Homework 4

Question 1 Given the following information for a tractor: (Note: Metric values are approximate conversions of the equivalent English values, therefore answers may be slightly different)

Rear Axle Weight	15500 lb (7000 kg)
Front Axle Weight	4500 lb (2000 kg)
Total Weight	20000 lb (9000 kg)
Wheel Base	110" (2800mm)
Center of Gravity	24.75" (622mm)(Distance from rear axle)
Drawbar Height	24" (600mm)

METHOD 1: Weight Transfer used directly (without using Xcg)

a) Determine the weight transfer to the rear wheels if a horizontal pull of 3000 lb (13.2 kN) is attached to the drawbar.

∇R_r $= P * Z_f / WB$

$= 3000 * 24 / 110$

=654 lb.

b) Under these conditions, is the weight transfer from the front wheels equal to the weight transfer to the back wheels.

Since the pull is horizontal then this will be the same as the rear.

c) Determine the horizontal pull required for the front wheels to begin lifting of the ground.

To lift of the ground the weight transfer must equal the static weight on the front tire (i.e $\nabla R_f = 4500$).

∇R_f $= P * Z_r / WB$

P $= \nabla R_f * WB / Z_r$

$= 4500 * 110 / 24$

= 20625 lb

METHOD 2: Dynamic weight calculated and then weight transfer calculated

a) Determine the weight transfer to the rear wheels if a horizontal pull of 3000 lb (13.2 kN) is attached to the drawbar.

R_r $=W*(WB-Xcg)/WB+ P * Z_f /WB$

$= 20000*(110-24.75)/110+3000 * 24 / 110$

=16 155 lb.

∇R_r = Rr - Rr`

=16155-15500

=654lb

b) Under these conditions, is the weight transfer from the front wheels equal to the weight transfer to the back wheels.

Since the pull is horizontal then this will be the same as the rear.

c) Determine the horizontal pull required for the front wheels to begin lifting of the ground.

To lift of the ground the weight transfer must equal the static weight on the front tire (i.e $\nabla R_f = 4500$).

R_f $=W*(Xcg)/WB- P * Z_r/WB$

$0=W*(Xcg)/WB- P * Z_r/WB$

$P= W*(Xcg)/WB/[Z_r/WB]$

$P=W*(Xcg)/ Z_r$

=20000*27/24

=22500 lb

Question 2: Determine the Drawbar Pull, Drawbar Power, Actual Travel Speed and Tractive Efficiency for an Case 2094 Tractor (See Nebraska Tests) at maximum drawbar power operating in 8^{th} Gear , with full tractor ballast under the following conditions

Preliminary Calc

Before you can use the ZOZ, chart you need to determine the static rear axle force, no-load speed, and axle power available. We will use the Nebraska Test to estimated these values for the drawbar tests on concrete.

Preliminary Data, form Nebraska Test

SRAF = 11230 lb
Drawbar Power = 98.66
Speed = 6.32
Slip % = 4.45

Calc zero slip speed
So = Sa / (1 - TR/100)
= 6.32/(1-4.45/100)
= 6.61 mph (This no-load speed does not change, provide all calculations are in 8th gear, maximum power)

Finding the Axle Power for Tractor in 9th Gear

From ZOZ Chart Read tractive efficiency (TE) to determine the axle power. At 4.45 % Slip, Project line from 4.45% slip to left until hit the curve for concrete, the project up to the TE (Drawbar Power/Axle Power) axis and read TE
TE = 0.92

Determine Axle Power
TE = Pdb / Pa
Pa = Pdb / TE
= 98.66 / 0.92
= 107.24 Hp

The maximum axle power and no load speed will be constant for any calculations for this tractor in 8th gear, and any amount of tractor ballast (SRAF), slip or travel reduction, soil conditions or tillage tool.

a) mounted plough in firm soil.

Using the ZOZ chart to determin Drawbar Power, Travel Speed and TE, Need to know the no-load speed & the ratio of SRAF/axle power

Calculate SRAF/axle power
SRAF/Pa = SRAF (lb) / Pa (Hp)
= 11230 / 107.24
= 105 lb/Hp

Now ready to use the ZOZ chart starting at bottom with no-load speed. Start with So at Bottom left axis (6.61 mph) projecting a horizontal line to right to the correct SRAF/Axle Power ratio in this case 105 lb/Hp. Project a vertical line up the upper right plot to intersect the correct soil/tillage tool combination (firm soil, mounted curve). Project to left a horizontal line to the correct soil type on the upper left plot in this case firm soil.

From this line

The slip can be read directly off the left hand axis of the right upper plot

Slip 9%

To determine the Drawbar Power project a line up from the relevant soil type curve (firm soil) to detemine drawbar power/rear axle power (TE) from the upper axis

Tractive Efficiency (0.78)

To determine the Drawbar Pull project a line down from the relevant family of soil/tillage tool (firm soil / semi mounted) curves to determine ration drawbar pull/SRAF

drawbar pull/rear axle force = 0.5

Calculate speed

Sa = So * (1 - TR/100)

= 6.16 * (1 - 9/100)

= 6.52 mph

Calculate Drawbar Power Pdb = Pa * TE

Pdb = Pa * TE

= 107 * 0.78

= 83 Hp (Note: The tractor still has to produce 107 Hp at the axle but only generates 83 Hp as opposed to 98.66 on concrete)

Calculate Drawbar Pull Fdb = SRAF * drawbar pull/rear axle force

Fdb = SRAF * 0.5

= 11230 * 0.5

= 5615 lb.f

b) towed plough tilled in tilled soil.

This is left for the student to find without help.

Question 3 A double acting hydraulic cylinder has a bore diameter of 4", a rod diameter of 2". The maximum pump pressure is 2200 psi. One cylinder port is connected to the pump, and the return line feeds directly into the reservior. Assume a pressure drop of 100 psi in both the pressure and return line to the cylinder. Pump delivery rate is 20 gal/min

a). What is the maximum load that can be moved when the cylinder is extending.

Max Force = P1*A1 - P2*A2
= [(2200-100)*π/4*4*4] - [(100)*π/4*(4*4-2*2))
=26389 - 942
= 25447 lb

b). What is the maximum load that can be moved when the cylinder is retracting.

Max Force = P2*A2 - P1*A1
= [(2200-100)*π/4*(4*4-2*2)] - [(100)*π/4*(4*4))
=19792-1257
= 18535 lb

c). How fast will the cylinder extend.

Velocity = Q(gal/min) * 231(in3/gal) / A1
= 20 *231/(π/4*4*4)
= 368 in/min

d). How fast will the cylinder retract.

Velocity = Q(gal/min) * 231(in3/gal) / A2
= 20 *231/(π/4*(4*4-2*2))
= 490 in/min

e). What is the flowrate of oil from the cylinder when it is retracting.

Q(out) = Q(in) * A1/A2
= 20 * (π/4*4*4)/(π/4*(4*4-2*2))
= 26.667 gal/min

OR

Q(out) = Velocity * A1/231
= 490 *(π/4*4*4)/231
= 26.667 gal/min

Question 4 Given the following specifications for a gear pump listed in a catalog.

Displacemnt = 1.8 in3/rev (29.5 cm3/rev)

Rate Speed = 2500 rpm

Rated Pressure = 3000 psi (20.7 Mpa)

Rated Delivery = 18 gal/min (68.13 l/min)

Power Input = 38 Hp (28.35 kW)

a). Calculate theoretical delivery.

$Qt = D * N / 231$

$= 1.8 * 2500 / 231$

= 19.48 gal/min

b). What is the volumetric efficiency?

Vol. Eff = Qa / Qt

= 18/19.48

= .924

c). What is the actual input Torque?

$T = P*33000 / 2\pi N$

$= 38 * 33000 / (2\pi * 2500)$

= 79.8 ft.lb

d). What is the theoretical input Torque?

$T = D * P / 2\pi / 12$

$= 1.8 * 3000 / 2\pi / 12$

= 71.6 ft.lb

e). Calculate the overall efficiency of the pump.

Overall = vol eff * mech. Eff

= .924 * .897

= 0.83

f). What is the mechanical efficiency.

Mechanical Eff. = Tt / Ta

= 71.6 / 79.8

= 0.897

Question 5 Given the following specifications for a motor listed in a catalog.

Displacemnt = 4 in3/rev (65.5 cm3/rev)
Rate Speed = 1800 rpm
Rated Pressure = 3000 psi (20.7 Mpa)
Required Delivery = 35 gal/min (130 l/min)
Power Output = 48 Hp (35.8 kW)

a). Calculate theoretical flowrate for the motor at rated speed.

Qt = D * N /231
= 4 * 1800 /231
= 31.2 gal/min

b). What is the volumetric efficiency?

Vol. Eff= Qt / Qa
= 31.2 / 35
= 0.89

c). What is the actual output Torque?

T = P*33000 / 2πN
= 48 * 33000 / (2π *1800)
= 140 ft.lb

d). What is the theoretical output Torque .

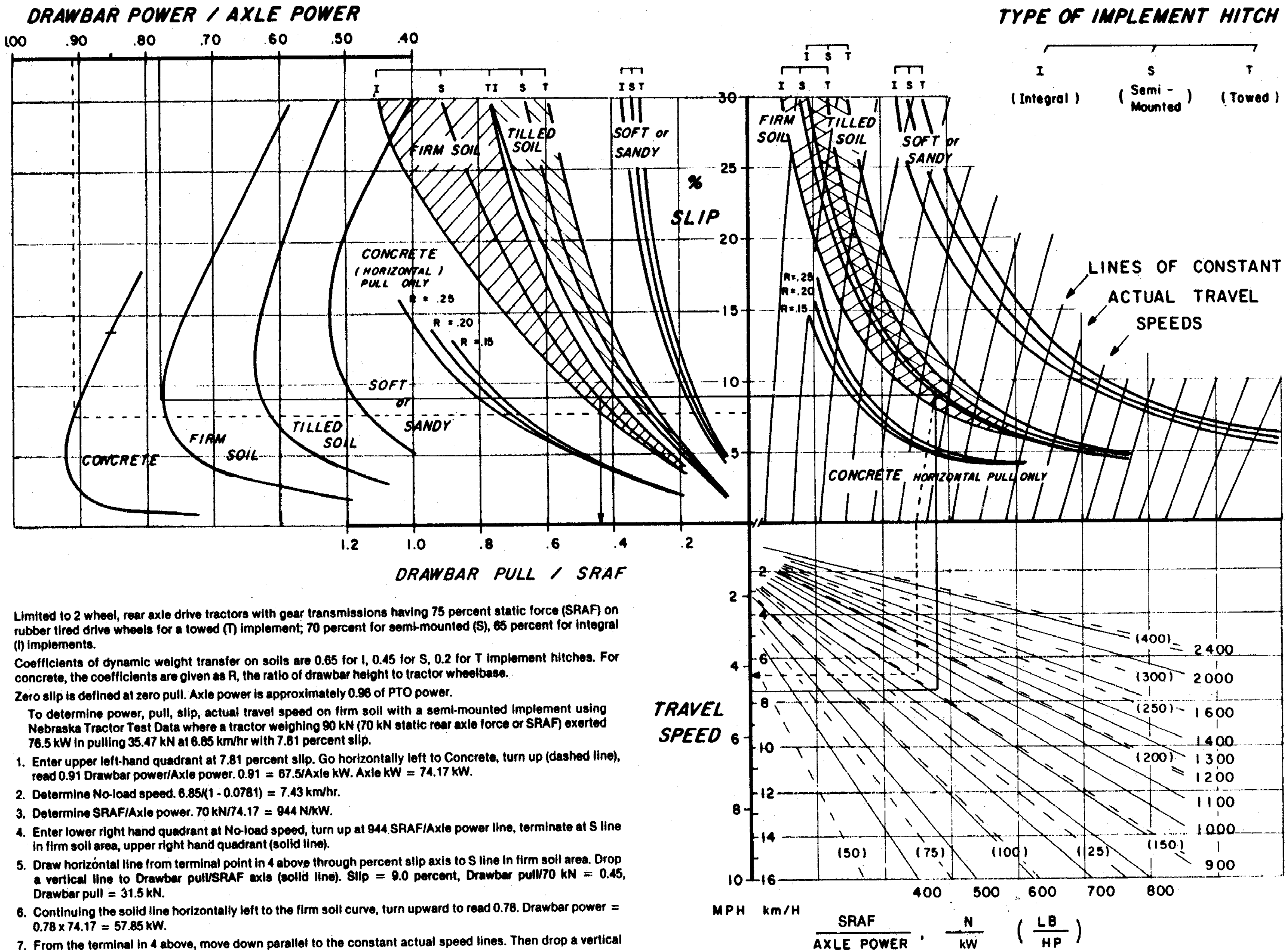
T = D * P /2π /12
= 4 * 3000 /2π/12
= 159 ft.lb

e). Calculate the overall efficiency of the motor.

Overall eff. = 0.88*0.89
= 0.78

f). Determine the mechanical efficiency of the motor.

Mech. Eff = Ta /Tt
= 140/159
= 0.88



Limited to 2 wheel, rear axle drive tractors with gear transmissions having 75 percent static force (SRAF) on rubber tired drive wheels for a towed (T) implement; 70 percent for semi-mounted (S), 65 percent for integral (I) implements.

Coefficients of dynamic weight transfer on soils are 0.65 for I, 0.45 for S, 0.2 for T implement hitches. For concrete, the coefficients are given as R, the ratio of drawbar height to tractor wheelbase.

Zero slip is defined at zero pull. Axle power is approximately 0.96 of PTO power.

To determine power, pull, slip, actual travel speed on firm soil with a semi-mounted implement using Nebraska Tractor Test Data where a tractor weighing 90 kN (70 kN static rear axle force or SRAF) exerted 76.5 kW in pulling 35.47 kN at 6.85 km/hr with 7.81 percent slip.

1. Enter upper left-hand quadrant at 7.81 percent slip. Go horizontally left to Concrete, turn up (dashed line), read 0.91 Drawbar power/Axle power. 0.91 = 67.5/Axle kW. Axle kW = 74.17 kW.
2. Determine No-load speed. 6.85/(1 - 0.0781) = 7.43 km/hr.
3. Determine SRAF/Axle power. 70 kN/74.17 = 944 N/kW.
4. Enter lower right hand quadrant at No-load speed, turn up at 944 SRAF/Axle power line, terminate at S line in firm soil area, upper right hand quadrant (solid line).
5. Draw horizontal line from terminal point in 4 above through percent slip axis to S line in firm soil area. Drop a vertical line to Drawbar pull/SRAF axis (solid line). Slip = 9.0 percent, Drawbar pull/70 kN = 0.45, Drawbar pull = 31.5 kN.
6. Continuing the solid line horizontally left to the firm soil curve, turn upward to read 0.78. Drawbar power = 0.78 x 74.17 = 57.85 kW.
7. From the terminal in 4 above, move down parallel to the constant actual speed lines. Then drop a vertical to the 944 SRAF/Axle power turning line, go left, and read 6.8 km/hr actual speed (dashed line).

FIGURE 16.9 Traction prediction chart (Reprinted from ASAE Data D230.4, *Agricultural machinery management*, revised December 1983)

NEBRASKA TRACTOR TEST 1525 — CASE 2094 POWERSHIFT DIESEL 12 SPEED

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crank shaft speed rpm	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—998 rpm)								
110.50	2100	7.175	0.455	15.40	187	65	75	28.96
(82.40)		*(27.157)*	*(0.276)*	*(3.034)*	*(86.1)*	*(18.5)*	*(23.8)*	*(97.80)*
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
97.14	2170	6.561	0.473	14.80	184	65	74	......
(72.44)		*(24.837)*	*(0.288)*	*(2.916)*	*(84.2)*	*(18.3)*	*(23.3)*	......
0.00	2302	2.310	.....	.....	174	66	75	......
(0.00)		*(8.744)*	.....	.....	*(78.9)*	*(18.9)*	*(23.9)*	......
49.97	2236	4.341	0.608	11.51	181	66	76	......
(37.26)		*(16.434)*	*(0.370)*	*(2.267)*	*(82.8)*	*(18.6)*	*(24.2)*	......
111.42	2100	7.230	0.454	15.41	187	66	75	......
(83.09)		*(27.368)*	*(0.276)*	*(3.036)*	*(86.1)*	*(18.6)*	*(23.6)*	......
25.33	2266	3.373	0.932	7.51	175	65	74	......
(18.89)		*(12.767)*	*(0.567)*	*(1.480)*	*(79.4)*	*(18.3)*	*(23.1)*	......
73.99	2205	5.366	0.508	13.79	183	66	75	......
(55.17)		*(20.311)*	*(0.309)*	*(2.716)*	*(83.6)*	*(18.9)*	*(23.9)*	......
Av 59.64	**2213**	**4.864**	**0.571**	**12.26**	**181**	**66**	**75**	**28.94**
Av (44.47)		***(18.410)***	***(0.347)***	***(2.416)***	***(82.5)***	***(18.6)***	***(23.7)***	***(97.73)***

DRAWBAR PERFORMANCE

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temp. °F (°C) Cool-ing med	Air wet bulb	Air dry bulb	Barom. inch Hg (kPa)
Maximum Available Power—Two Hours 8th (3-2) Gear											
98.66	5851	6.32	2099	4.45	7.143	0.507	13.81	192	70	76	29.03
(73.57)	*(26.02)*	*(10.18)*			*(27.039)*	*(0.308)*	*(2.721)*	*(88.6)*	*(21.1)*	*(24.2)*	*(98.01)*
75% of Pull at Maximum Power—Ten Hours 8th (3-2) Gear											
79.36	4443	6.70	2195	3.26	6.136	0.541	12.93	190	70	74	28.86
(59.18)	*(19.76)*	*(10.78)*			*(23.226)*	*(0.329)*	*(2.548)*	*(87.6)*	*(20.9)*	*(23.2)*	*(97.44)*
50% of Pull at Maximum Power—Two Hours 8th (3-2) Gear											
54.15	2962	6.86	2219	2.05	4.807	0.621	11.27	188	73	82	28.87
(40.38)	*(13.18)*	*(11.03)*			*(18.197)*	*(0.378)*	*(2.219)*	*(86.4)*	*(22.8)*	*(27.5)*	*(97.47)*
50% of Pull at Reduced Engine Speed—Two Hours 10th (4-1) Gear											
54.20	2962	6.86	1456	2.09	3.850	0.497	14.08	189	73	83	28.83
(40.41)	*(13.18)*	*(11.04)*			*(14.574)*	*(0.302)*	*(2.773)*	*(86.9)*	*(22.5)*	*(28.1)*	*(97.34)*
MAXIMUM POWER IN SELECTED GEARS											
90.78	11910	2.86	2126	14.83		4th (2-1) Gear		189	68	70	29.00
(67.69)	*(52.98)*	*(4.60)*						*(87.2)*	*(20.0)*	*(21.1)*	*(97.93)*
98.04	8979	4.09	2101	7.18		5th (2-2) Gear		191	70	74	28.91
(73.11)	*(39.94)*	*(6.59)*						*(88.3)*	*(21.1)*	*(23.3)*	*(97.62)*
99.08	7975	4.66	2101	6.08		6th (3-1) Gear		192	70	74	28.91
(73.88)	*(35.47)*	*(7.50)*						*(88.6)*	*(21.1)*	*(23.3)*	*(97.62)*
98.50	7068	5.23	2101	5.33		7th (2-3) Gear		192	70	75	28.91
(73.45)	*(31.44)*	*(8.41)*						*(88.9)*	*(21.1)*	*(23.9)*	*(97.62)*
100.12	5924	6.34	2100	4.34		8th (3-2) Gear		192	70	75	28.90
(74.66)	*(26.35)*	*(10.20)*						*(88.9)*	*(21.1)*	*(23.9)*	*(97.59)*
98.64	4619	8.01	2099	3.25		9th (3-3) Gear		193	70	75	28.90
(73.55)	*(20.54)*	*(12.89)*						*(89.2)*	*(21.1)*	*(23.9)*	*(97.59)*

LUGGING ABILITY IN 8th (3-2) GEAR

Crankshaft Speed rpm	2100	1892	1683	1472	1255	1053
Pull—lbs	5924	6436	6756	6827	6689	6349
(kN)	*(26.35)*	*(28.85)*	*(30.28)*	*(30.60)*	*(29.98)*	*(28.46)*
Increase in Pull %	0	9	14	15	13	7
Power—Hp	100.12	97.50	90.84	80.18	67.10	53.52
(kW)	*(74.66)*	*(72.71)*	*(67.74)*	*(59.79)*	*(50.03)*	*(39.91)*
Speed—Mph	6.34	5.68	5.04	4.40	3.76	3.16
(km/h)	*(10.20)*	*(9.14)*	*(8.12)*	*(7.09)*	*(6.05)*	*(5.09)*
Slip %	4.34	4.80	4.95	5.10	4.95	4.80

Department of Agricultural Engineering

Dates of Test: May 30 to June 16, 1984

Manufacturer: J. I. CASE COMPANY, 700 State Street, Racine, Wisconsin 53404

FUEL, OIL AND TIME: Fuel No. 2 Diesel **Cetane No.** 46.0 (rating taken from oil company's inspection data) **Specific gravity converted to 60°/60°** *(15°/15°)* 0.8408 **Fuel weight** 7.000 lbs/gal *(0.839 kg/l)* **Oil SAE** 30 **API service classification** SF, CD **To motor** 4.354 gal *(16.481 l)* **Drained from motor** 4.085 gal *(15.463 l)* **Transmission and final drive lubricant** Case Powergard PTF transmission fluid **Total time engine was operated** 40.0 hours.

ENGINE: Make Case Diesel **Type** six cylinder vertical **Serial No.** *10356640* **Crankshaft** lengthwise **Rated rpm** 2100 **Bore and stroke** 4.625" × 5.0" *(117.5 mm × 127 mm)* **Compression ratio** 16.0 to 1 **Displacement** 504 cu in *(8259 ml)* **Starting system** 12 volt **Lubrication** pressure **Air cleaner** two paper elements **Oil filter** one full flow cartridge **Oil cooler** radiator for hydraulic and transmission oil **Fuel filter** two paper cartridges and prestrainer **Muffler** vertical **Cooling medium temperature control** two thermostats.

CHASSIS: Type standard with duals **Serial No.** *9932956* **Tread width** rear 60" *(1524 mm)* to 124" *(3150 mm)* front 60" *(1524 mm)* to 88" *(2235 mm)* **Wheel base** 110" *(2794 mm)* **Center of gravity** (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels 25.7" *(652 mm)* Vertical distance above roadway 40.7" *(1034 mm)* Horizontal distance from center of rear wheel tread 0" *(0 mm)* to the right/left **Hydraulic control system** direct engine drive **Transmission** selective gear fixed ratio with partial (3) range operator controlled powershift **Advertised speeds mph (km/h)** first 1.9 *(3.1)* second 2.5 *(4.0)* third 3.2 *(5.2)* fourth 3.2 *(5.2)* fifth 4.3 *(6.9)* sixth 4.9 *(7.9)* seventh 5.4 *(8.7)* eighth 6.5 *(10.5)* ninth 8.1 *(13.0)* tenth 9.9 *(15.9)* eleventh 13.2 *(21.2)* twelfth 18.1 *(29.1)* reverse 3.2 *(5.2)*, 5.4 *(8.7)*, 8.1 *(13.0)* **Clutch** wet multiple disc hydraulically power actuated by foot pedal **Brakes** wet multiple disc hydraulically power actuated by two foot pedals which can be locked together **Steering** hydrostatic **Turning radius** (on concrete surface with brake applied) right 161.8" *(4.11 m)* left 161.8" *(4.11 m)* (on concrete surface without brake) right 182.2" *(4.63 m)* left 182.2" *(4.63 m)* **Turning space diameter** (on concrete surface with brake applied) right 338" *(8.59 m)* left 338" *(8.59 m)* (on concrete surface without brake) right 382.2" *(9.71 m)* left 382.2" *(9.71 m)* **Power take-off** 534 rpm at 2100 engine rpm and 998 rpm at 2100 engine rpm.

TRACTOR SOUND LEVEL WITH CAB	dB(A)
Maximum Available Power—Two Hours	77.5
75% of Pull at Maximum Power—Ten Hours	77.0
50% of Pull at Maximum Power—Two Hours	77.5
50% of Pull at Reduced Engine Speed—Two Hours	74.5
Bystander in 12th (4-3) gear	88.0

TIRES, BALLAST AND WEIGHT		With Ballast	Without Ballast
Rear Tires	—No., size, ply & psi *(kPa)*	Inner Two 18.4-38; 8; 14 *(95)* Outer Two 18.4-38; 6; 14 *(95)*	Inner Two 18.4-38; 8; 14 *(95)* Outer Two 18.4-38; 6; 14 *(95)*
Ballast	—Liquid (each)	None	None
	—Test Equip (each)	78 lb *(35 kg)*	None
Front Tires	—No., size, ply & psi *(kPa)*	Two 11.00-16; 8; 40 *(275)*	Two 11.00-16; 8; 40 *(275)*
Ballast	—Liquid (each)	None	None
	—Cast Iron (each)	125 lb *(57 kg)*	None
Height of Drawbar		19.5 in *(495 mm)*	19.5 in *(495 mm)*
Static Weight with Operator	—Rear	11230 lb *(5094 kg)*	10920 lb *(4953 kg)*
	—Front	3520 lb *(1597 kg)*	3270 lb *(1483 kg)*
	—Total	14750 lb *(6691 kg)*	14190 lb *(6436 kg)*

REPAIRS and ADJUSTMENTS: No repairs or adjustments.

REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test codes and the technically equivalent ISO test codes or official Nebraska test procedure. For the maximum power tests, the fuel temperature at the injection pump return was maintained at 180°F *(82.2°C)*. Six gears were chosen between 15% slip and 10 mph *(16.1 km/h)*.

We, the undersigned, certify that this is a true and correct report of official Tractor Test No. **1525**, July 19, 1984.

LOUIS I. LEVITICUS
Engineer-in-Charge

K. VON BARGEN
W. E. SPLINTER