop valve and easily accessed hand crank, made changing depth convenient. Ease of frame leveling was good. Lateral leveling was easily accomplished. Front-to-back leveling required adjusting each outrigger wheel which was time consuming. Harrow adjustment was very good. Only two bolts had to be loosened. Ease of replacing sweeps and shanks was good. Soil abrasion to the bottom sweep bolts was slight. Access to U-bolt nuts for shank replacement was inconvenient.

Power Requirements: In secondary tillage, at 3 in (75 mm) and 6 mph (9.7 km/h), a tractor with 215 hp (160 kW) PTO horsepower is suggested for a 41.3 ft (12.6 m) wide chisel plow. In primary tillage, at 4 in (100 mm) and 5 mph (8.0 km/h), a tractor with 250 hp (185 kW) is suggested.

Operator Safety: The transport height for the 41.3 ft (12.6 m) chisel plow was 17.5 ft (5.3 m) which required extreme caution when transporting. The wings folded well over center and did not require transport locks.

Operator's Manual: The operator's manual was excellent and included lubrication and maintenance instructions, adjustments, operating instructions, safety cautions and warnings, and a parts list. Assembly instructions were included in a separate manual.

Mechanical History: Rocks bent wheel rims, wheel bearing caps, and valve stem protectors. Three shanks were bent. Some other minor mechanical problems occurred during the test.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Supplying a 1.5 in (38 mm) wrench with the chisel plow.
2. Modifications to ease positioning of harrow lock up mechanisms.
3. Supplying a hitch safety chain as standard equipment.
4. Modifications to prevent damage to the center frame transport lock positioning mechanism and lock bar.

Senior Engineer: J.D. Wasserman

Project Engineer: H.D. Kydd

THE MANUFACTURE STATES THAT

With regard to recommendation number:

1. Most farmers carry an adjustable wrench of adequate size to adjust the 1.5 in (38 mm) nuts and since these nuts are seldom adjusted, Flexi-coil does not plan to supply a 1.5 in (38 mm) wrench with the chisel plow.
2. The design of the harrow lock up mechanism is under review.
3. At this time, Flexi-coil offers, as optional equipment, a hitch safety chain that meets ASAE Standards.
4. The transport lock positioning mechanism and lock bar were redesigned and the new design is standard on all models of 800 chisel plows manufactured since the summer of 1988.

GENERAL DESCRIPTION

The Flexi-coil 800 chisel plow is a trailing, three section cultivator suitable for primary and secondary tillage operations. It is available in widths from 25 to 62 ft (7.6 to 18.9 m). The test machine was 41.3 ft (12.6 m) wide with a 12.8 ft (3.9 m) center section, and two 14.2 ft (4.3 m) wing sections.

The spring cushion shanks are arranged in three rows with a front-to-center row spacing of 62 in (1575 mm) and a center-to-rear row spacing of 38 in (965 mm) with some center and front row shanks offset around the wheels. It has 41 spring cushion shanks on 12 in (305 mm) spacings.

The main and wing sections consist of various frame members connected with flexible joints containing ball joints and/or polyurethane spacers. The main frame is supported by two pairs of dual wheels and two outrigger wheels. The wing frames are each supported by one pair of dual wheels and one outrigger wheel. Each set of dual wheels and outrigger wheel are linked with a rockshaft. One hydraulic cylinder rotates the four rockshafts to control tillage depth. The wings fold into transport with two hydraulic cylinders connected in parallel.

A tractor with two remote hydraulic controls is needed to operate the Flexi-coil 800 chisel plow. The test machine was equipped with optional three row tine harrows.

Detailed specifications are given in APPENDIX 1. FIGURE 1 shows the location of special components.

SCOPE OF TESTS

The Flexi-coil 800 was operated in the field conditions shown in TABLE 1 for 130 hours while cultivating about 2150 ac (870 ha). It was evaluated for quality of work, ease of operation and adjustment, power requirements, operator safety, and suitability of the operator's

manual. Extended durability testing was not conducted. Mechanical failures were recorded.

Table 1. Operating Conditions

FIELD CONDITIONS	HOURS	FIELD AREA	
		ac	ha
Operation			
- primary	46	830	340
- secondary	84	1320	530
TOTAL	130	2150	870
Soil Type			
- sand	17	300	120
- loam	86	1350	550
- clay	27	500	200
TOTAL	130	2150	870
Stony Phase			
- stone free	42	770	310
- occasional stones	46	740	300
- moderately stony	31	480	190
- very stony	11	160	70
TOTAL	130	2150	870

RESULTS AND DISCUSSION

QUALITY OF WORK

Penetration: Penetrating ability of the Flexi-coil 800 was very good in most field conditions.

Machine weight and sweep pitch both affect penetration. A slightly positive no-load sweep pitch is required to maintain proper penetration. Manufacturers use many combinations of shank and sweep stem angles to obtain the desired sweep pitch (FIGURE 2).

No load sweep pitch was 20, which was adequate to maintain penetration in most field conditions.

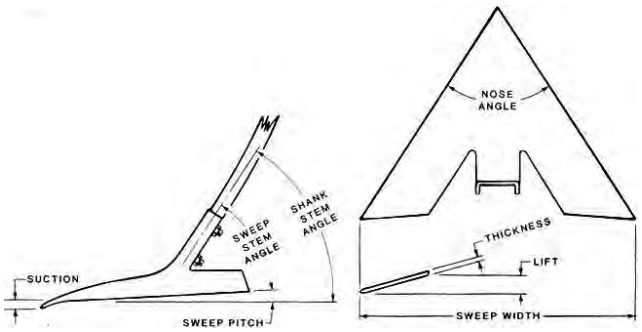


FIGURE 2. Shank and Sweep Terminology.

Depth Uniformity: Depth uniformity was very good in primary tillage and excellent in secondary tillage.

A uniform tillage depth is very important when a cultivator is used for seeding or seedbed preparation. It is also important for other operations such as incorporating chemicals, deep banding fertilizer and killing weeds. Tillage depth uniformity depends on the cultivator's ability to follow changing ground contours.

The Flexi-coil 800 followed rolling contours very well, maintaining uniform depth across its width. Even with sudden contour changes in a field, depth remained very uniform due to the flexibility between the various frame components.

During normal cultivator operation, downward forces are exerted on the front of a cultivator. On a rigid hitch cultivator, these forces are resisted by the tractor through the hitch. On a floating hitch cultivator, these forces are resisted by the outrigger wheels. As the draft increases, these downward forces on the outrigger wheels increase causing greater wheel sinkage or tire deflection which could affect front-to-rear depth uniformity.

In secondary tillage, where depth uniformity is most important, the outrigger wheels on the Flexi-coil 800 maintained uniform depth between the front and rear shanks. In very heavy pulling primary conditions, minor differences in depth of 0.5 in (13 mm) were measured between the front and rear shanks. The outrigger wheels could be adjusted to correct for this but this was time consuming.

A cultivator shank mechanism must maintain a low sweep pitch. If sweep pitch is too high, furrow bottom ridging occurs and results in an uneven tillage depth. Excessive sweep pitch also causes rapid sweep tip wear and higher draft. PAMI has selected 7° as the maximum sweep pitch that will produce an acceptable furrow bottom for most operations. This pitch results in a depth difference of about 0.7 in (19 mm) across the furrow bottom on a 12 in (305 mm) spacing machine. The 0.7 in (19 mm) furrow bottom variation is the maximum that is acceptable. Lower amounts are desirable especially when seeding.

The sweep pitch characteristics of the Flexi-coil 800 are shown in FIGURE 3. The no-load sweep pitch was 2°. The lower sloped line shows how an increase in force gradually flexed the shank as indicated by a slight increase in sweep pitch. At a horizontal force of 660 lb (2.9 kN) the shank began to trip as the cushion spring preload was overcome. This is the point on the curve where the steep upper curve begins. At a horizontal force of 730 lb (3.3 kN) the sweep pitch exceeded 70. This is the point where the steep curve crosses the shaded grey horizontal line. PAMI recommends that sweep pitch be maintained below 70 to provide an acceptable furrow bottom. Operating in conditions where soil forces exceed that value will result in a nonuniform furrow bottom. The curve above the shaded grey horizontal line shows how the forces increase as the shank trips over an obstacle.

Performance of the Flexi-coil 800 can be determined by comparing its sweep pitch characteristics to the actual horizontal force that the shanks will encounter in the field. Research has been conducted to determine the typical prairie soil forces acting on soil tools located in the front row of a cultivator while operating at different depths in primary and secondary tillage (APPENDIX II). The pitch and therefore performance of the soil tools can be predicted by comparing the researched soil forces to the counteracting shank force (FIGURE 3) developed by the shank assembly.

The Flexi-coil 800 shank force at a 70 sweep pitch was 730 lb (3.3 kN) which was greater than all shown soil forces. This indicates that the 16 in (406 mm) sweeps will maintain a uniform tillage or seeding depth while operating in primary and secondary tillage. The chisel plow would also maintain 2 in (50 mm) spikes, and banding knives at a uniform working depth while operating in primary and secondary tillage.

The trip force of 660 lb (2.9 kN) is higher than all typical soil forces. This would minimize shank assembly wear as the soil forces would not cause partial tripping or continuous movement of the assembly parts.

There were two sweeps beyond the outer wheels allowing adequate overlap without running a wheel on cultivated soil. Running all wheels on untilled soil helps maintain a uniform tillage depth.

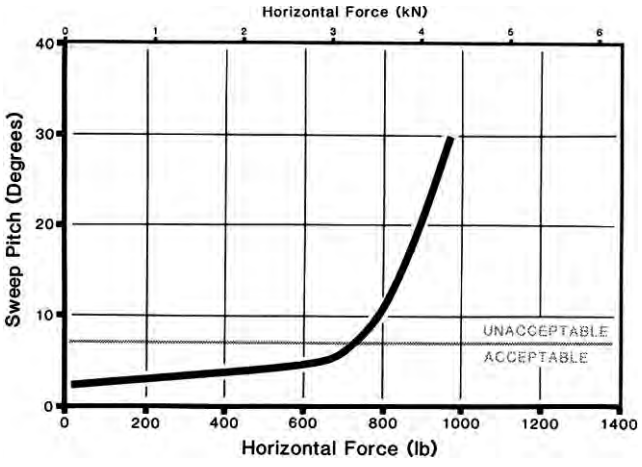


FIGURE 3. Effect of Horizontal Shank Force on Sweep Pitch.

Stone Protection: Stone protection was very good.

FIGURE 4 shows the lifting pattern when shanks on the Flexi-coil 800 encounter stones or field obstructions. A lift height of 12 in (305 mm) normally prevents shank and sweep damage in fields with many large rocks. Trip force must be high enough to hold the shank in position. Large increases in force, higher than the trip force, are undesirable as they may cause shank or sweep damage.

The maximum lift height for the Flexi-coil was 12 in (305 mm)

when equipped with 16 in (406 mm) McKay sweeps. This lift height was slightly lower in several locations where the wing of the sweep contacted the wheel rockshaft under the frame before reaching full lift height. However, no sweep or shank damage occurred in these locations. The shank tripped when forces exceeded 660 lb (2.9 kN). Three shanks bent during the test.

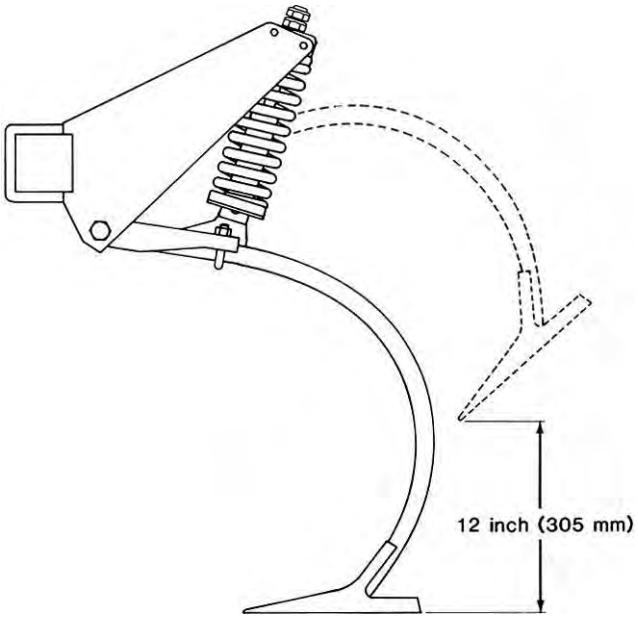


FIGURE 4. Shank Lifting Pattern.

Trash Clearance: Trash clearance was very good.

The 12 in (305 mm) spacing Flexi-coil sweep tip-to-frame clearance was 29 in (737 mm). Similar to other chisel plows, low and moderate amounts of trash passed through the Flexi-coil 800 without plugging. However, in heavy or damp trash the chisel plow occasionally plugged along the back row and under wheel rockshafts. Sweep-to-ground clearance was 10.5 in (270 mm) when fully raised in the field position.

In very damp conditions, mud and trash, that were carried around by tires, built up above the rockshaft pivot and rubbed on the tires. The optional mud scrapers were later installed and prevented this build-up.

Surface Finish: Field surface finish was good and similar to other chisel plows.

A smooth field surface is required for proper seedbed preparation and improves operator comfort on the following operation. Cultivators with narrower spacings typically leave smoother fields than those with wider spacings.

In heavy trash, the harrows left bunches on the field surface (FIGURE 5), typical of all mounted harrows. In light trash, the harrows effectively distributed trash and levelled the ridges left by the cultivator to produce a uniform seedbed.

FIGURE 5. Typical Field Surface in Heavy Trash Conditions.

Skewing and Stability: Skewing increases weed misses, variation in row spacing, and requires frequent operator steering corrections. The sweep pattern of the Flexi-coil 800 (FIGURE 6) was symmetrical so no side forces were imposed on the chisel plow.

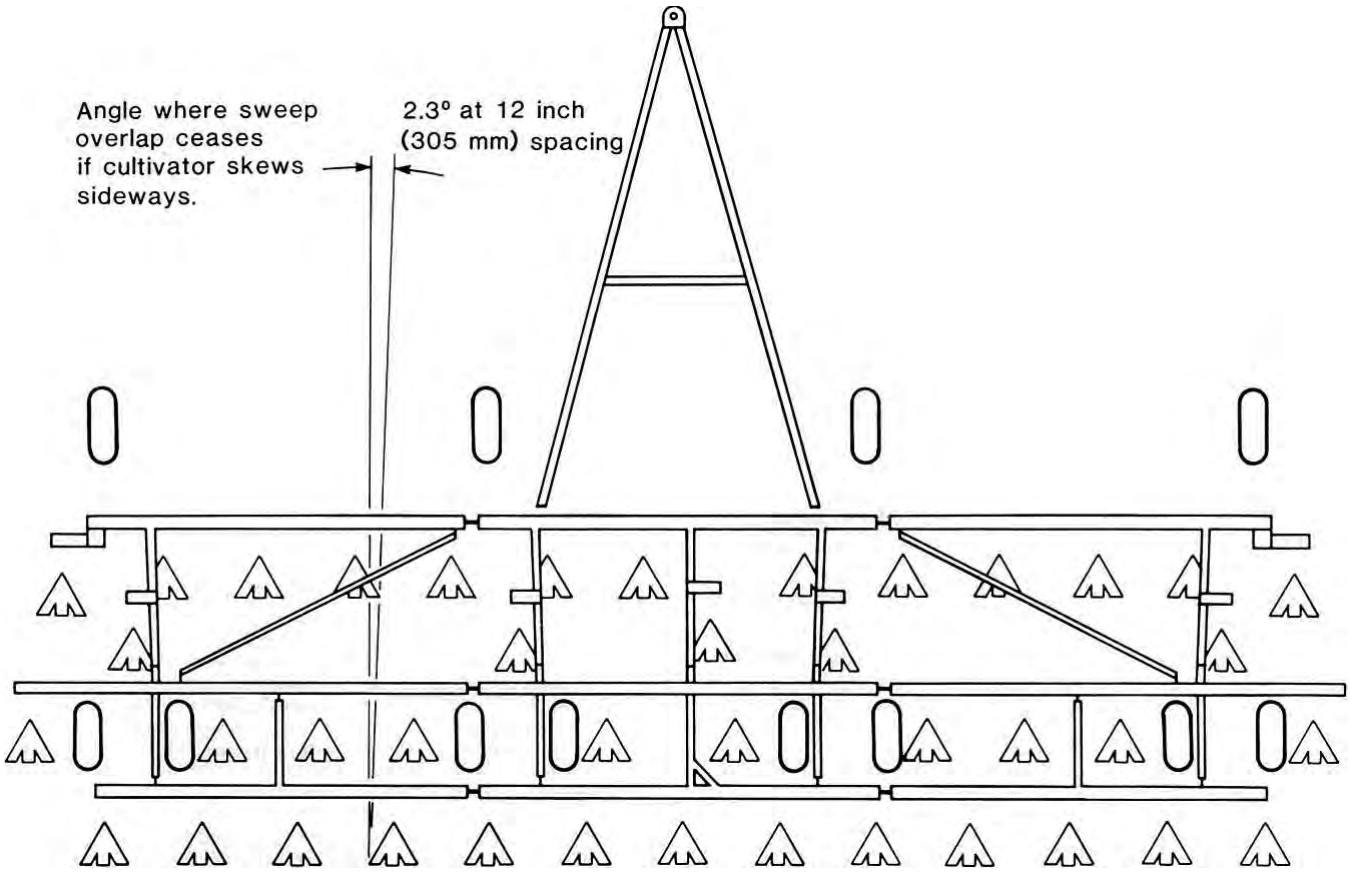


FIGURE 6. Sweep Pattern 12 in (305 mm) Shank Spacing.

The Flexi-coil 800 was stable and skewing was minimal, even on hillsides or where soil hardness varied across machine width. The Flexi-coil 800 did not skew on flat land when depth settings were uniform across the machine width. With 16 in (406 mm) sweeps, the chisel plow had to skew more than 2.3° for weed misses to occur.

EASE OF OPERATION AND ADJUSTMENT

Maintenance: Ease of maintenance was good.

Lubrication was convenient with good access to all grease fittings. Front rockshaft pivots required greasing daily or every 10 hours. Rear rockshaft pivots, wing lift hinge pivots, depth control pivots, evener link pivots, hitch pivots, front outrigger pivots and front parallel arms required greasing every week or 50 hours. The wheel bearings required greasing annually or every 200 hours.

Hitching: Ease of hitching was very good.

The hitch jack and rigid hitch link made one-man hitching easy. Hitch weight was positive in transport and field position with mounted harrows.

Transporting: Ease of transporting was very good.

It was easily placed in transport position (FIGURE 7) by one person in less than 2 minutes from the tractor. The wings folded well over center so no wing locks were required. The center frame transport lock was automatically positioned as the wings were raised if the proper procedure was followed. If the proper sequence was not followed, the mechanism could be damaged. At certain harrow settings, the harrow lock up mechanisms had to be used to provide clearance under the harrows when transporting on gravel roads.
A slow moving vehicle emblem (SMV) was provided.

FIGURE 7. Transport Position.

Transport width of the test machine was 18.1 ft (5.5 m) when equipped with mounted harrows. Transport height of the 41.3 ft (12.6 m) chisel plow was 17.5 ft (5.3 m). Extreme caution was needed when transporting on public roads, through gates, over bridges and beneath power lines.

The Flexi-coil 800 towed very well without bounce or sway at normal tractor transport speeds. A wheel tread of 12.9 ft (3.9 m) provided sufficient stability in transport position. Sweep-to-ground clearance was 8.5 in (216 mm), when lowered onto the transport lock.

Maneuverability: Maneuverability was very good. The rear tires of the four-wheel drive test tractor did not contact the hitch during turns. The outside shank was not visible to the operator as it was hidden behind the outrigger wheel which requires greater operator skill to reduce overlap or when working close to obstacles.

Depth Adjustment: Ease of setting tillage depth was very good.

Tillage depth was controlled by one cylinder and a mechanical linkage to a rockshaft at each set of wheels. The hydraulic stop valve on the depth control cylinder set tillage depth. Changing depth setting was convenient with an easily accessed hand crank.

Frame Leveling: Ease of leveling the frame was good.
Lateral leveling was easily accomplished by adjusting the connecting linkages between the rockshafts. However, a 1.5 in (38 mm) wrench was required for lateral leveling. This is larger than typically carried by farmers. It is recommended that the manufacturer consider supplying a 1.5 in (38 mm) wrench with the chisel plow. Front-to-back adjustment was accomplished by adjusting the position of the outrigger wheel axle in the outrigger wheel fork. This adjustment was time-consuming but only had to be done with large changes in soil type or condition.

Harrow Adjustment: Ease of adjusting the optional harrows was very good.

The harrow frame was levelled by loosening two bolts. The tine angle could be adjusted to five different positions. Adjustment ranges for tine angle and harrow spring preload were adequate for most conditions.

The harrow lock up mechanisms held the harrows up when not required but were difficult to position due to binding of parts. It is recommended that the manufacturer consider modifications to ease positioning of harrow lock up mechanisms.

Sweep and Shank Replacement: Ease of sweep and shank replacement was good.

Soil abrasion to the lower sweep bolts was slight and did not hamper removal providing bolt length was selected so no threads extended through the nut.

Shank replacement was accomplished in less than five minutes by removing one bolt and one U-bolt. Access to U-bolt nuts was limited and inconvenient.

POWER REQUIREMENTS

PAMI has measured cultivator power requirements on many cultivators in many different field conditions as explained in APPENDIX III. From these field measurements, average power requirements for a typical cultivator have been determined to assist farmers in matching tractor and cultivator sizes. These tractor sizes (TABLE 2) have been adjusted to include tractive efficiency and represent a tractor operating at 80% of its maximum PTO rating.

TABLE 2. Tractor Size: PTO Power (hp (KW)) Required for Operations with a Typical 41.3 ft (12.6 m) Cultivator

	DEPTH		SPEED - mph (km/h)			
OPERATION	in	mm	5.0	(8.0)	6.0	(9.7)
Primary	3 4	75 100	200 250	150 185	240 305	180 225
Secondary	3 4	75 100	180 230	135 170	215 280	160 210

In typical secondary tillage conditions of 6 mph (9.7 km/h) and a depth of 3 in (75 mm), average cultivator power requirements were 5.2 hp/ft (12.7 kW/m) (APPENDIX III). In typical primary tillage conditions of 5mph (8.0 km/h) and a depth of 4 in (100 mm), average power requirements were 6.1 hp/ft (14.9 kW/m). Therefore, the tractor PTO horsepower recommended to pull the 41.3 ft (12.6 m) Flexi-coil 800 cultivator in those conditions were 215 hp (160 kW) in secondary tillage and 250 hp (185 kW) in primary tillage.

More power will be required at greater depths, in hills, or in heavy soils known to have higher power requirements. Average cultivator power requirements per unit width for different conditions, depths, and speeds are given in APPENDIX III.

OPERATOR SAFETY

Extreme caution is needed when transporting most folding cultivators to avoid contacting power lines. Minimum power line heights over farmland or secondary roads vary in the three prairie provinces. In Alberta and Manitoba, lines over roads may be as low as 16 ft (4.8 m). In Saskatchewan, they may be as low as 17 ft (5.2 m). In all three provinces, lines in farmyards may be as low as 15 ft (4.6 m).

Extreme caution was required when transporting the 41.3 ft (12.6 m) wide three section Flexi-coil 800 as transport height was 17.5 ft (5.3 m). The legal responsibility for safe passage under utility lines rests with the machinery operator and not with the power utility or machinery manufacturer. All provinces have regulations governing maximum permissible equipment heights on various types of public roads. If height limits are exceeded, the operator must contact power and telephone utilities before moving.

The test machine was 18.1 ft (5.5 m) wide in transport position and required caution when moving. A slow moving vehicle sign was provided as standard equipment.

Transport locks were not required for the wings as they folded well over center. The center frame transport lock was automatically

positioned as the wings were raised. The rigid hitch link and hitch jack allowed safe hitching by one person. An industry standard for hitch safety chains has been adopted by the American Society of Agricultural Engineers (ASAE). A hitch safety chain for transporting on public roads was not supplied but was optional. PAMI recommends that the manufacturer consider supplying a hitch safety chain as standard equipment.

The load on the center section tires did not exceed the maximum load rating of the tire manufacturer.

OPERATOR'S MANUAL

The operator's manual was excellent.

It included lubrication and maintenance instructions, adjustments, operating instructions, safety cautions and warnings and a parts listing. It was well written and clearly illustrated. Assembly procedures were included in a separate manual.

MECHANICAL HISTORY

TABLE 3 outlines the mechanical history of the Flexi-coil 800 during 130 hours of field operation while cultivating 2150 ac (870 ha).

The intent of the test was evaluation of the functional performance. The following mechanical problems occurred during testing. An extended durability test was not conducted.

TABLE 3. Mechanical History.

ITEM	OPERATING HOURS	EQUIVALENT FIELD AREA ac	(ha)
-Some hydraulic hoses hung too low so they were tied up to prevent damage at	the start of the test		
-A tire was cut by a sweep and replaced at	95	1550	(630)
-One shank was bent and replaced at	95	1550	(630)
-Two additional shanks were bent slightly and replaced at	the end of the test		
-The center frame transport lock bar and positioning mechanism was bent and straightened at	the end of the test		
-Two wheel rims, two wheel bearing caps, and several valve stem protectors were bent by rocks; these were straightened at	the end of the test		

Tire Clearance: A tire was cut by a sweep and had to be replaced. This occurred when a wing tilted a considerable amount below the main frame when traveling along a narrow approach with the wings down. The wings were down to clear a low power line. This was not a normal transporting condition and no further problems occurred.

Rock Damage: Two wheel rims, two wheel bearing caps, and several valve stem protectors were bent as large rocks passed between the wheels and the adjacent shank. No flats or failures resulted. These parts were straightened at the end of testing.

Center Frame Transport Lock: The center frame transport lock positioning mechanism hung below the frame which resulted in this mechanism being bent by a rock. Also, the lock bar under the cylinder was bent by a shank as the shank tripped over a rock. The mechanism and the lock bar was straightened at the end of the testing. It is recommended that the manufacturer consider modifications to prevent damage to the center frame transport lock positioning mechanism and lock bar.

APPENDIX I

SPECIFICATIONS

Make:	Flexi-coil
Model:	800
Serial Number:	0800 A00 - 1021616
Manufacturer:	Flexi-coil Ltd. P.O. Box 1928 Saskatoon, Saskatchewan S7K 3S5

OVERALL DIMENSIONS:	**FIELD POSITION**	**TRANSPORT POSITION**
-width	41.3 ft (12.6m)	18.1 ft (5.5 m)
-length with mounted harrows	30.6 ft (9.3 m)	30.6 ft (9.3 m)
-height	5.6 ft (1.6 m)	17.5 ft (5.3 m)
-ground clearance	10.5 in (270 mm)	8.5 in (216 mm)
-wheel tread	36.8 ft (11.2 m)	12.9 ft (3.9 m)

Shanks:	
-number	41
-lateral spacing	12.0 in (305 mm)
-trash clearance (frame to sweep tip)	29 in (737 mm)
-number of shank rows	3
-distance between rows	
-front to center	62 in (1575 mm)
-center to rear	38 in (965 mm)
-shank cross section	2 x 1.25 in (51 x 32 mm)
-shank stem angle	52°
-sweep hole spacing	2.25 in (57 mm)
-sweep bolt size	1/2 x 2.25 in
Hitch:	
-type	floating, eliminates need for hitch height adjustment
Depth Control:	single hydraulic cylinder with a stop valve
Frame:	
-cross section	4 in (102 mm) square tubing
Tires:	
-center section	4, 9 - 15LT, 8 ply Farm Highway Service
-wing section	4, 9.5L - 15, 6 ply
-outrigger wheels	4, 9.5L - 15, 6 ply
Number of Lubrication Points:	
-grease fittings	52
-wheel bearings	12
Hydraulic Cylinders:	
-depth control	1, 4 x 24 in (102 x 610 mm)
-wing lift	2, 4 x 32 in (102 x 813 mm)

WEIGHTS: (Without Harrows)	**FIELD POSITION**	**TRANSPORT POSITION**
-right wing wheels	2405 lb (1093 kg)	
-right center wheels	3760 lb (1709 kg)	6210 lb (2822 kg)
-left center wheels	3690 lb (1677 kg)	6080 lb (2764 kg)
-left wing wheels	2435 lb (1107 kg)	
-hitch	380 lb (173 kg)	3801b (173kg)
TOTAL	12670 lb (5759 kg)	12670 lb (5759kg)

WEIGHTS: (With Mounted Harrows)	**FIELD POSITION**	**TRANSPORT POSITION**
-right wing wheels	2750 lb (1250 kg)	
-right center wheels	4070 lb (1850 kg)	6765 lb (3075 kg)
-left center wheels	3940 lb (1791 kg)	6650 lb (3022 kg)
-left wing wheels	2655 lb (1206 kg)	
-hitch	380 lb (173 kg)	380 lb (173 kg)
TOTAL	13795 lb (6270 kg)	13795 lb (6270 kg)

Optional Equipment Included:
- -mounted harrows (three row)
- -mud scrapers

Optional Equipment Available:
- -7.2 and 9 in (182 and 229 mm) spacing with 350 lb (1.6 kN) trip mechanism
- -rigid shanks
- -width options from 25 to 62 ft (7.6 to 18.9 m)
- -mounted harrows (four row)
- -cultivator lighting package
- -safety chain

APPENDIX II

SOIL FORCES TABLES

The following tables give typical horizontal forces acting on sweeps, spikes, and banding knives located in the front row of a cultivator while operating at different depths in primary and secondary tillage on the prairies. These values are relevant for 95% of all prairie conditions. Higher forces may be encountered in extremely heavy, dry, or compacted soils.

These values can be used to determine how well the shank assemblies are suited to the various operations. Comparing the sweep pitch curve of the assembly to these soil forces will indicate whether the assembly will hold the soil tool below the acceptable 70 sweep pitch.

For example, an assembly should be suitable for primary tillage with a 16 in (400 mm) sweep at 5 in (125 mm) depth if it will not exceed 70 sweep pitch below 500 lb (2.2 kN) soil force.

TABLE 4. Forces Required (lb (kN)) in Primary Tillage for Various Soil Tools.

	SWEEPS				
	FIELD CULTIVATOR	HEAVY DUTY CULTIVATOR			
DEPTH	11 in (275 mm)	12 in (305 mm)	16 in (406 mm)	SPIKE 2 in (50 mm)	BANDING KNIFE 1 in (25 mm)
in (mm)	lb (kN)	lb (kN)	lb (kN)	lb (kN)	lb (kN)
2 (50)	110 (0.5)	190 (0.8)	220 (1.0)	–	–
3 (75)	140 (0.6)	230 (1.0)	280 (1.2)	150 (0.7)	–
4 (100)	180 (0.8)	310 (1.4)	370 (1.6)	190 (0.8)	320 (1.4)
5 (125)	–	420 (1.9)	500 (2.2)	260 (1.2)	390 (1.7)
6 (150)	–	–	–	360 (1.6)	540 (2.4)

TABLE 5. Forces Required (lb (kN)) in Secondary Tillage for Various Soil Tools.

	SWEEPS				
	FIELD CULTIVATOR	HEAVY DUTY CULTIVATOR			
DEPTH	11 in (275 mm)	12 in (305 mm)	16 in (406 mm)	SPIKE 2 in (50 mm)	BANDING KNIFE 1 in (25 mm)
in (mm)	lb (kN)	lb (kN)	lb (kN)	lb (kN)	lb (kN)
2 (50)	110 (0.5)	170 (0.8)	220 (1.0)	–	–
3 (75)	140 (0.6)	220 (1.0)	280 (1.2)	130 (0.6)	–
4 (100)	170 (0.8)	280 (1.2)	370 (1.6)	180 (0.8)	290 (1.3)
5 (125)	–	370 (1.6)	500 (2.2)	290 (1.1)	380 (1.7)
6 (150)	–	–	–	320 (1.4)	490 (2.2)

APPENDIX III

POWER REQUIREMENTS

Draft Characteristics

Draft requirements have been measured on several cultivators in many different field conditions over the past years. Average draft requirements have been determined from these measurements.

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 variations in machine make, making it difficult to measure any significant draft differences between makes of cultivators.

Since there is little or no draft difference between machines, PAMI has averaged the results obtained over the years and has used these to determine tractor size recommendations.

Recommended Tractor Size

The following tables show PTO power required to pull cultivators in various conditions at the given depths and speeds. Tractor power requirements have been adjusted to include a tractive efficiency of 80% in primary and 70% in secondary tillage and represent a tractor operating at 80% of maximum PTO power on a level field. These power requirements can be used along with the maximum PTO ratings, as determined by Nebraska tests or as presented by the tractor manufacturer, to select the appropriate tractor. Higher power will be required in hills or in heavy soils. Cultivators with marked differences in spacing, number of rows, or configuration may require more or less power.

Recommended tractor size may be determined by selecting the required horsepower per foot from the appropriate table and multiplying by the width of cultivator. For example, in primary tillage at 4 in (100 mm) and 5 mph (8.0 km/h), 6.1 hp/ft (14.9 kW/m) is required. Therefore, for a 41.3 ft (12.6 m) cultivator in those conditions, 250 PTO hp (185 kW) is recommended.

TABLE 6. Tractor PTO Power Per Unit Width (hp/ft (kW/m)) Required in Primary Tillage.

	SPEED - mph (km/h)		
DEPTH in (mm)	4.0 (6.4)	5.0 (8.0)	6.0 (9.7)
2 (50)	2.7 (6.6)	3.4 (8.3)	4.1 (10.0)
3 (75)	3.8 (9.3)	4.8 (11.7)	5.8 (14.2)
4 (100)	4.9 (12.0)	6.1 (14.9)	7.4 (18.1)
5 (125)	6.0 (14.7)	7.5 (18.4)	9.0 (22.0)

TABLE 7. Tractor PTO Power Per Unit Width (hp/ft (kW/m)) Required in Secondary Tillage.

	SPEED - mph (km/h)		
DEPTH in (mm)	4.0 (6.4)	5.0 (8.0)	6.0 (9.7)
2 (50)	2.3 (5.6)	3.0 (7.3)	3.6 (8.8)
3 (75)	3.4 (8.3)	4.3 (10.5)	5.2 (12.7)
4 (100)	4.5 (11.0)	5.6 (13.7)	6.8 (16.6)
5 (125)	5.5 (13.5)	7.0 (17.1)	8.4 (20.6)

APPENDIX IV

MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

Excellent	Fair
Very Good	Poor
Good	Unsatisfactory

SUMMARY CHART

FLEXI-COIL 800 CHISEL PLOW

RETAIL PRICE	$31,749.00 (March, 1989, f.o.b. Humboldt, Sask., 41.3 ft (12.6 m) width, 650 lb (2.9 kN) trips, optional 3 row harrows, McKay sweeps, and mud scrapers.)
QUALITY OF WORK	
Penetration	**Very Good;** in most conditions
Depth Uniformity	**Very Good;** in primary tillage; followed ground contours very well but slight front to-rear variation in high draft conditions **Excellent;** in secondary tillage; very uniform
Stone Protection	**Very Good;** 12 in (305 mm) trip height; slightly lower at wheel rockshafts
Trash Clearance	**Very Good;** cleared low and moderate amounts of trash
Surface Finish	**Good;** similar to other chisel plows
Skewing	Stable
EASE OF OPERATION AND ADJUSTMENT	
Maintenance	**Good;** Convenient access, larger number of grease fittings
Hitching	**Very Good;** one-man hitching easy
Transporting	**Very Good;** automatic center frame transport lock, high in transport
Maneuverability	**Very Good;** tractor tires did not contact hitch on turns
Depth Adjustment	**Very Good;** easily accessed hand crank
Frame Levelling	**Good;** lateral leveling was easy; outrigger wheel adjustment was time consuming
Harrow Adjustment	**Very Good;** easily levelled by loosening 2 bolts
Sweep and Shank Replacement	**Good;** slight abrasion on sweep bolt did not hamper removal; access to nuts on shank U-bolts was inconvenient
POWER REQUIREMENTS	
Secondary Tillage	215 hp (160 kW) at 3 in (75 mm) and 6 mph (9.7 km/h)
Primary Tillage	250 hp (185 kW) at 4 in (100 mm) and 5 mph (8 km/h)
OPERATOR SAFETY	high in transport; wings folded well over center and did not require transport locks
OPERATOR'S MANUAL	Excellent; well written and clearly illustrated
MECHANICAL HISTORY	Three shanks bent; wheel rims, bearing caps and valve stem protectors bent by rocks

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