ALBERTA
FARM
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RESEARCH REPORT

RL0894

REPORT ON

ARTICULATED FOUR TRACK TRACTOR
FIELD TESTS

PREPARED FOR
IN-HOUSE RESEARCH

Alberta
AGRICULTURE

ARTICULATED FOUR TRACK TRACTOR FIELD TESTS

Research Project RL0894

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Abstract

The Alberta Farm Machinery Research Centre tested a Case-IH 9250 articulated tractor equipped with four Gilbert and Riplo "GripTrac" rubber belt tracks. The tractor and track combination demonstrated excellent pulling capability and operated at very low slip levels. The ground pressure, the steering and the ride characteristics were better than either two track rubber belt tractors or radial rubber tire equipped four-wheel drive tractors. The overall tractive efficiency for the tractor was lower than similar horsepower two track or radial rubber tire tractors.

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Introduction

During the week of 6 November 1994, the Alberta Farm Machinery Research Centre tested a Case-IH 9250 articulated four-wheel drive tractor equipped with four Gilbert and Riplo "GripTrac" rubber belt tracks. The tractor and track combination was custom built by a local Case-IH dealer in a configuration very similar to the QuadTrac prototypes that have been displayed and demonstrated at farm shows by Case Corporation.

Machine Description

The test machine was a 1994 Case-IH Model 9250 with a 300 hp Cummins L10 engine. The wheel assemblies had been replaced with four separate triangular "GripTrac" rubber belt track assemblies manufactured by the Gilbert and Riplo Company of Ravenna, Michigan. A side view of the tractor is shown in Figure 1 and a front view in Figure 2.

Figure 1. Side View of Tractor.

Figure 2. Front View of Tractor.

The drive roller for each "GripTrac" assembly was bolted to the tractor axle hub where the wheel rims had been. Each drive roller was 990 mm (39 in) in diameter and was constructed with a center section divided with 20 rounded-edge plates that served as gear teeth. A structural member ran across the tractor underneath each axle and provided a pivot point for each track assembly that was directly below the centre line of the drive roller. Each track assembly formed an assymetrical triangle about the drive roller. The track frame held five lower wheels, a front and rear 500 mm (19.75 in) diameter idler, and three 250 mm (10 in) diameter rollers. Four of the rollers were rigidly mounted in the lower frame bar. Belt tensioning was accomplished with a hydraulic accumulator system that pushed the end idler (either front or rear, depending on how the track was mounted) out along the axis of the frame. The rubber belt tracks were 775 mm (30.25 in) wide belts with a chevron ground engaging lug pattern on the outside surface and centre drive lugs on the inside surface. Typically seven lugs were fully engaged in the drive roller teeth. Since the diameter of the drive roller was significantly less than the diameter of the drive tires that had been replaced, the net gear ratio of the tractor and, hence the speed in each gear, was reduced by some 30 percent.

Figure 3 is a photo and drawing of a side view of a single track with significant dimensions. Figure 4 gives dimensions for the overall tractor configuration. As shown in Figure 1, on this tractor the rear track frames were reversed compared to the front tracks. This gave extra clearance in the centre of the tractor but meant the rear tracks ran with the tensioning idler on the tight side of the rubber belt. The tractor and track assemblies had been operated for some 200 hours.

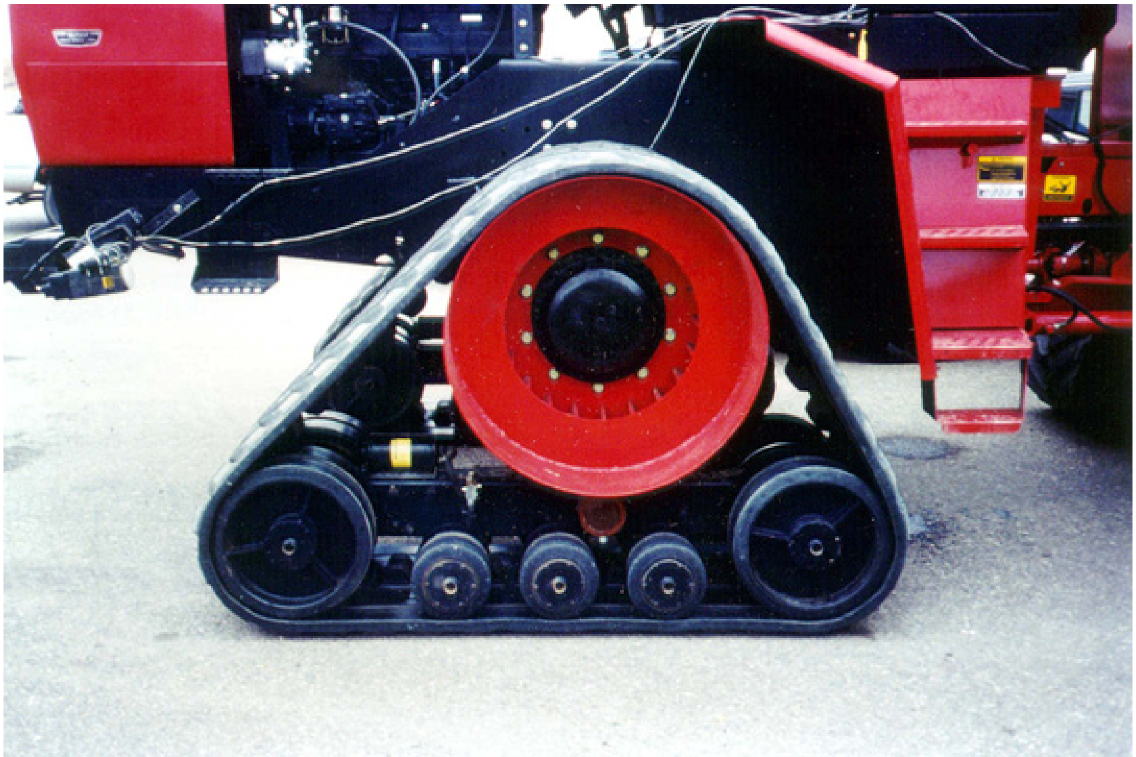

Figure 3. Side View of a Single Track.

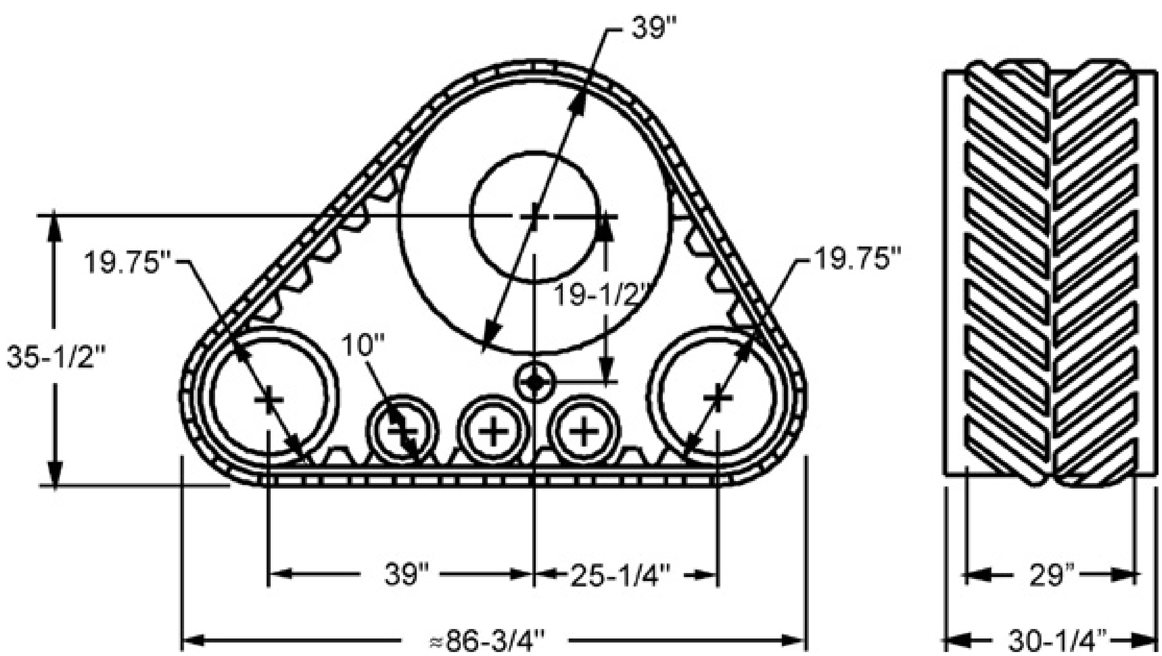

Figure 4. Overall Tractor Dimensions.

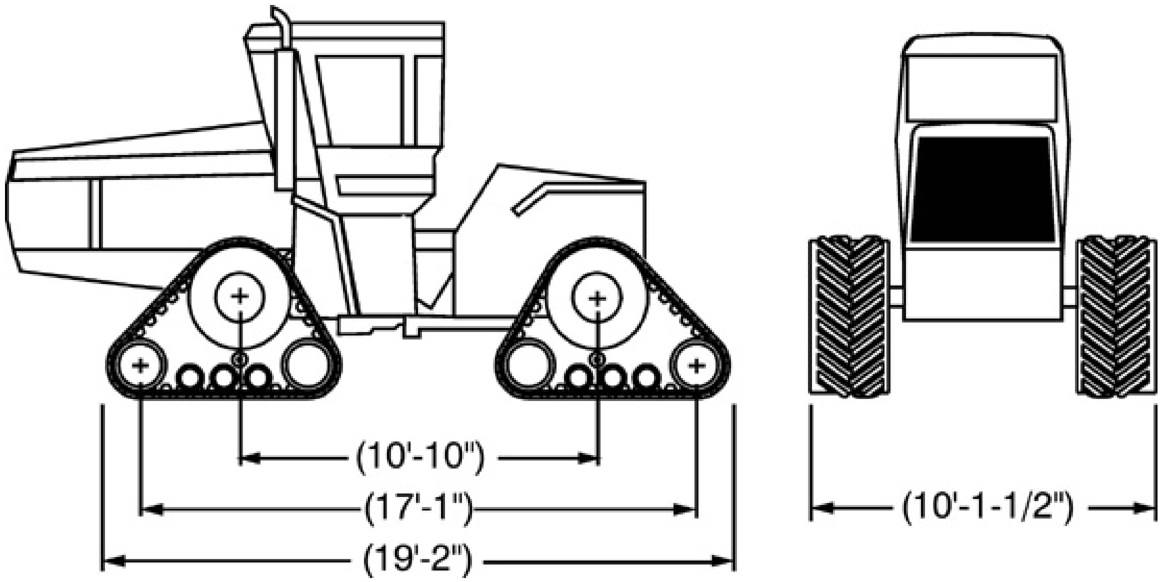

Figure 4. Overall Tractor Dimensions.

The tractor was equipped with a PTO and a three-poim hitch. Total weight of the tractor with a three quarter full fuel tank was 16,700 kg (36,850 lb). The static front axle weight was 9,200 kg (20,280 lb) or 55 percem of the total, and the rear axle weight was 7,500 kg (16,570 lb) or 45 percent of the total.

Scope of Tests

Two sets of performance tests were run on consecutive days in both primary and secondary tillage in a level clay loam soil. The weather during the tests was typical for November, with light winds and temperatures ranging from 5° to 10° C (40° to 50° F). Ground conditions were relatively dry, with soil moisture estimated at around 20 percem. A 13 m (43 ft) Friggstad chisel plow equipped with cultivator shovels was used to provide a drawbar load and the tillage depth was adjusted to vary the load. Power delivery efficiency was evaluated by comparing in-field drawbar performance measurements to PTO dynamometer measurements taken just before the tests. Steering, ride and general mobility were subjectively evaluated. Where appropriate, comparisons were made to a Case-IH 9260 equipped with 20.8 R38 radials that was tested in similar conditions in 1991, and to a Ford New Holland 946 with 20.8 R42 radials that was tested in 1993.

Test Results, Comments and Discussion

Tractive Performance Issues

1. Pull

The tractor achieved a maximum pull-to-weight ratio of 0.7. This was higher than a similar wheel tractor and was reached at lower slip levels. The results were the same in both the primary and secondary tillage tests. Figures 5 and 6 are plots of pull versus slip for the track tractor, Figure 5 in primary tillage and Figure 6 in secondary. The dotted line in Figures 5 and 6 is a composite of data from similar tests on a Case 9260 and a Ford New Holland 946 as shown in Figure 7. The track tractor pull/slip curve is much steeper than the one for the wheel tractor. At a 5 percent slip level the track tractor pulled almost twice as much as the wheel tractor.

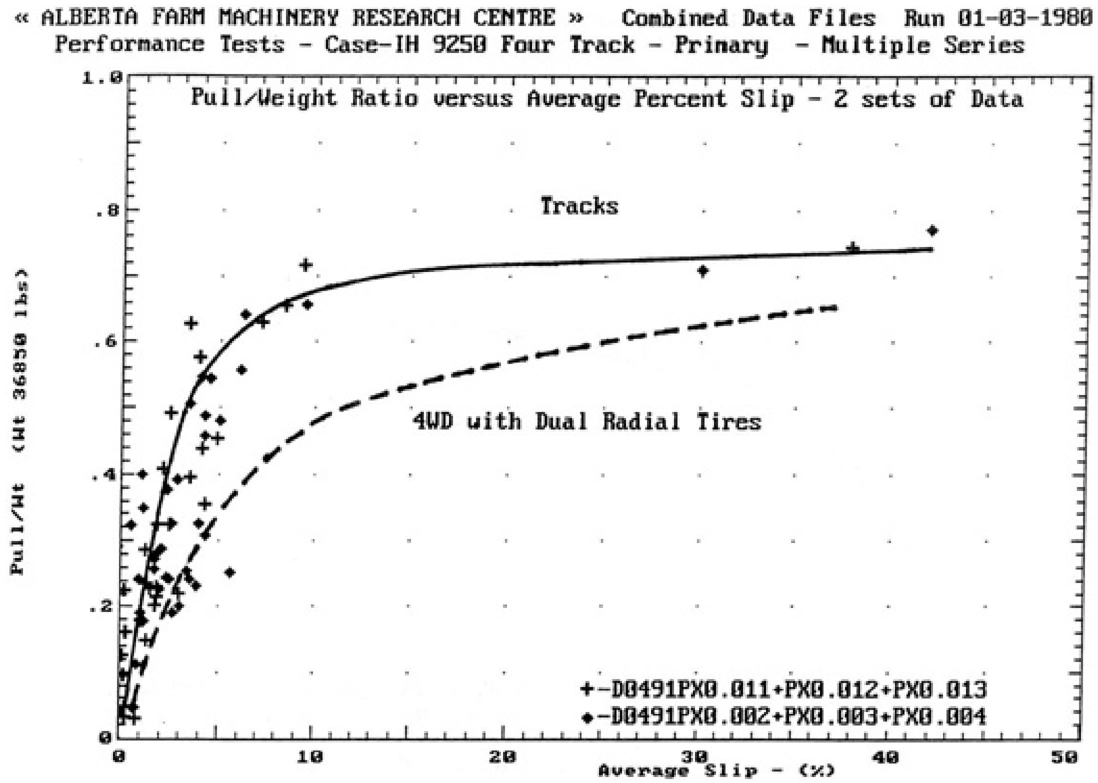

Figure 5. Pull to Weight vs. Slip in Primary Tillage - Case 9250 Four Track Machine.

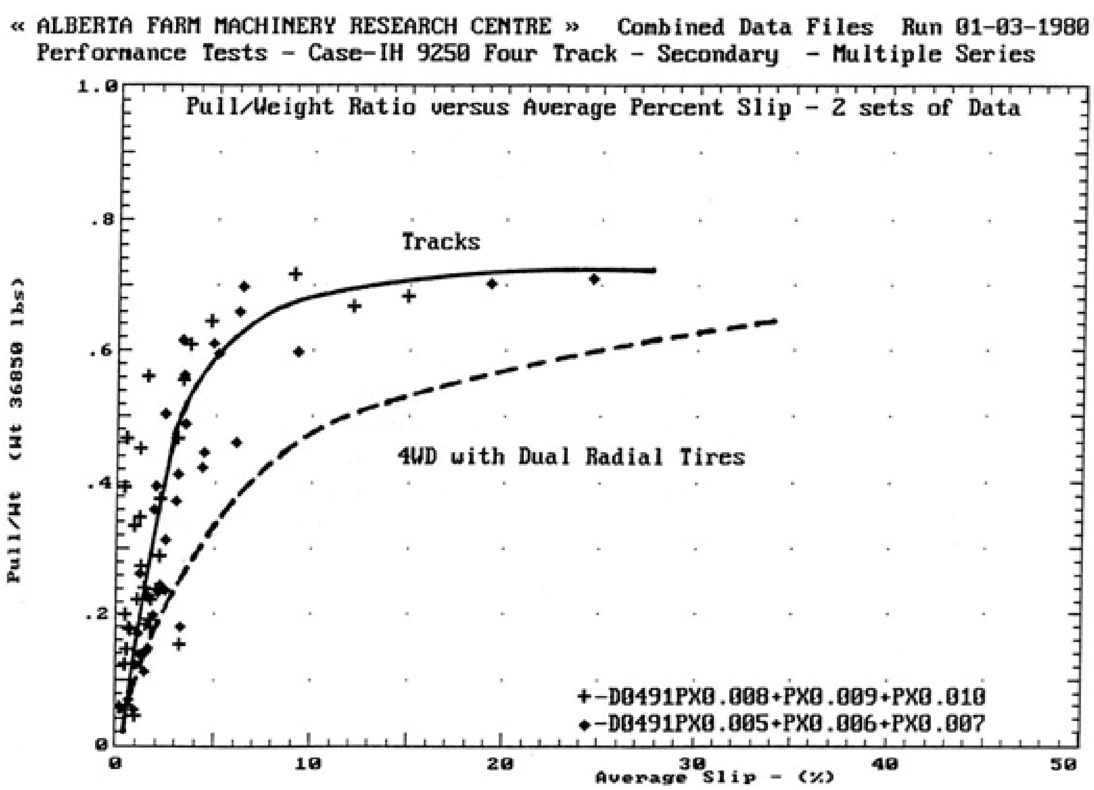

Figure 6. Pull to Weight vs. Slip in Secondary Tillage - Case 9250 Four Track Machine.

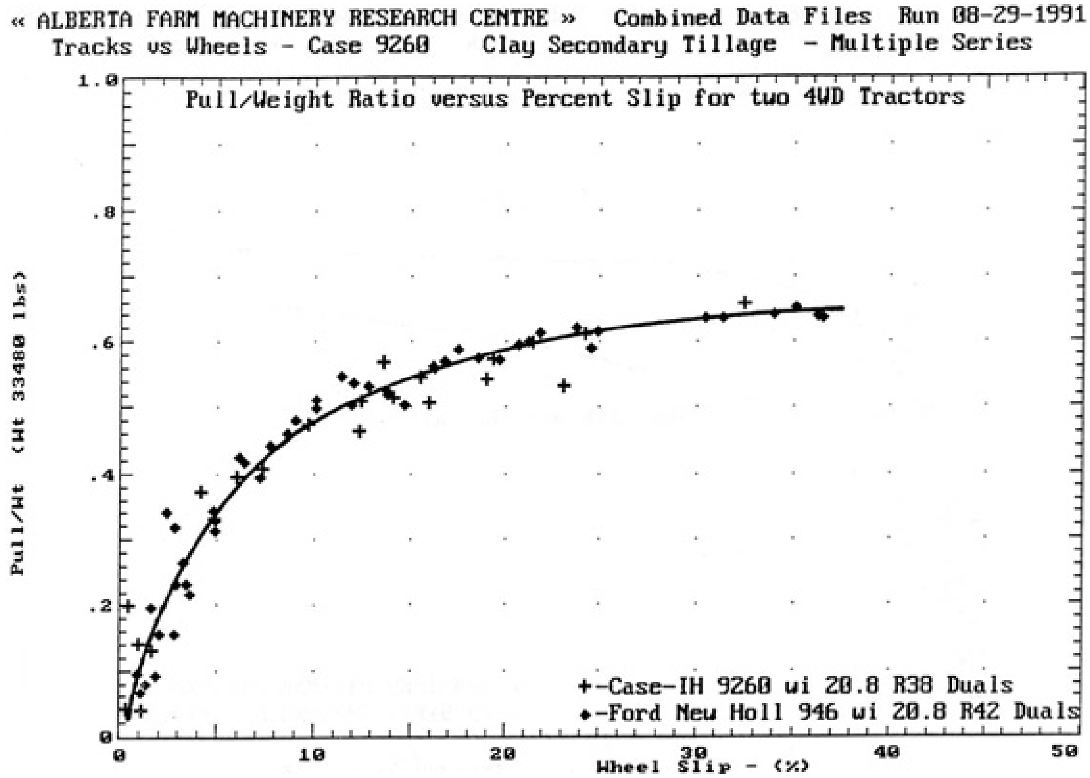

Figure 7. Pull to Weight vs. Slip in Secondary Tillage - Case 9260 with 20.8 R32 Dual Tires and Ford New Holland 946 with 20.8 R42 Dual Tires.

2. Slip

Under normal loads the rubber track equipped tractor operated at very low slip levels. As the tracks began to slip, the left front and right rear track slipped more than the other two. This was attributed to the torque exerted by the drive lines tending to lift the left front and right rear comers of the tractor. The differing slip from side to side made it necessary to measure slip on each front track and plot against the average of the readings from the two front tracks.

3. Power Delivery Efficiency

The rubber track equipped tractor was not as efficient as a rubber tire tractor. Power delivery efficiency (defined as drawbar power over developed PTO power) peaked at about 72 percent for the track tractor. This occurred at a slip of around 4 percent (Figures 8 and 9) and a pull-to-weight ratio of around 0.6 (Figures 10 and 11). Again, there was no difference between the primary and secondary tillage conditions. This compared to a peak of 76 percent for both four-wheel drive tractors at a slip of around 4 percent (Figure 12) and a pull-to- weight ratio of around 0.4 (Figure 13). Again, the dotted line on the graphs is a composite from the Case 9260 and Ford New Holland 946 as shown in Figures 12 and 13.

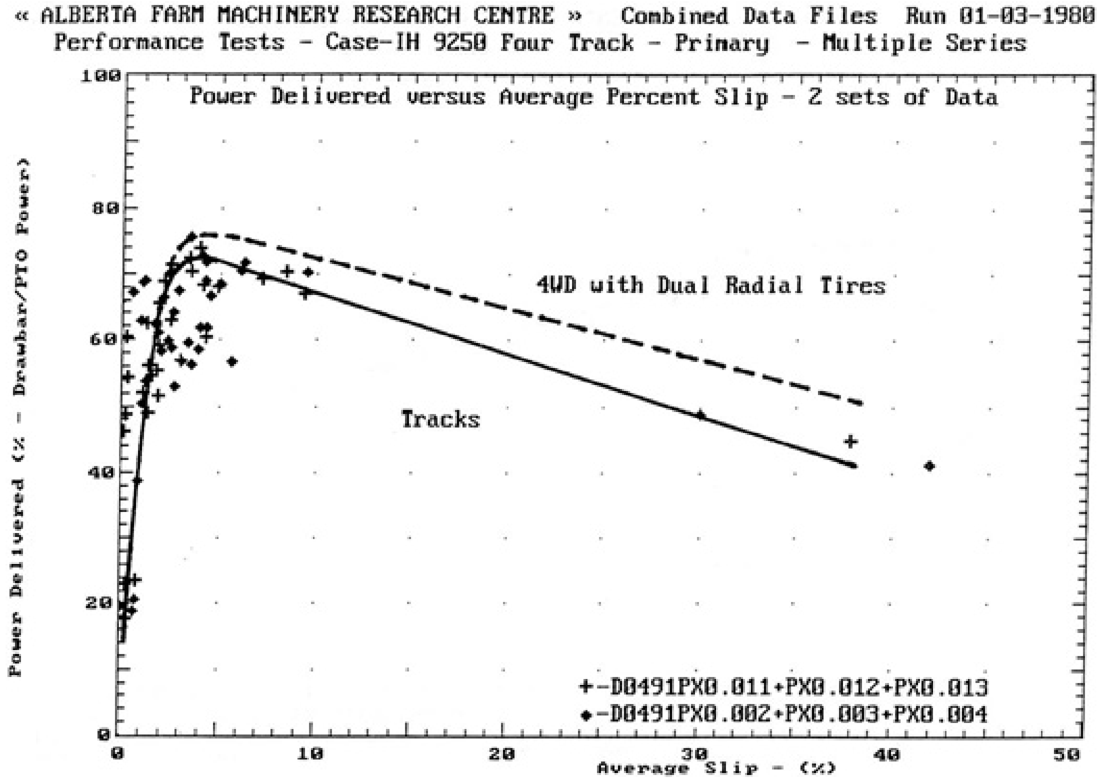

Figure 8. Power Delivery Efficiency vs. Percent Slip in Primary Tillage - Case 9250 Four Track Machine.

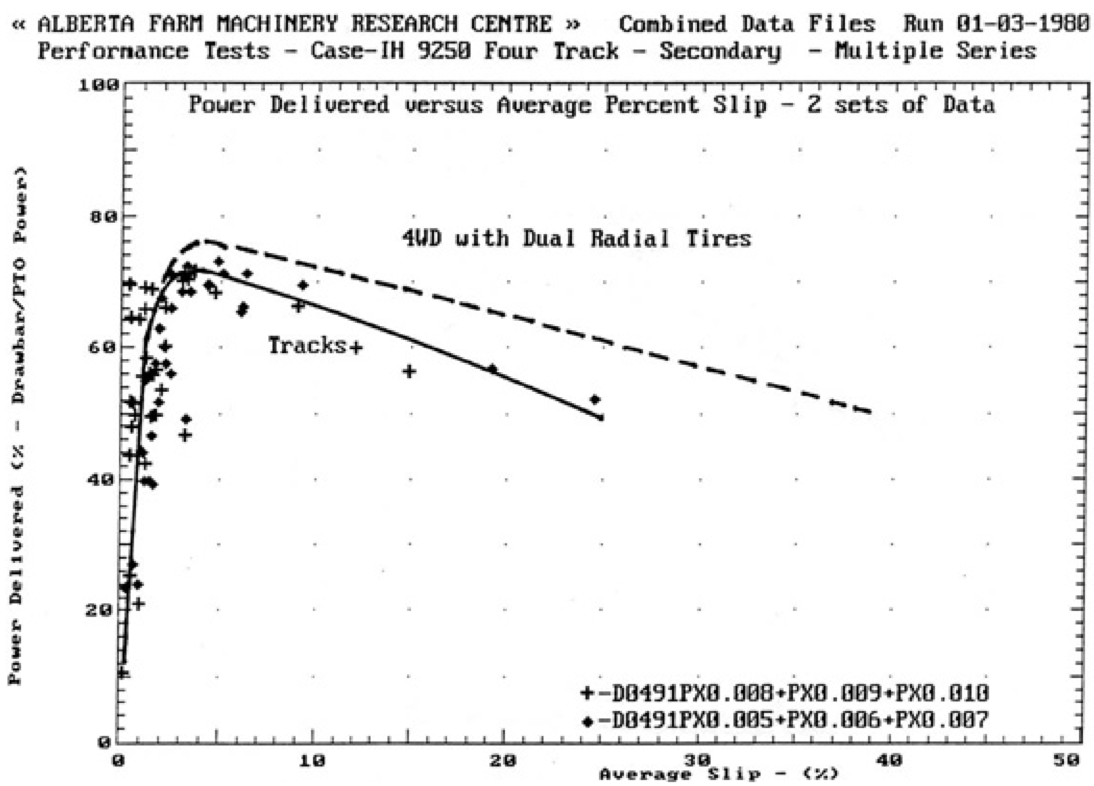

Figure 9. Power Delivery Efficiency vs. Percent Slip in Secondary Tillage - Case 9250 Four Track Machine.

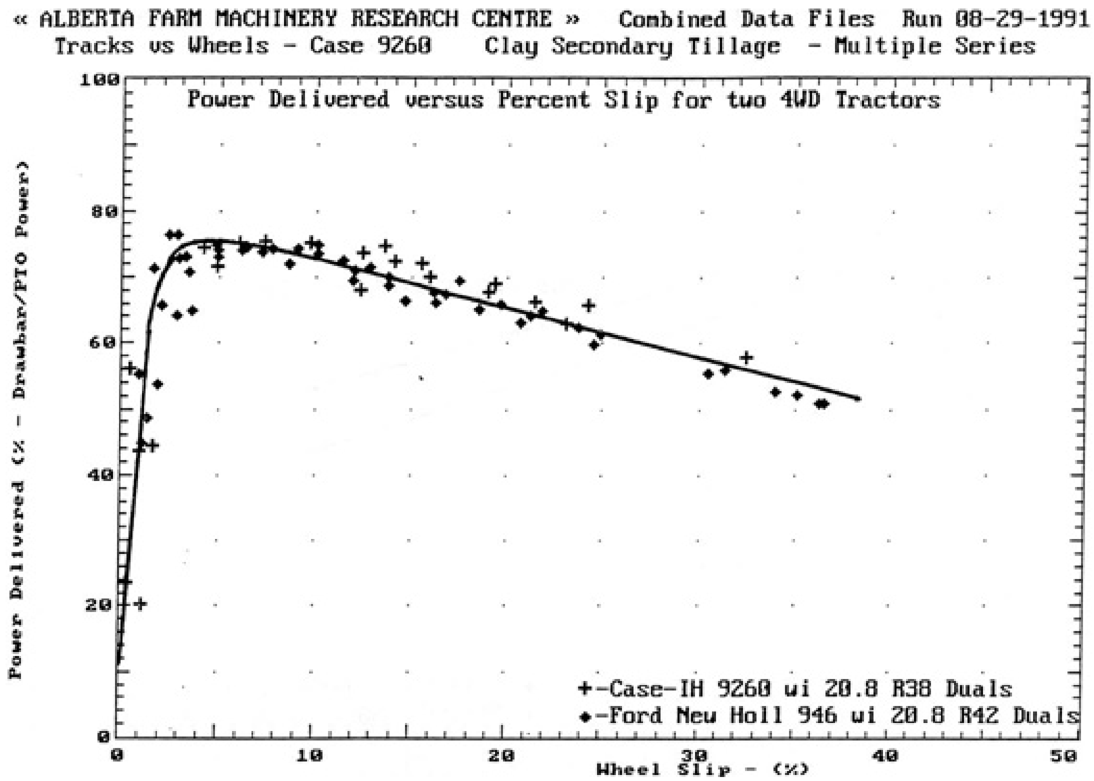

Figure 10. Power Delivery Efficiency vs. Percent Slip in Secondary Tillage - Case 9260 with 20.8 R32 Dual Tires and Ford New Holland 946 with 20.8 R42 Dual Tires.

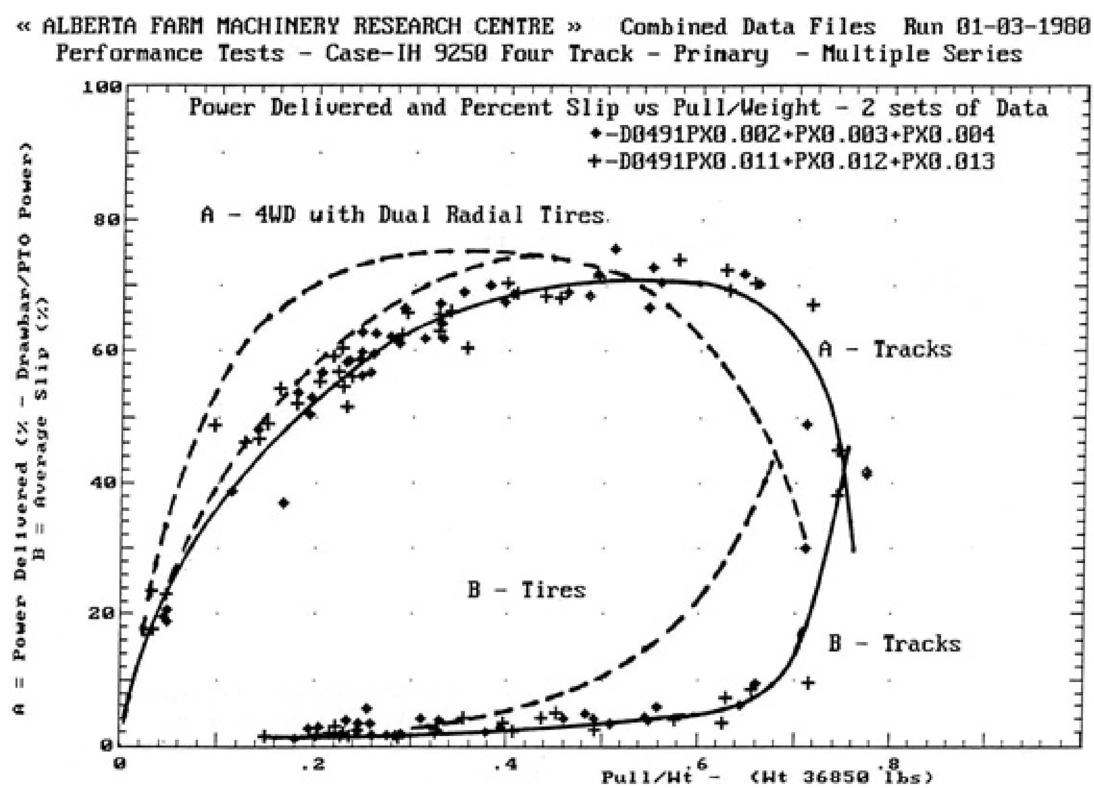

Figure 11. Power Delivery Efficiency vs. Pull-to-Weight in Primary Tillage - Case 9250 Four Track Machine.

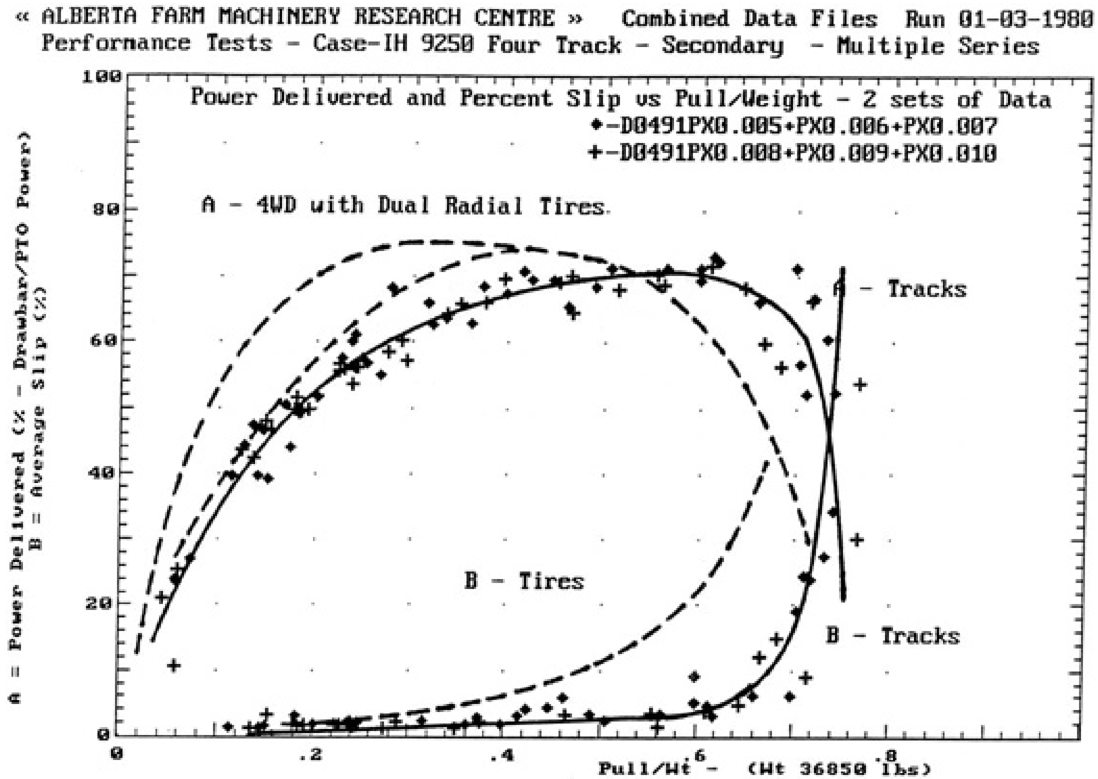

Figure 12. Power Delivery Efficiency vs. Pull-to-Weight in Secondary Tillage - Case 9250 Four Track Machine

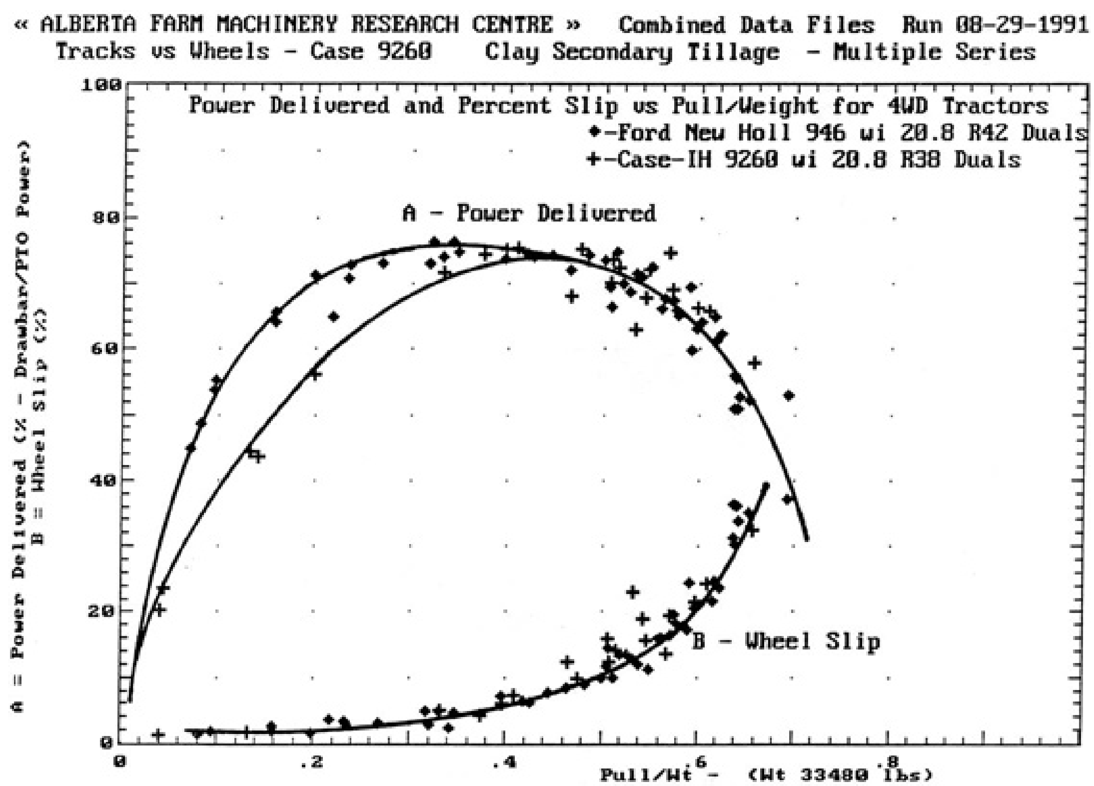

Figure 13. Power Delivery Efficiency vs. Pull-to-Weight in Secondary Tillage - Case 9260 with 20.8 R32 Dual Tires and Ford New Holland 946 with 20.8 R42 Dual Tires.

The rubber track machine developed its maximum efficiency at a higher pull-to-weight ratio than the wheel tractors did (Figures 10 and 11). This pull level is beyond where most farmers tend to operate their tractors.

4. Rolling Resistance

In an effort to understand the lower efficiency of the rubber belt tractor, the towing force required to pull the tractor was measured. Towing force is similar to rolling resistance, although usually somewhat higher because of the gearing and drag from the transmission components. On the secondary tillage field surface following a start-up pull of around 2,200 N (10,000 lb), the moving towing force was around 940 N (4,200 lb) - see Figure 14. This compares to values of 560 N (2,500 lb) for a John Deere 8760 equipped with 20.8 R42 duals and values of 470 N (2,100 lb) for a Caterpillar Challenger 65. On pavement the start-up pull remained around 2200 N (10,000 lb) and the moving towing force was around 510 N (2,300 lb) - see Figure 15.

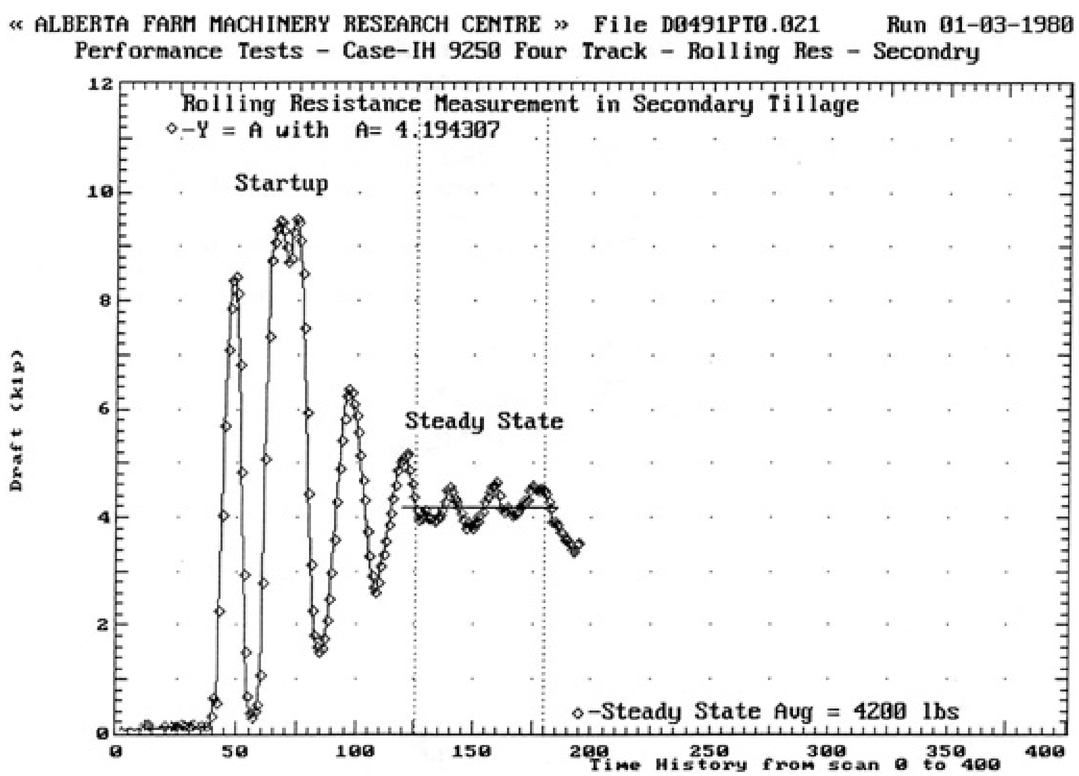

Figure 14. Time History of Draft Required to Pull Case 9250 Four Track Tractor in Secondary Tillage.

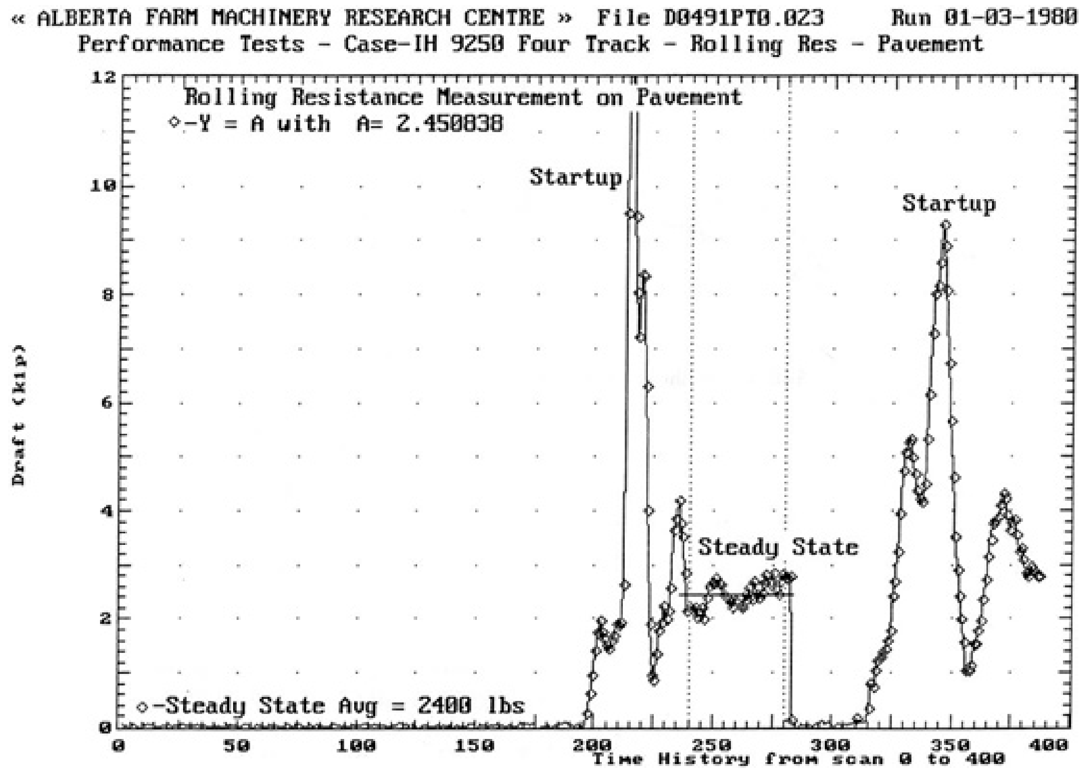

Figure 15. Time History of Draft Required to Pull Case 9250 Four Track Tractor on Pavement.

Assuming the average rolling resistance for the tractor is some 470 N (2,100 lb) higher than for an equivalent wheel tractor would explain the lower power efficiency. Figures 16 and 17 are the same plots as Figure 10 and 11, except the power calculation has been redone with an additional 470 N (2,100 lb) added to the pull. While this is an over simplification, it shows the effect of additional rolling resistance on power delivery effectiveness and suggests increased rolling resistance is the reason for the lower efficiency.

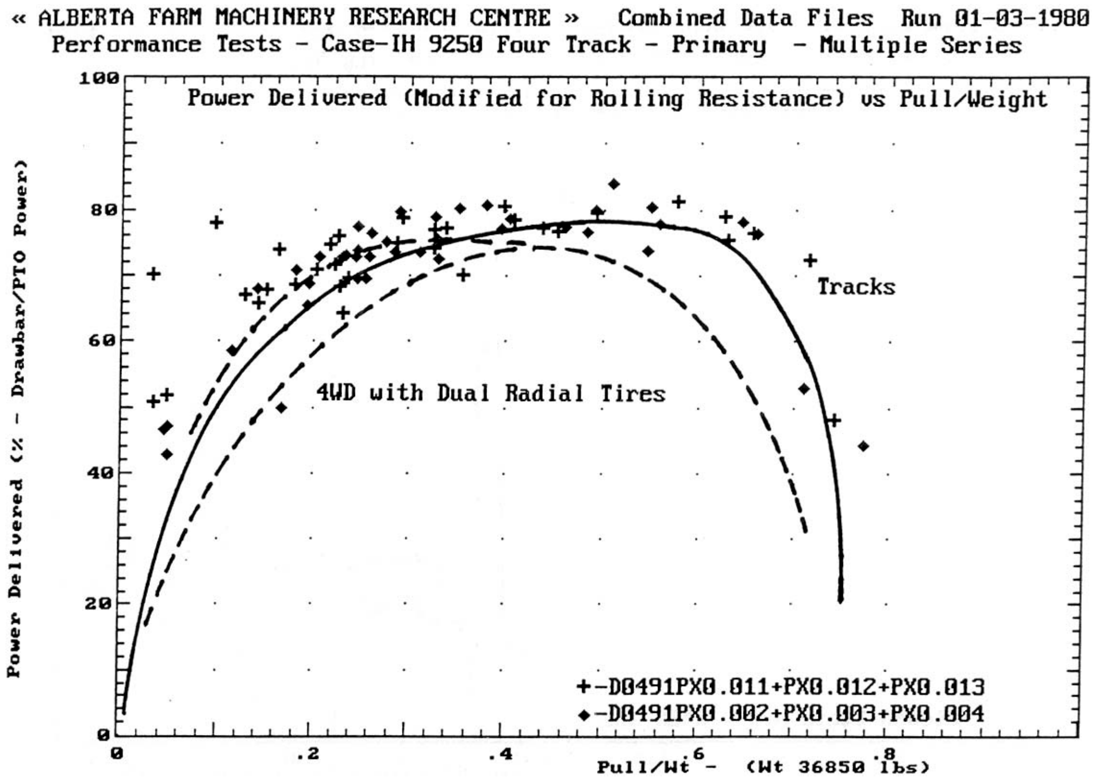

Figure 16. Corrected Power Delivery Efficiency vs. Pull-to-Weight in Primary Tillage - Case 9250 Four Track Machine (corrected by adding a load equivalent to the rolling resistance increase).

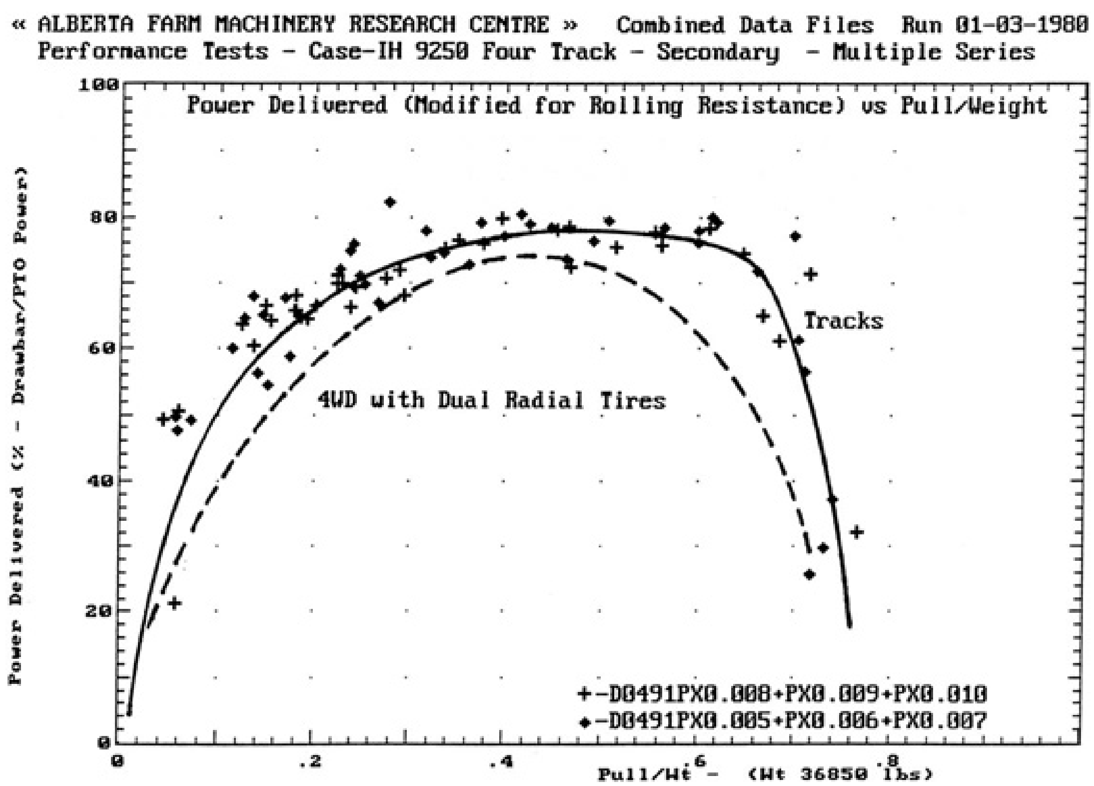

Figure 17. Corrected Power Delivery Efficiency vs. Pull-to-Weight in Secondary Tillage - Case 9250 Four Track Machine (corrected by adding a load equivalent to the rolling resistance increase).

5. Dynamometer Tests

The PTO power was measured immediately before the field tests and plotted against engine speed as shown in Figure 18. Engine speed was then measured in the field and used to determine the input power level for the efficiency calculation. At the rated speed of 2100 rpm, the tractor showed PTO power of 190 kw (255 hp), as expected, 85 percent of the nominal 224 kw (300 hp) engine power level.

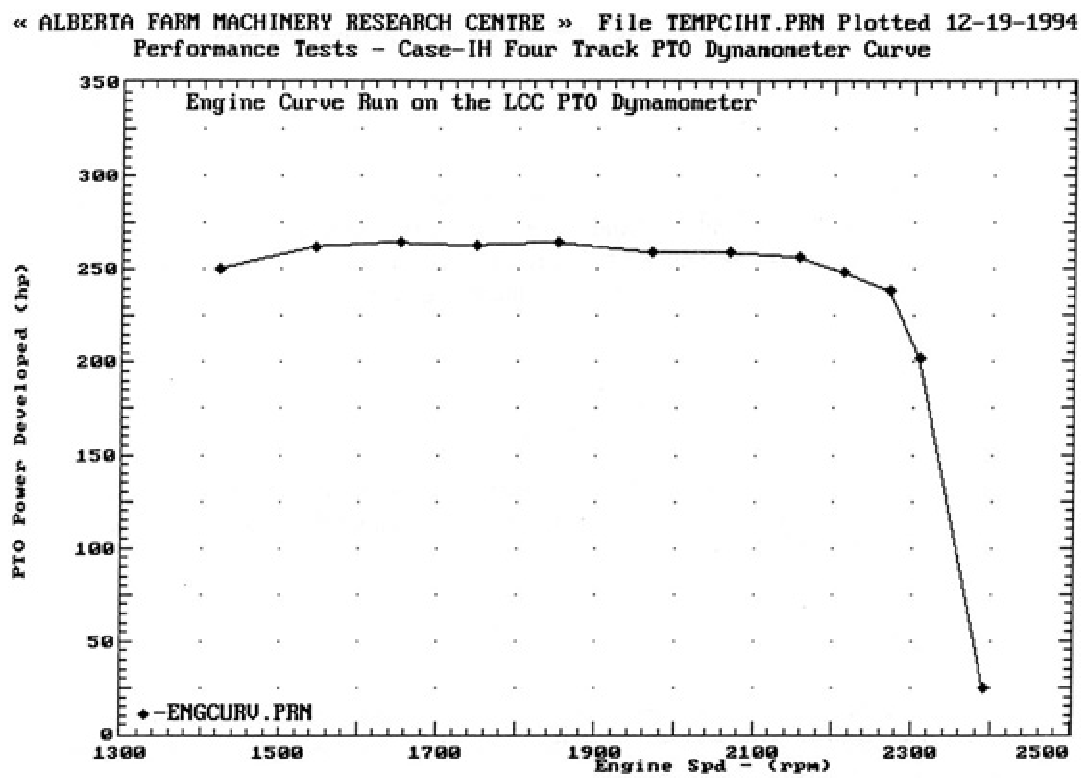

Figure 18. Measured PTO Power vs. Engine Speed on Case 9250 Four Track Machine.

Compaction

The rubber track equipped tractor had an average ground pressure of 0.26 kg/cm² (3.7 psi). This is substantially lower than pressures attainable by conventional wheel tractors and could significantly reduce compaction effects. The tractor had a total footprint of 4 x 213.4 x 76.2 = 65,044 cm² (4 x 84 x 30 = 10,080 in²). This calculates to a static 0.28 kg/cm² (4.0 psi) front and 0.23 kg/cm² (3.3 psi) rear. In reality, the ground pressures were different under load. As the tractor pulled, the track assemblies tended to twist, with the front of each track digging in and the rear lifting because the pivot point was not on the centre of the drive. This meant actual ground pressure under the track, while not easily determined, was higher than a static average would indicate. The reverse mounted rear track was more affected by this than the front track because of the shorter front lever arm.

Steering

Steering and control of the tractor was excellent in all conditions. On the field surface the steering was precise and the tractor went exactly where it was pointed. Steering performance under full load was no different than steering with no load. When cornering under full load, the tractor showed no tendency to slip toward the centre of the turn. In a sharp turn, the minimum turning circle diameter for the tractor was 12 m (39 ft). There was no tendency for the tracks to slip, push or otherwise disturb the soil when the tractor was turning. When the tractor was stationary there was not enough hydraulic force to pivot the front and rear sideways except on pavement or concrete. On the road, the tractor had no tendency to whip or over steer (albeit at its reduced top speed of 20 km/h (12.5 mph)).

Ride

The ride quality was excellent in all conditions. The long wheel base and wide stance of the tractor presented a stable and smooth riding platform. In the field there was none of the sidewall produced low frequency vibrations experienced by wheel tractors. The tendency of the tracks to pivot over obstructions reduced any vibration or displacement induced by ground contour. On the road there was none of the lug bar produced high frequency vibration sometimes experienced by wheel tractors.

Visibility

Visibility from the cab was excellent in all conditions. Since the tracks were narrower and lower than tires, it was possible to see soil and field conditions directly in front, beside and behind the tractor. This made it easy to judge tractor location relative to crop rows.

General Suitability of Use

When considering general farm use of the tractor, two concerns became apparent, both related to the 30 percent reduction in gearing that resulted from moving from the larger diameter tires to the smaller diameter track drive gear. The overall effect was to reduce the tractor speed by 30 percent in each gear. This meant the first six gears in the 12-speed transmission were of little use. In seventh gear, full rpm speed was 7.5 km/h (4.7 mph) and this was probably the lowest speed that pulling operations would be expected. The excess of low speed gears was annoying when starting the tractor out. This was true under load and especially on the road where it was difficult to get the tractor moving quickly, even with the built-in skip shift feature on the transmission. Top speed on the tractor was reduced from the normal 29 km/h (18 mph) to 20 km/h (12.5 mph) and this was a problem if the tractor needed to be roaded any distance.

It should be possible to adjust the net final gear ratio and bring the speeds back to normal by making modifications to the drive train, either in the outboard planetary gear sets or in the drive axle f'mal gear ratios. However, conversation with engineers at Gilbert and Riplo raised a concern about the effect on the tracks of prolonged operation on the road at 29 km/h (18 mph).

Reliability

The tractor was not operated long enough to directly address reliability, but areas of concern could be the rubber belt tracks, the track frames and the transmission and drive train.

There was no observable wear on the rubber belts or on the track rollers from the 200 hours that they had been used. Discussion with a previous operator suggested there had been weld durability problems with the track frames after the tractor had been roaded some distance while carrying a large rotavator on the three-point hitch.

The lower gearing and improved pull-to-weight ratio made it possible to put substantially higher loads into the drive train than what the original design would produce. Case Corporation representatives felt that continually working in the high gears on the top shaft of the transmission would not be a problem for this particular engine/transmission combination. Discussion with a previous operator suggested there had been driveline problems as a result of being able to pull far heavier than designed loads and Case representatives also stated the tractor should only be used at speeds above 8 km/h (5 mph). Because of the increased pull-to-weight capability resulting from the tracks, pulling in gears and speeds below this could dramatically increase the loads on driveline components.

Cost

The Gilbert and Riplo "GripTrac" rubber belt track assemblies present a substantial cost increase. The substitution of four tracks for four sets of dual 20.8 R42 tires and rims added $40,000 (Canadian) to the $125,000 (Canadian) price of a standard Case-IH 9250 tractor, about a 30 percent increase. These prices are approximate, represent the dealer-supplied Canadian pricing in November 1994, and do not include taxes and freight.

Other issues

All the tests were mn on relatively level ground. The overall width of the tractor is less than that of a comparable dual tire equipped tractor and this may adversely affect the lateral stability on side slopes. This may be somewhat offset by the lower centre of gravity that the track frames provide. While the tracks may respond differently in pulling or in steering on side slopes compared to on the level, no test work was done to evaluate such effects.

The tractor tested had the rear tracks mounted in the reverse direction from the front ones. With the non-symmetrical shape of the tracks, this allowed more clearance between the back of the front track and the front of the rear track when the tractor was fully articulated. This also meant the rear tracks were running with the tensioning idler on the tight side of the track. Observation of the tractor under load clearly showed the rear track belts loosened as the load increased. After the tests and the resulting discussion, the dealer switched the rear tracks around to be the same direction as the front ones so the idler would be on the loose side. This reduced the clearance when turning enough that the ladder to the operator's cab had to be modified, but it did not require that the maximum turning angle be reduced.

Conclusions

The tractor and track combination represents a novel approach to the delivery of traction power. The pluses of the design are the maneuverability, the narrow overall width, the ride characteristics and the low ground pressures. The negatives are the cost, the relative complexity and the lower power delivery efficiency. Whether the pluses outweigh the minuses is a management decision that a farm owner will have to make based on the specific farm situation.

Appendix

Field Test Runs

The following is a list of the field tests that were run. Runs 2 through 13 are time histories taken with the tractor at full throttle and draft gradually increased from zero until either the tractor spun out or the engine pulled down to near stall. Values were measured for draft, ground speed, right front track speed, left front track speed, vertical acceleration at the front axle centreline and engine speed. Values were calculated and included for drawbar power, left and right slip, and PTO power. Runs 21 to 24 are time histories of the pull required to move the tractor from stationary to maintain a 3 km/h (2 mph) speed.

Test Number	Date	Machine	Field Condition	Gear	Data File
2	10/31/94	Case 9250T	Primary	6	D0491PTO.002
3	10/31/94	Case 9250T	Primary	8	D0491PTO.003
4	10/31/94	Case 9250T	Primary	10	D0491PTO.004
5	10/31/94	Case 9250T	Secondary	6	D0491PTO.005
6	10/31/94	Case 9250T	Secondary	8	D0491PTO.006
7	10/31/94	Case 9250T	Secondary	10	D0491PTO.007
8	11/01/94	Case 9250T	Secondary	6	D0491PTO.008
9	11/01/94	Case 9250T	Secondary	8	D0491PTO.009
10	11/01/94	Case 9250T	Secondary	10	D0491PTO.010
11	11/01/94	Case 9250T	Primary	6	D0491PTO.011
12	11/01/94	Case 9250T	Primary	8	D0491PTO.012
13	11/01/94	Case 9250T	Primary	10	D0491PTO.013
21	11/01/94	Case 9250T	Secondary	FreeRoll	D0491PTO.021
22	11/01/94	Case 9250T	Secondary	FreeRoll	D0491PTO.022
23	11/01/94	Case 9250T	Pavement	FreeRoll	D0491PTO.023
24	11/01/94	Case 9250T	Pavement	FreeRoll	D0491PTO.024