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AN EVALUATION OF AGRICULTURAL TRACTORS HYDRAULIC LIFT PERFORMANCE

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by

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The current OECD Code 2 detailing the procedures for the hydraulic lift test of agricultural tractors, section 4.3, published lift values that were sometimes unattainable. The static weight of 2WD, two wheel drive, and MFWD, mechanical front wheel drive, tractors and the amount of lifting force have increased at a greater rate than the amount of static weight on the front axle. This increase in lifting force has led to a decrease in the percent of weight as the upward support force on the front axle of a tractor. Many of the 2WD and MFWD unballasted tractors tested at the Nebraska Tractor Test Laboratory (NTTL) since 1995 were discovered to have lift forces sufficient to raise the front axle off of the ground given the current maximum achievable lifting capacity measured during testing.

Equations for calculating the maximum realistic achievable lifting capacity of tractors were developed based on maintaining a minimum amount of upward support force on the front axle. A test to determine how much upward support force at the front axle was sufficient to maintain adequate steering control of tractors was developed. Operator feedback from this test determined that 20% of the total tractor weight as the upward support force on the front axle had significantly greater steering control when compared to 15%. A sample proposal was drafted to

be sent to OECD to update the hydraulic lift test in Code 2 requiring limiting the maximum lifting force published such that a minimum of 0% of the total unballasted tractor weight as the upward support force on the front axle for 2-track tractors, and 20% for 2WD and MFWD, and 4WD tractors.

This proposal utilized a series of equations based on several different tractor characteristics to determine the maximum realistic achievable lifting capacity of agricultural tractors that were tested at OECD accredited test facilities. Ballasted weight configurations were also incorporated for maximum realistic achievable lifting capacity of tractors under this new proposal. A sample of what future publications with these changes could resemble was prepared for the John Deere 6150M tractor.

DEDICATION

I dedicate this thesis to my friends and family for all of their moral support throughout graduate school.

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CHAPTER 1. INTRODUCTION

The Nebraska Tractor Test Laboratory (NTTL) has received five to six inquiries per year over the last decade from farmers about the lifting capacity of their tractors per Roger Hoy, Director of the NTTL. These farmers used NTTL tractor test reports to determine the lifting forces their tractors could develop at the three point hitch, but then realized after purchase that these lift values were not achievable as the front wheels lifted off the ground. At times, producers had to use larger tractors to handle these heavier three-point implements. Further, if there was insufficient weight as the upward support force on the front axle, steering control was compromised potentially leading to a serious accident.

CHAPTER 2. LITERATURE REVIEW

The first OECD standard code for the Official Testing of Agricultural Tractors was approved in 1959 (OECD, 2014 b). The most current code, OECD Code 2 section 4.3, is the official testing procedure for the hydraulic lift test of agriculture and forestry tractor performance, as seen in Appendix A, (OECD, 2014 a).

Since the first OECD code for hydraulic lift was introduced, the hydraulic lift test has changed several times. For example, in the 1979 version of the code, the hydraulic lift test procedure required the front axle of the tractor to be loosely strapped down to determine the lifting force at which the front axle of the tractor raised off the ground (OECD, 1979). This procedure was changed to prevent the tractor from moving during testing. The current OECD code requires that "The tractor shall be so secured that the reactive force of the hydraulic power lift deflects neither tyres nor suspension." (OECD, 2014 a)

Per the existing OECD Code 2 (OECD, 2014 a), tractors were tested at two different lift points at the rear of the tractor: 1) at the lower hitch points and 2) on a coupled frame. For lift at the lower hitch point, an external vertical downward force was applied to a horizontal bar connecting the two lower hitch points. Comparatively, the lift on a coupled frame required use of a frame with the lifting force applied at the frame's center of mass at a point 610 mm behind the rear of the lower hitch points as shown in Figure 2.1. This distance of 610 mm has endured since the 1979 version (OECD, 1979). The frame geometry for three-point attachment characteristics was based on the linkage category of the tractor and International Standard (ISO) 730-1:2014 (ISO, 2014).

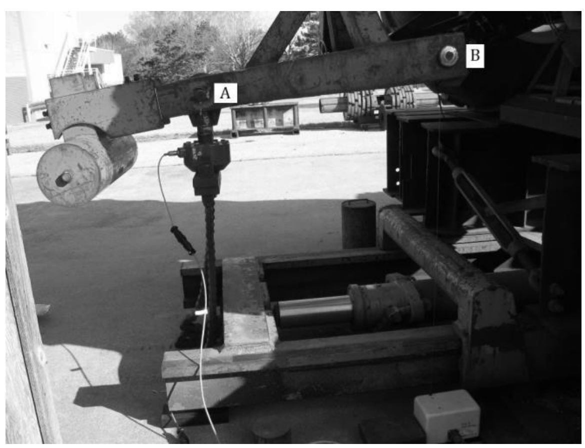

Figure 2.1. Hydraulic lift test setup with 610 mm coupled frame. Point B is the lower hitch points and point A is the point of application of the lifting force and the center of mass of the frame, 610 mm behind the lower hitch point (A).

For testing with and without the 610 mm coupled frame, the lower links were first adjusted so they were horizontal. Then the upper center link was adjusted so that the hitch points and the center of gravity of the 610mm coupled frame were in the same horizontal plane.

Two different means of reporting the data were analyzed throughout this research, OECD and NTTL test reports. OECD test reports include a full summary of the tests performed on the tractor. OECD reports were issued for every approved report of a tractor that was tested at an OECD accredited test station. NTTL test summary reports were a general summary of the measured performance of tractors tested. NTTL test summaries were published for all tractors tested in Nebraska. Also, manufacturers may request that Nebraska summary reports be prepared for tractor models with approved OECD reports from other OECD accredited test stations. These NTTL test summaries are readily available at tractortestlab.unl.edu/test reports. Nebraska law requires that to sell any current tractor model 100 horsepower or more must be tested at an accredited test station and meet the advertised claims. Upon approval of the Nebraska Tractor Test Board of Engineers, these tractors receive a sales permit to allow the sale of these tractors in Nebraska.

The current code (OECD, 2014 a) requires that the lifting force shall be determined at a minimum of six points evenly spaced throughout the range of movement of the lift, with one of these points at each extremity. These forces were then corrected to 90% of the actual value. The minimal lifting capacity of these corrected forces constitutes the maximum vertical lifting force. Approved OECD tests reports include this maximum corrected vertical force, as well as a table that includes the lifting forces at the various heights used during testing (OECD, 2014 a).

Approved NTTL reports only include the maximum lifting force exerted through the whole range of movement.

According to Nebraska Tractor Test Board Action 35, when tractors have multiple three-point hitch configurations available, the three-point hitch configuration most commonly sold in Nebraska must be tested (Kocher, 2011). Other three point hitch configurations were tested if requested by the manufacturer as optional tests.

Tractors for testing are currently divided into five distinct categories based on the Nebraska Tractor Test Board Action 27 (Kocher, 2013):

1) "2-wheel drive (2WD), or mechanical front wheel drive (MFWD),
2) 4-wheel drive articulated or rigid frame where all tires are the same size (4WD),
3) half-track drive (2-track drive at one axle, wheels at the other axle),
4) 2-track drive, or
5) 4-track drive."

For the purpose of this research three chassis types were used by combining some of the above types into:

1) 2-wheel drive (2WD), mechanical front wheel drive (MFWD), and half-track drive (2-track drive at one axle, wheels at the other axle),
2) 4-wheel drive articulated or rigid frame where all tires are the same size (4WD), and 4-track drive, and
3) 2-track drive.

For purposes of determining weight on the front axle, half-track tractors were analyzed in the same manner as 2WD and MFWD tractors by investigating the moments taken about the center of the rear axle. 4WD articulated tractors may be studied in the same manner as 4WD track tractors since the analyses follow the same lifting principal.

2.1 Weight Required for Drawbar Testing

To maintain steering controllability, tractors tested according to OECD Code 2 have other provisions that require a minimum upward support force at the front axle of the tractor. Section 4.4.1.6 of OECD Code 2, requires a minimum upward support force at the front axle for drawbar testing (eq. 1). Eighty percent of the weight exerted by the front wheels on the ground multiplied by the wheelbase must be greater than the maximum drawbar pull multiplied by the static height above ground of the line of draft in the test for drawbar power, as seen below (OECD, 2014 a).

$$\text{``}PH \leq 0.8\, WZ \qquad (1)$$

Where:

P is the maximum drawbar pull;

H is the static height above the ground of the line of draught;

W is the static weight exerted by the front wheels on the ground;

Z is the wheelbase."

2.2 Tractor Capacity Trends

In order to determine a tractor's hydraulic lift capacities throughout the last two decades, the total static weight of the tractor (W_T), the static front axle weight (F_{FS}), and the maximum achievable lifting capacities through the full range of movement (F_L) were examined for trends. These trends were studied for three categories of tractors: 2WD and MFWD, 4WD, and 2-track tractors. Graphs were developed for nearly all of the tractors over 112 kW (150 HP) that were tested at NTTL between 1995 and 2014. An observation noticed while examining the test reports was that some models from the same manufacturer had the same hitch lifting capacity. For example, John Deere model numbers: 8245R, 8270R, 8295R, 8320R, 8370R all achieved the exact same lifting capacity of 90 kN. These data were documented in Appendix D. These tractors were tested by NTTL in 2014 and have the same three-point lift system.

2.2.1 2WD and MFWD Tractors (including half-track)

An analysis of weight and hydraulic lift force over the years revealed that the total tractor weight of 2WD and MFWD tractors over 112 kw (150 HP) tested at NTTL had increased at an average rate of 1.51 kN per year between 1995 and 2014. This trend was illustrated in Figure 2.2 which was obtained from NTTL test reports and listed in Table D (Appendix D). During the same period, the hydraulic lifting force of these tractors also increased at an average rate of 1.66 kN per year, while the static weight at the front axle increased at a lesser average rate of 0.69 kN per year. Since the average rate of increase of the static weight at the front axle was smaller than the average rate of increase of the hydraulic lifting force, it was conceivable that over this time period for unballasted tractors, the ratio of hydraulic lifting force at which the front wheels would have come off the ground to the reported hydraulic lifting force has continually decreased.

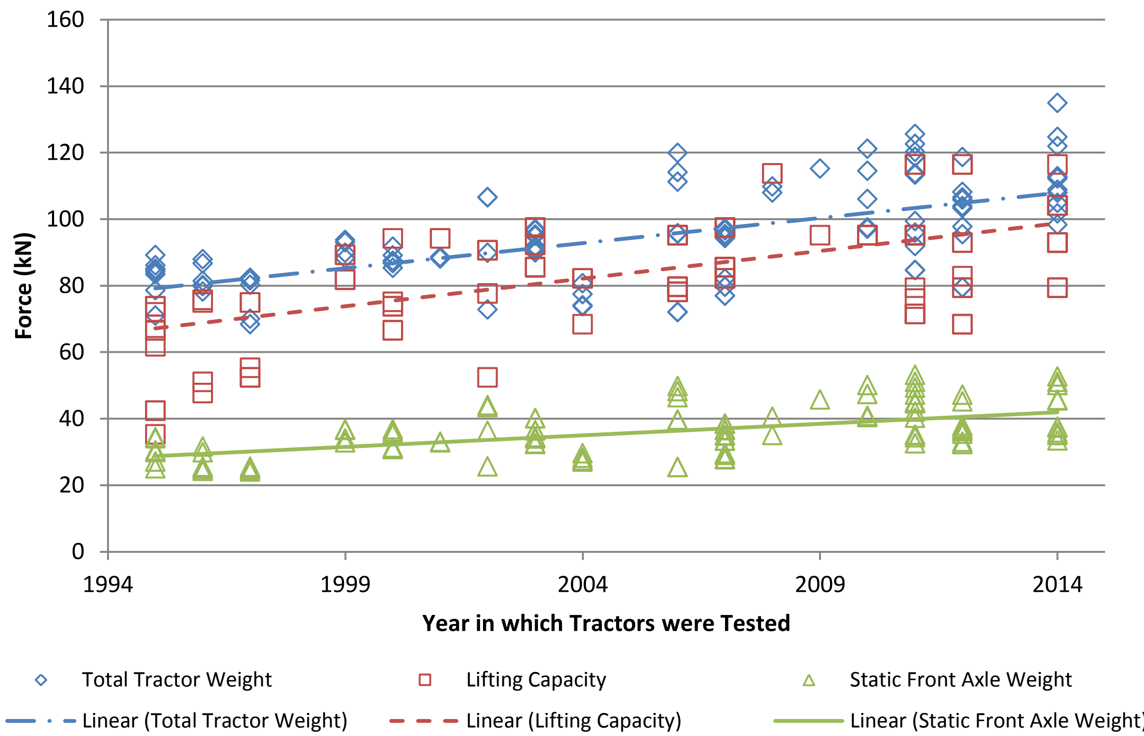

Figure 2.2. Trends of hydraulic lifting capacity and tractor weight distribution for 2WD and MFWD Tractors greater than 112 kw (150 HP) tested at the NTTL between 1995 and 2014.

2.2.2 4WD Tractors

Figure 2.3 was developed using data from NTTL test reports for 4WD tractors listed in Table E (Appendix E). Between 1996 and 2014, the trend for 4WD tractors showed an increasing amount of static weight on the front axle of 2.08 kN per year, nearly the same as the rate at which the three-point lifting capacity increased, 1.98 kN per year (fig. 2.3). During this time period, the total weight of these tractors increased at a rate of 3.33 kN per year. These trends suggest that there may not have been a change in whether the static weight at the tractor front axle of unballasted 4WD tractors was sufficient to utilize the full capacity of the hydraulic lift without the front wheels coming off the ground.

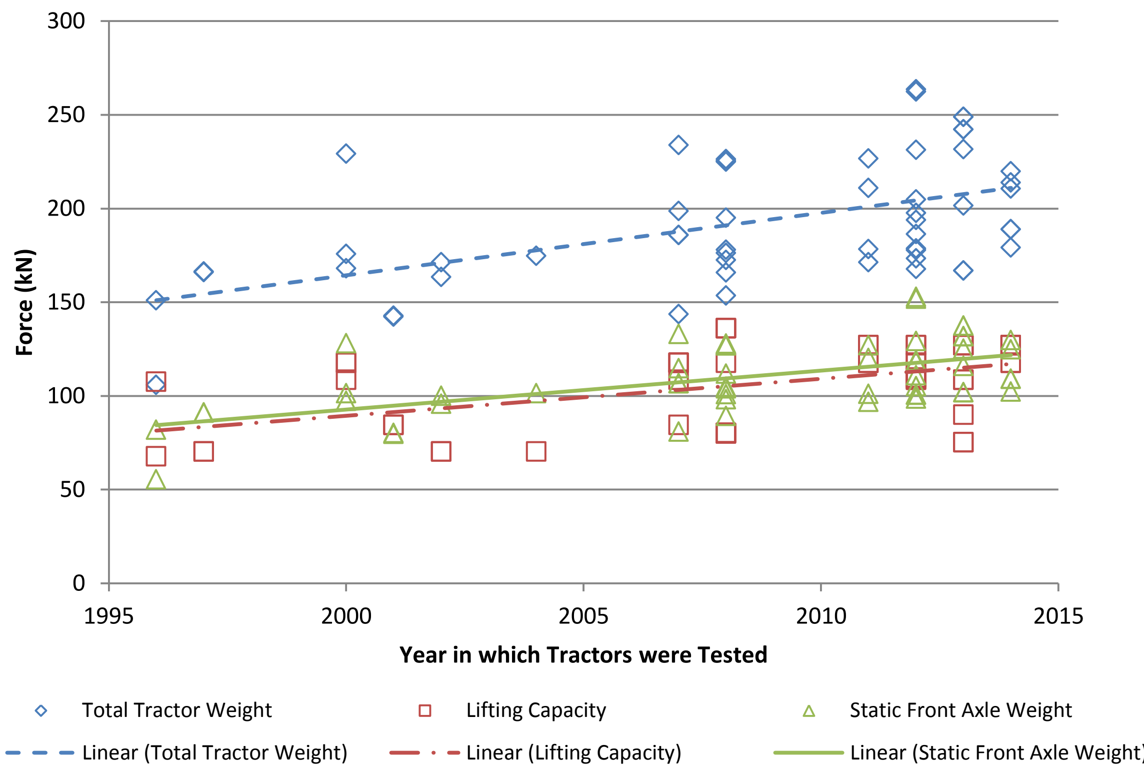

Figure 2.3. Trends of hydraulic lifting capacity and tractor weight distribution for 4WD Tractors tested at the NTTL between 1996 and 2014.

2.2.3 2-Track Tractors

2-track tractors that were tested at an accredited test facility only have their total weight published. It was therefore not possible to determine the equivalent weight distributions on the front and rear track-laying wheels from available test report data, so Figure 2.4 for 2-track tractors does not include front axle weight trends. The data shown in Figure 2.4 and listed in Table F (Appendix F) were obtained from

NTTL test reports on 2-track tractors. The total weight of 2-track tractors has increased at a rate of 2.03 kN per year from 1998 through 2014. However; the three-point lifting force of these tractors has increased at a rate of 1.29 kN per year during this same time period. It can be concluded that manufacturers were increasing the total tractor weight faster than the lifting capacity of the tractor for 2-track tractors.

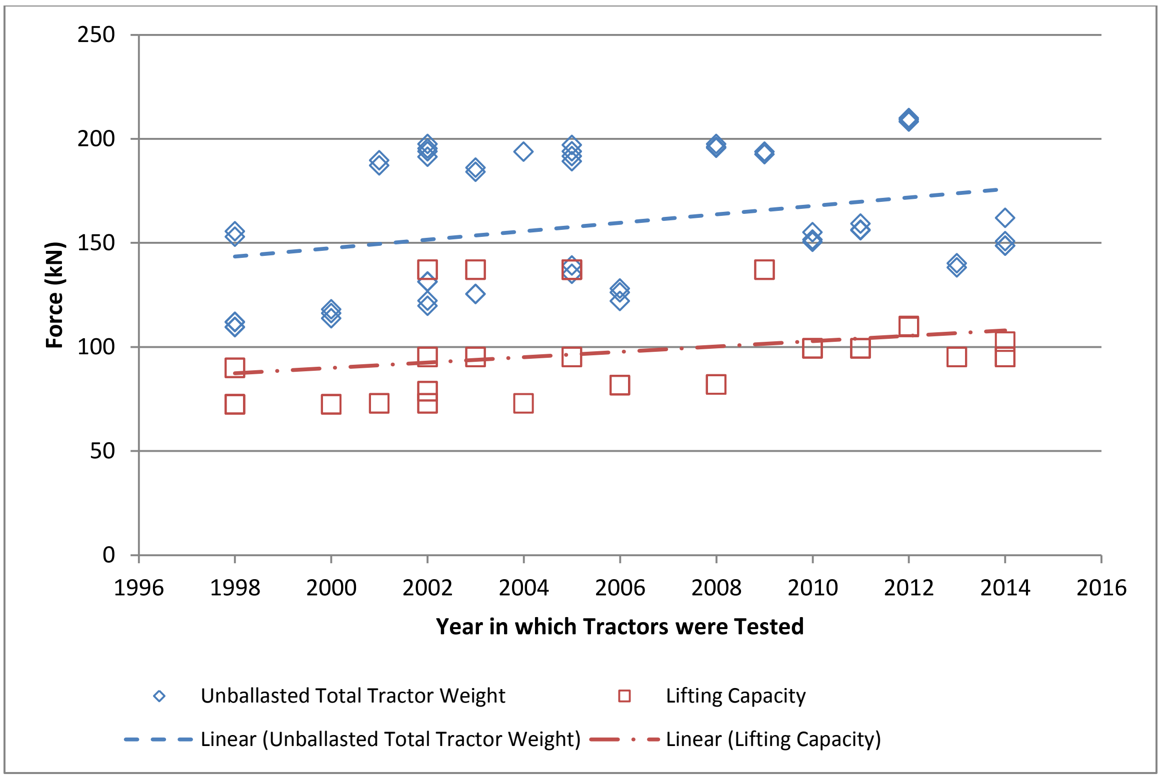

Figure 2.4. Trends of hydraulic lifting capacity and tractor weight distribution for 2-track Tractors tested at the NTTL between 1998 and 2014.

CHAPTER 3. GOALS AND OBJECTIVES

The goal of this research was to determine the achievable lifting capacity that can be realistically utilized during various three-point operations. Instead of just looking at the physical lifting capacity of the tractor's three-point, this study looked at the achievable realistic lifting capacity based on the amount of weight remaining on the front wheel of the tractor as the upward support force.

Specific objectives were to:

1. Determine whether tractor operators believed having 20% of the total tractor weight as the upward support force at the front axle provided better front wheel steering control of a tractor than 15% of the total tractor weight.
2. Explore the current state of the OECD Code 2 hydraulic power lift test results to determine the percentage of total tractor weight remaining as the upward support force on the front axle of the tractor given the maximum achievable lift published in the OECD test reports
3. If needed, propose changes to the OECD Code 2 Hydraulic Power Lift Test to overcome the limitations of the current test procedure

CHAPTER 4. MATERIALS AND METHODS

A tractor was loaded at various weight distributions to determine the minimal amount of weight remaining on the front axle as the upward support force required for adequate steering. Equations were developed to determine the realistic achievable lifting capacity based on the minimum amount of upward support force at the front axle necessary for reasonable steering control.

4.1 Test for Effect of Weight Distribution on Steering Control

A group of 21 experienced tractor operators were used to evaluate the effectiveness of the front wheel steering to control tractor travel direction with 15% and 20% of total tractor weight as the upward support force on the front axle. A Case IH DX 55 tractor with the MFWD disengaged was used for the steering control test. Four 63.5 kg Case IH rear axle weights along with four 42 kg Massey Ferguson rear axle weights were attached to a 154 kg three point lift frame. The static weight of the front and rear axle on the tractor in this configuration without the operator, were measured as 478.5 kg and 2642 kg, respectively, which resulted in 15.3% of the total mass supported by the front, steerable axle. The 19.5% front axle weight distribution was achieved by attaching four 63.5 kg Case IH rear axle weights and one 42 kg Massey Ferguson rear axle weights on the same 154 kg three point lift frame. The front and rear static weights of the tractor in this configuration, without the operator, were measured to be 583 kg, and 2408.5 kg, respectively.

Three different nominal speeds were selected, 10.1, 8.4, and 6.6 km h^{-1} (gears H1, M4, and M3, on a DX 55 at 2000 engine rpm), but the order of the speeds were randomly assigned to each participant. Operators were instructed to turn the tractor at the maximum turning angle in a 14 m by 28 m area. Each tractor operator drove the tractor on two different days. On day one, the operators drove the tractor in a figure eight pattern twice in succession for each speed on a loose gravel surface. After three repetitions, for each speed, participants were surveyed for the first weight distribution. With at least a week of wait time, the same participant was asked to complete the course again following the same rules, with the order of speed still randomized, for the other weight distribution. Nearly half of the participants completed the 15% front axle weight distribution during the first iteration, and the rest operated the tractor at the 20% front axle weight distribution during the first iteration.

The survey consisted of the following questions:

1) On a scale of one to ten, with one being the worst, rate the quality of the tractor's steering at the given weight distribution and speed.
2) In your opinion did the tractor have an adequate amount of weight on the front axle for steering?
3) In your opinion did the tractor's front wheels skid at the given weight distribution and speed?

The results were analyzed using the 2015 Statistical Analysis System, SAS. The first survey question was analyzed using the proc glimmex procedure with an alpha value of 0.05. The treatments were the two different weight distributions, and the experimental units where each tractor operator. The dependent variable was the operator's responses to the three speeds at the two weight distributions. Tables summarizing participants' responses to all the survey questions were developed.

4.2 Moment Calculation

When a tractor lifts a piece of equipment with the rear three-point hydraulic lift system, the force required to lift that implement creates a moment about the rear axle of the tractor. This moment acts in opposition to the moment resulting from the force of gravity on the tractor acting through the center of mass of the tractor. The combined effect of these two moments results in a reduction of the upward support force at the front axle necessary to maintain rotational equilibrium of the tractor about the line where the rear tires impact the ground surface. As the lifting force increases, the downward force on the tractor's rear axle increases, and the upward support force at the front axle decreases.

The total tractor weight was equal to the sum of the weight measured on the front axle during static weighing (F_{Fs}), and the weight measured on the rear axle during static weighing (F_{Rs}) (eq. 2) as shown in Figure 4.1. These two weights can be either with the tractor ballasted or unballasted, and were given in the test reports for every 2WD, MFWD, and 4WD tractor tested.

$$W_T = F_{Fs} + F_{Rs} \tag{2}$$

The center of mass location (CM) on the tractor was calculated from equation 3 based on the geometry shown in Figure 4.1 where W_B is the tractor wheelbase.

$$CM = \frac{F_{Fs}(W_B)}{W_T} \tag{3}$$

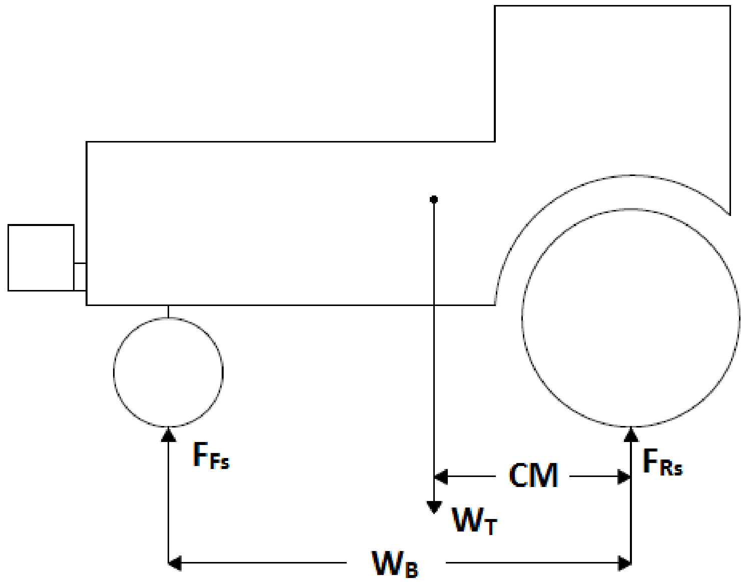

Figure 4.1. Free body diagram of a 2WD or MFWD tractor as weighed during an OECD Code 2 test to determine the weight distribution and center of mass.

Next, equation 4 was obtained for static rotational equilibrium about the line where the rear tires touch the ground surface in Figure 4.2 with the convention that a counterclockwise moment was positive.

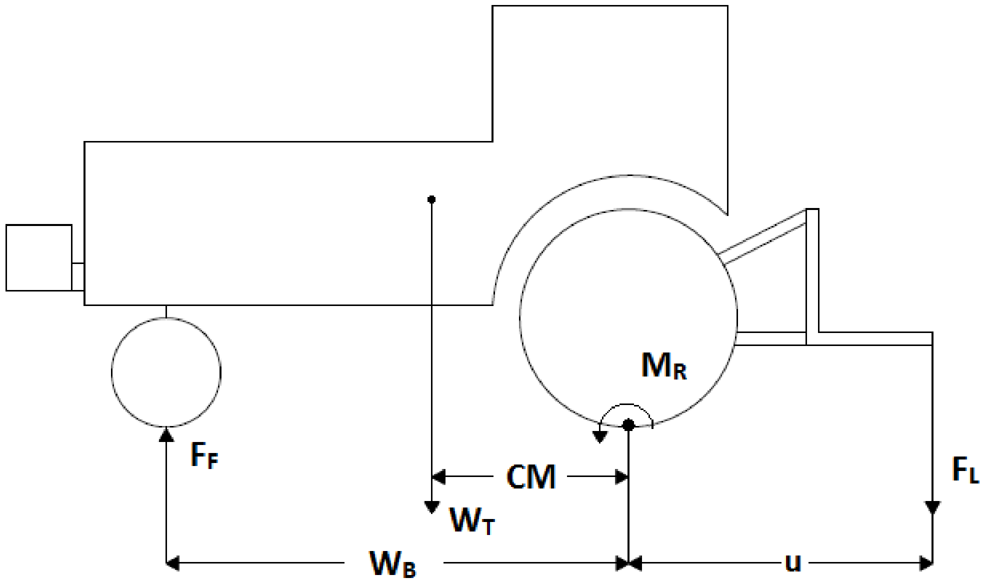

Figure 4.2. Free body diagram of a 2WD or MFWD tractor on level ground while exerting a lifting force on the hydraulic lift to lift the load F_L.

$$\sum M_R = W_T(CM) - F_F(W_B) - F_L(u) = 0 \tag{4}$$

Where:

M_R – the moment about the line where the rear tires touch the ground surface with counterclockwise moment being positive

F_F – the upward support force from the ground surface supporting the tractor at the front axle while the tractor is exerting a lifting force with the hydraulic lift

F_L – the vertical lifting force exerted by the hydraulic lift

u – total horizontal length from the center of the rear axle of the tractor to the point of application of the lifting force exerted by the hydraulic lift

Subsequently the amount of upward support force that must be maintained at the front axle was determined by multiplying the total tractor weight (eq. 2), by the percentage of total tractor weight ($\%_w$), ballasted or unballasted, that must be exerted as the upward support force at the front axle in order to maintain reasonable steering control (eq. 5).

$$F_F = \%_w * W_T \tag{5}$$

If one knows the percentage of total tractor weight required for the upward support force at the front axle to maintain reasonable steering, these equations can be solved to determine the upper limit of the vertical lift force (eq. 6).

$$F_L = \frac{(F_{Fs} - (W_T * \%_w)) * W_B}{u} \tag{6}$$

Alternatively, given a particular vertical lift force, the equation can be solved for the corresponding percentage of total tractor weight that must be acting as the upward support at the front axle (eq. 7). Note that a negative value for this percentage of total tractor weight indicates that the front axle will lift off the ground when the tractor tries to exert the particular vertical lift force. In this case, the conditions required for static rotational equilibrium are no longer met.

$$\%_w = \frac{F_{Fs} - \left(\frac{F_L * u}{W_B}\right)}{W_T} \tag{7}$$

4.3 Length of Lever Arm of the Lifting Force

To be able to solve the equations for the maximum realistic achievable lift, the horizontal length behind the center of the rear axle to the point of application of the lift force (u) was calculated. For lift on a 610 mm coupled frame, the load on the coupled frame was applied at Point A in Figure 2.1. Point B represents the point at which the coupled frame was attached to the three-point hitch. The height above ground was measured at two points during the lift test, points A and B. Both of these lifting distances were needed to determine the exact length behind the center of the rear axle to where the load was applied.

Figure 4.3 illustrates the OECD Code 2 hydraulic lift test linkage geometry (OECD, 2014 a). All of the dimensions shown in Figure 4.3 were published in each individual OECD tractor test report, except for the additional letter G, which was the vertical distance of rear axle axis above the ground. An example OECD test report provided these dimensions in Table 1.1.1, page 11, of the test report for the John Deere 6150M, Appendix H. Distance G, shown in Figure 4.3, was needed to calculate the length of the lever arm of the lifting force, and needs to be published in future OECD publications. Length G was published in the NTTL summary reports, shown on the last page in Appendix G for the John Deere 6150M. Figure 4.4 was modified from Figure 4.3 to also show the coupled frame with the necessary lengths and angles used for calculating the horizontal distance u. Other distances shown in Figure 4.3 that were not used to determine distance u were removed from Figure 4.4 for clarity.

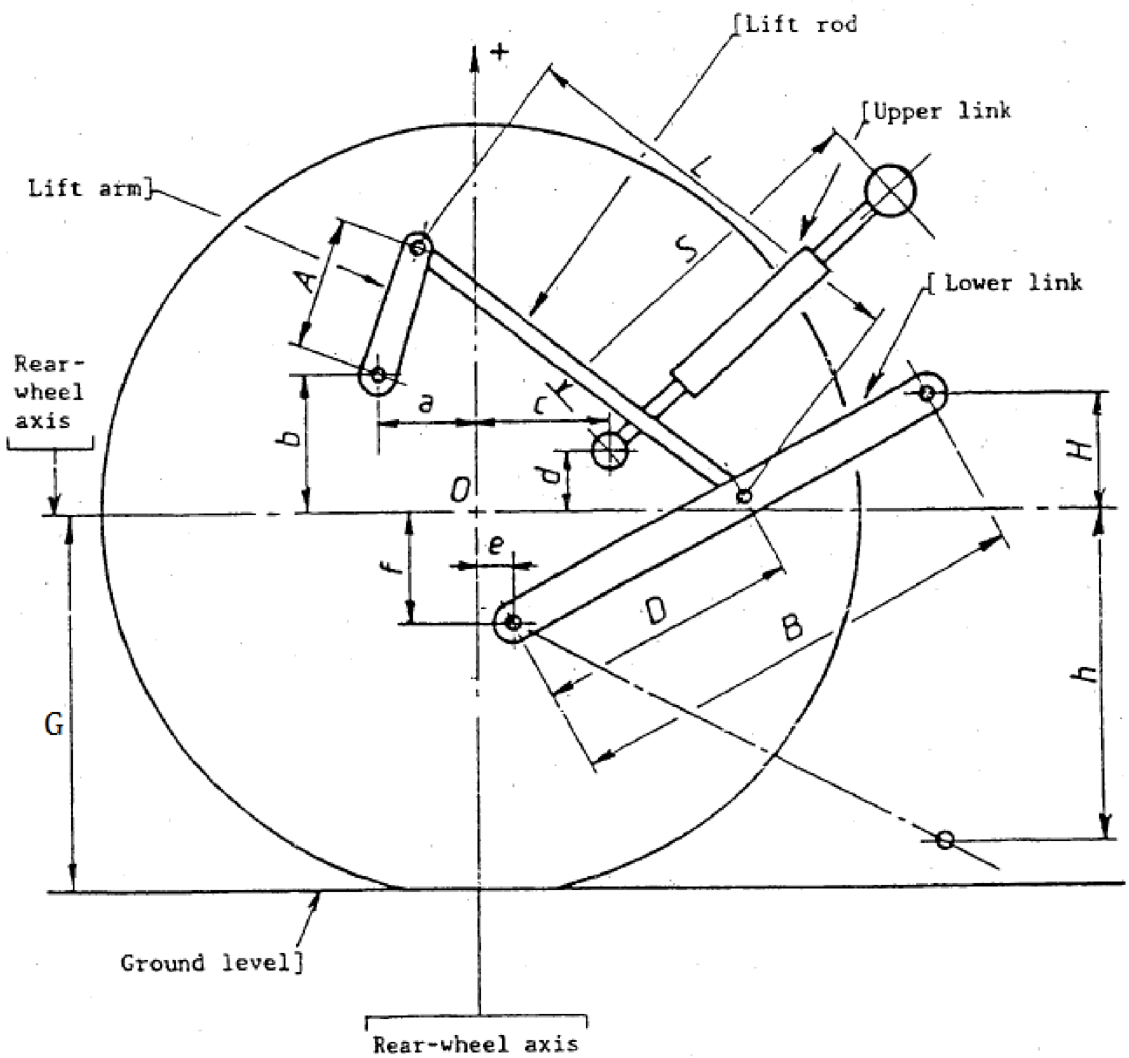

Figure 4.3. Linkage geometry as used in the hydraulic lift portion of the OECD Code 2 test of tractor performance (OECD 2014 a)

Where:

B – the length of lower three-point links

e – horizontal rearward distance between the point where the lower three-point links are attached to the tractor chassis, and the center of the rear axle

f – vertical distance between the point where the lower three-point links are attached to the tractor chassis, and the center of the rear axle

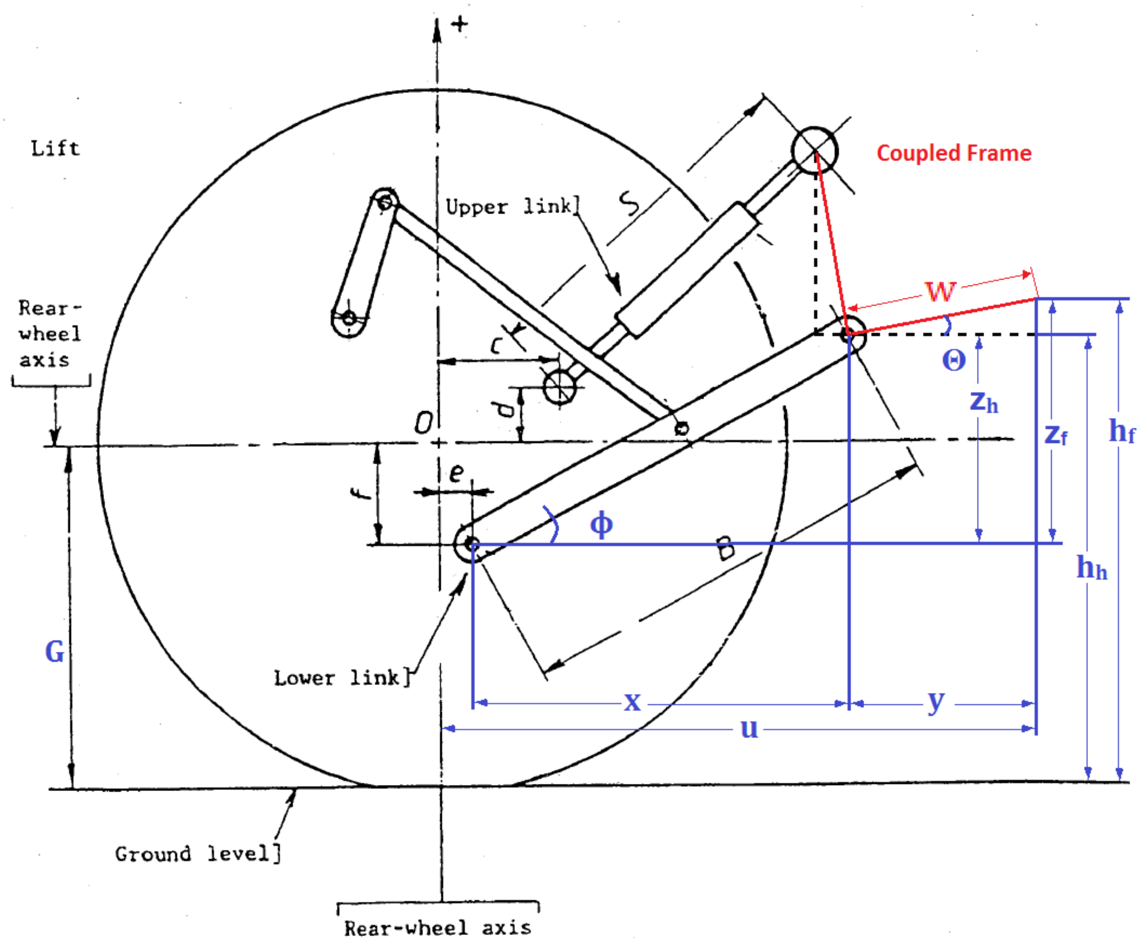

Figure 4.4. Hydraulic lift linkage geometry and coupled frame with additional angles and distance used to determine distance u, the horizontal rearward distance from the rear axle centerline to the point of application of the lifting force, F_L, on the coupled frame for the OECD Code 2 test of hydraulic lifting force.

Where:

Θ – angle of the lower portion of the coupled frame relative to the horizontal at the given z_f height measured during testing

ϕ – angle of the lower links of the hydraulic lift relative to the horizontal at the given z_h height measured during testing

w – distance between the lower link hitch points and the point of application of the lifting force on the coupled frame (typically 610 mm) x – horizontal rearward component of the length of the lower three-point links

y – horizontal rearward component of dimension w

z_h – height of the lower link hitch points relative to the lower link pivot point

z_f – height of the center of gravity of the coupled fame relative to the lower link pivot points

h_h – height of the lower link hitch points relative to the ground

h_f - height of the center of gravity of the coupled fame relative to the ground

For the hydraulic lift test in OECD Code 2, the vertical distance of the lower link hitch points above the point where the lower links attached to the tractor chassis and, distances z_h and z_f from Figure 4.4, were recorded for each of the hydraulic lift positions during the test. Using the geometry in Figure 4.4, angles ϕ and Θ were calculated to be:

$$\phi = \sin^{-1}\left(\frac{z_h}{B}\right) \quad (8)$$

$$\Theta = \sin^{-1}\left(\frac{z_f - z_h}{w}\right) \quad (9)$$

To understand how angles ϕ and Θ were calculated consider the following example using data from Nebraska OECD Tractor Test 2080 – Summary 896 of John Deere's 6150M tractor. Data from both the OECD (Appendix H) and the NTTL test summary (Appendix G) were used to calculate these angles. This tractor was tested October – November 2013, and approved by OECD on March 26, 2014 (OECD, 2013). This John Deere 6150M hydraulic lift was tested in several different configurations, but all of them were category 3N and followed the current OECD Code 2 procedures. There was a possibility of two different types of cylinders, 2 x 80 mm and 2 x 85 mm cylinders, and three different top link mounting positions, top, middle, and bottom hole. The test configuration with the category 3N three-point, 2 x 85 mm cylinders, and with the top link in the top hole was selected for this example because this configuration achieved the largest maximum achievable lifting force when compared to the other tested configurations.

OECD hydraulic lift spreadsheets with lift test data for the John Deere 6150M category 3N 2x85 mm cylinders with the top link in the top hole for a lift at the hitch point, and at the 610 mm coupled frame are presented in Tables 4.1 and Tables 4.2, respectively. These examples were calculated using the highest lifting height achievable for the John Deere 6150M.

The hitch offset (cell G8 in both tables 4.1 and 4.2) was determined by subtracting the lower link height (cell C9 in both tables 4.1 and 4.2) from the height of the hitch point above the ground with the three point hitch in the down position, from the OECD report (230 mm). The load offset (cell G9 in table 4.2) was determined by subtracting the lower link height (cell C9 in both table 4.1 and 4.2) from the height above ground of the point of application of the lifting force on the coupled frame with the three-point hitch in the down position, from the OECD report (229 mm). The "distance from axle" in tables 4.1 and 4.2, which refers to the horizontal distance from the rear wheel axis to the lower link pivot point (cell C8 in both tables 4.1 and 4.2), lower link length (cell C10 in both tables 4.1 and 4.2), and top link length (cell G7 in table 4.2) were obtained from the OECD test report, Appendix H. The lower link height above the ground was calculated by subtracting the vertical distance between the point where the lower three-point links are attached to the tractor chassis, and the center of the rear axle (f) from the vertical distance of the rear axle above the ground (G). Distance G was obtained from the last page of the NTTL summary for John Deere 6150M in the hitch dimensions as tested-no load section. Distance f was obtained from the OECD test report, Appendix H Table 1.1.1. The hitch and load offsets represent the decrease in height from the height of the lower link pivot points to the hitch point and point of application of the lifting force on the coupled frame, respectively, with the three point hitch in the lowest position.

The raw data collected during testing was recorded in rows 18 through 24 for both Tables 4.1 and 4.2. The hitch distance and the load distance were the increase in height for the hitch points and the point of application of the load on the coupled frame, respectively, relative to the height of those points when the three points lift was down in its lowest position. The lift force was the amount of force the tractor lifted at the given height without the addition of the weight of the frame. The observed lift was the total lifting force the tractor achieved, which was the sum of the weight of the frame and the lift force. The 90% of observed lift was the published lifting value in both the NTTL test summary and OECD test report.

Table 4.1. Raw hydraulic lift test data for John Deere 6150M for lift force applied at the hitch point on the three-point linkage.

	A	B	C	D	E	F	G	H
1	**OECD Hydraulic Lift Test Data**							
2		Test #	2080					
3		Tractor:	John Deere 6150M					
4		Set-up:	Category 3N, 2 x 85mm cylinders, Top Link in Top Hole					
5								
6	**OECD Lift Test at QC Ends**							
7		Test date:	14-Nov-13					
8		Distance from axle:	160.0	mm		Hitch offset:	-230.0	mm
9		Lower link height:	620.0	mm		Tare:	0.5	kN
10		Lower link length:	975.0	mm				
11								
12						Height		
13				Calc	Calc	Related		90 % of
14	Hitch	Load	Lift	Mast	Link	to Level	Observed	Observed
15	Distance	Distance	Force	Angle	Angle	Links	lift	lift
16	(x)	(u)		(θ)	(ϕ)	(z_h)		(F_L)
17	mm	mm	kN	deg	deg	mm	kN	kN
18	0	NA	57.3	NA	-23.6	-390	57.9	52.1
19	84	NA	57.9	NA	-18.3	-306	58.5	52.6
20	180	NA	59.0	NA	-12.4	-210	59.6	53.6
21	282	NA	60.2	NA	-6.4	-108	60.7	54.7
22	382	NA	61.4	NA	-0.5	-8	61.9	55.7
23	485	NA	62.8	NA	5.6	95	63.4	57.0
24	583	NA	64.3	NA	11.4	193	64.8	58.3
25	645	NA	64.5	NA	15.2	255	65.1	58.6
26	682	NA	63.8	NA	17.5	292	64.4	57.9

The lift height relative to level links (z_h) (column F, rows 18 to 26 in table 4.1) was calculated by subtracting the lower link height (cell C9 in table 4.1) and the hitch offset (cell G8 in table 4.1) from the corresponding hitch distance (column A rows 18 to 26 in table 4.1). Using the data from row 26 in able 4.1 as an example, the height relative to level links (z_h) was calculated by subtracting the lower link height, 620 mm (cell C9 in table 4.1), and the hitch offset, -230 mm (cell G8 in table 4.1), from the hitch distance, 682 mm (cell A26 in table 4.1) giving the result of 292 mm (cell F26 in table 4.1). The lower link length for the John Deere 6150 M was obtained from Table 4.1 as 975 mm (cell C10 in table 4.1). Using equation 8 to calculate the corresponding value for ϕ (cell E26 in table 4.1):

$$\phi = \sin^{-1}\left(\frac{z_h}{B}\right) = \sin^{-1}\left(\frac{292\ \text{mm}}{975\ \text{mm}}\right) = 17.5^\circ$$

Table 4.2. Raw OECD hydraulic lift test data for John Deere 6150M for lift force applied at the coupled frame.

	A	B	C	D	E	F	G	H
1	**OECD Hydraulic Lift Test Data**							
2		Test #	2080					
3		Tractor:	John Deere 6150M					
4		Set-up:	Category 3N, 2 x 85mm cylinders, Top Link in Top Hole					
5								
6	**OECD Lift Test at 24 inches (610mm) Rear of Hitch Points**							
7		Test date:	14-Nov-13			Top link length:	640.0	mm
8		Distance from axle:	160.0	mm		Hitch offset:	-230.0	mm
9		Lower link height:	620.0	mm		Load offset:	-232.0	mm
10		Lower link length:	975.0	mm		Tare:	12.7	kN
11								
12						Height		
13				Calc	Calc	Related		90 % of
14	Hitch	Load	Lift	Mast	Link	to Level	Observed	Observed
15	Distance	Distance	Force	Angle	Angle	Links	lift	lift
16	(x)	(u)		(θ)	(ϕ)	(z_f)		(F_L)
17	mm	mm	kN	deg	deg	mm	kN	kN
18	-1	-3	46.8	-0.1	-23.6	-391	59.6	53.6
19	80	76	44.8	-0.2	-18.5	-312	57.5	51.8
20	182	181	44.1	0.1	-12.3	-207	56.8	51.1
21	280	289	43.5	1.0	-6.5	-99	56.2	50.6
22	381	401	42.6	2.0	-0.5	13	55.3	49.8
23	483	519	42.4	3.6	5.5	131	55.2	49.7
24	578	636	40.5	5.7	11.1	248	53.3	47.9
25	646	723	38.8	7.5	15.2	335	51.5	46.4
26	684	775	37.5	8.7	17.6	387	50.2	45.2

In Table 4.2, the lift height (of the point of application of the lifting force on the coupled frame) (z_f, column F, rows 18 to 26 in table 4.2) was calculated by subtracting the lower link height (cell C9 in table 4.2) and the load offset (cell G9 in table 4.2) from the corresponding load distance (column B, rows 18 to 26 in table

4.2). Using the data from row 26 in table 4.2 as an example, the frame height related to level links, z_f, was calculated by taking the difference of the lower link height, 620 mm (cell C9 in table 4.2), and the load offset, -232 mm (cell G9 in table 4.2), from the load distance at the highest position, 775 mm (cell B26 in table 4.2) giving a result of 387 mm (cell F26 in table 4.2). The calculation for the mast angle (ϕ) in column D of Table 4.2, also required the calculation of z_f, although that information is not shown in this table. As in Table 4.1, z_h was calculated by subtracting the lower ling height (620 mm in cell C9 in table 4.2) and the hitch offset (-230 mm in cell G8 in table 4.2) from the hitch distance (column A, row 18 to 26 in table 4.2). Using the values from row 26 in table 4.2 as an example, z_h was determined to be 294 mm, and using equation 9 to calculate Θ:

$$\Theta = \sin^{-1}\left(\frac{z_f - z_h}{w}\right)$$

$$= \sin^{-1}\left(\frac{387\text{ mm} - 294\text{ mm}}{610\text{ mm}}\right) = 8.7°$$

Given the geometry of the hydraulic lift during the lifting force test as shown in Figure 4.4 the dimensions x and y can be determined as follows:

$$x = B * \cos(\phi) \tag{10}$$

$$y = w * \cos(\Theta) \tag{11}$$

Once x and y were calculated for any particular position of the hydraulic lift, distance u was calculated as follows:

$$u = e + x + y \tag{12}$$

Once values for u have been determined, the lifting force (F_L) at which the upward support force at the tractor's front axle is 20% of the total tractor weight can be determined using equation 6. The OECD Code 2 requirement for the hydraulic lift included a determination of the lift force at two locations. One of those locations was at the lower hitch link points, which was be represented in equation 11 by using a distance of zero for w, which sequentially causes y to equal zero in equation 12. The second location was specified with a distance w equal to 610 mm.

Chapter 5. Results and Discussion

5.1 Test for Effect of Weight Distribution on Steering Control Results

Table 5.1 shows the response to each of the survey questions from the 21 participants that drove the DX 55 for the weight distribution test at 10.1 km h^{-1}. Similarly, Table 5.2 and Table 5.3 show the responses at the 8.4 km h^{-1} and 6.6 km h^{-1} speeds respectively. An asterisk (*) indicated missing data because some participants were not able to contribute for both iterations of the test.

Table 5.1. Response of the tractor operators to the survey questions regarding the effect of tractor weight distribution on steering control for the travel speed of 10.1 km h^{-1}.

	Percent of Total Tractor Weight as the Upward Ground Support Force at the Front Axle					
	15%			20%		
Participant #	Q1	Q2	Q3	Q1	Q2	Q3
1	2	y	n	5	y	n
2	2	y	n	7	n	y
3	7	y	y	7	n	y
4	3	y	n	7	y	y
5	2	y	n	*	*	*
6	4	y	n	*	*	*
7	4	y	n	7	n	y
8	3	y	n	5	y	y
9	6	y	n	6	y	n
10	2	y	n	*	*	*
11	4	y	y	6	y	y
12	2	y	n	7	n	y
13	3.5	y	n	*	*	*
14	3	y	n	*	*	*
15	3	y	n	*	*	*
16	5	y	n	*	*	*
17	*	*	*	8	n	y
18	*	*	*	5	y	n
19	*	*	*	6	y	n
20	*	*	*	2	y	n
21	*	*	*	8	n	y

Table 5.2. Response of the tractor operators to the survey questions regarding the effect of tractor weight distribution on steering control for the travel speed of 8.4 km h^{-1}.

Participant #	Percent of Total Tractor Weight as the Upward Ground Support Force at the Front Axle					
	15%			20%		
	Q1	Q2	Q3	Q1	Q2	Q3
1	5	y	n	9	n	y
2	4	y	n	8	n	y
3	9	y	y	9	n	y
4	5	y	n	9	n	y
5	4	y	n	*	*	*
6	9	n	y	*	*	*
7	6	y	n	7	n	y
8	5	y	y	9	n	y
9	7	n	y	8	n	y
10	3	y	n	*	*	*
11	5	y	y	8	y	y
12	3	y	n	9	n	y
13	5	y	n	*	*	*
14	6	y	n	*	*	*
15	3	y	n	*	*	*
16	8	n	n	*	*	*
17	*	*	*	10	n	y
18	*	*	*	8	n	y
19	*	*	*	7	y	y
20	*	*	*	3	y	n
21	*	*	*	8	n	y

Table 5.3. Response of the tractor operators to the survey questions regarding the effect of tractor weight distribution on steering control for the travel speed of 6.6 km h^{-1}.

Participant #	Percent of Total Tractor Weight as the Upward Ground Support Force at the Front Axle					
	15%			20%		
	Q1	Q2	Q3	Q1	Q2	Q3
1	7.5	y	y	10	n	y
2	7	n	y	10	y	y
3	10	n	y	10	n	y
4	7	n	n	10	n	y
5	6	n	y	*	*	*
6	9	n	y	*	*	*
7	7	n	n	9	n	y
8	7	y	y	10	n	y
9	8	n	y	10	n	y
10	5	y	y	*	*	*
11	7	y	y	10	n	y
12	7	y	n	10	n	y
13	7	n	y	*	*	*
14	7	n	y	*	*	*
15	7	n	y	*	*	*
16	9	n	y	*	*	*
17	*	*	*	10	n	y
18	*	*	*	9	n	y
19	*	*	*	9	n	y
20	*	*	*	8	n	y
21	*	*	*	8.5	n	y

Table 5.4 showed the SAS output for the test of simple effect comparison for the operator responses to survey question 1 for each of the tractor front axle weight distributions at each travel speed. It was determined that, at each travel speed, the participants indicated the weight distribution with 20% of the total tractor weight as the upward support force at the front axle produced a significantly greater steering control (more than two points better on a scale of one to ten points) than

the 15% weight distribution. There appears to be a trend of steering control rating decreasing as travel speed increased.

Table 5.4. Summary of responses, and SAS output to survey question 1 rating each of the tractor weight distributions at each of the three travel speeds for the quality of tractor steering control from steering wheel inputs on a figure 8 track (10 = high quality, 1 = low quality).

Travel Speed km h^{-1}	Mean of responses for 15% front axle weight distribution	Mean of responses for 20% front axle weight distribution	Difference among means for question 1, 20% - 15% front axle weight distribution	Standard Error	t Value	Pr > |t|
10.1	3.47	6.14	2.6741	0.560	4.78	<.0001
8.4	5.44	8.00	2.5625	0.673	3.82	0.0007
6.6	7.34	9.54	2.192	0.363	6.03	0.0001

As shown in Table 5.5, at the 10.1 km h^{-1} travel speed, only 12.5% of the tractor operators thought that the 15% front axle weight distribution had adequate upward support force at the tractor's front axle to maintain sufficient steering control compared to 64.3% for the 20% front axle weight distribution. At the 6.6 km h^{-1} travel speed, however, over 80% of tractor operators thought the 15% front axle weight distribution had adequate upward support force at the front axle of the tractor to maintain sufficient steering control. All of the tractor operators thought the 20% front axle weight distribution at 6.6 km h^{-1} travel speed provided adequate steering control.

Table 5.5. Summary of tractor operators' responses to survey question 2 regarding whether there was sufficient upward support force at the front axle to maintain adequate steering control on the figure 8 test course for each of the tractor weight distributions at each of the three travel speeds

Travel Speed	Percent of tractor operators responses to survey question 2 that there was sufficient upward support force at the front axle to maintain adequate steering control for the front axle weight distribution of:		Difference among means for Question 2, 20% - 15% front axle weight distributions
km h-1	15%	20%	
10.1	12.5%	64.3%	51.8%
8.4	31.3%	92.9%	61.6%
6.6	81.3%	100.0%	18.8%

Table 5.6 shows the front wheels skidding effect that tractor operators experienced while driving this tractor on the figure eight course. All of the tractor operators said the tractor skidded at 10.1 km h^{-1} with the 15% front axle weight distribution, while only 57.1% believed the tractor skidded with the 20% front axle weight distribution. At the 6.6 km h^{-1} travel speed, however, 31.3% of the tractor operators believed the tractor skidded with the 15% front axle weight distribution, and 7.1% believed the tractor skidded with the 20% front axle weight distribution.

Table 5.6. Summary of tractor operators' responses to survey question 3 regarding whether the tractor's front wheels skidded straight ahead rather than responding to steering wheel inputs to turn on the figure 8 test course for each of the tractor weight distributions at each of the three travel speeds.

Travel Speed	Percent of tractor operators responses to survey question 3 that the tractor's front wheels skidded straight ahead rather than responding to steering wheel inputs for the weight distributions of		Difference among means for question 3, 20% - 15% front axle weight distributions
km h-1	15%	20%	
10.1	100.0%	57.1%	-42.9%
8.4	81.3%	21.4%	-59.8%
6.6	31.3%	7.1%	-24.1%

The 20% front axle weight distribution was determined to be significantly different than the 15% front axle weight distribution based on the responses to survey question 1. The tractor operators' responses to survey question 2 and 3 provided additional evidence that they believed the 20% front axle weight distribution provided better steering control than the 15% front axle weight distribution. The tractor operators responses to the second survey question showed that over 90% of the operators believed the 20% front axle weight distribution provided an adequate amount of weight on the front axle for steering with speeds of 8.4 and 6.6 km h^{-1}.

5.2 Lifting capacity Trends

5.2.1 2WD and MFWD Tractors (including half-track)

Figure 5.1 shows the percent of unballasted total tractor weight remaining as the upward support force on the front axle with the maximum corrected vertical lift force value on the coupled frame. Figure 5.1 was constructed using the data in Appendix D and equation 6 for most 2WD and MFWD tractors tested at the NTTL greater than 112 kw (150 HP) since 1988. These data show that, the average weight as the upward support force at the front axle of an unballasted tractor with the maximum corrected force on the coupled frame has been negative (front wheels theoretically lift off the ground) increasingly negative the last two decades. This means that the average 2WD and MFWD tractor tested each year using the OECD Code 2 hydraulic lift test would have lifted the front wheels off the ground when the total available lift force was present.

On average, ballasted tests of 2WD and MFWD tractors have gradually decreased the percentage of total tractor weight as the upward support force on the front axle (fig. 5.1). These ballasted tractors had a greater percentage of total tractor weight as the upward support force on the front axle compared to unballasted tractors. However; this force was still negative, indicating the front wheels would lift off the ground at lifting forces less than those listed in the test reports. These tractors were ballasted primarily for drawbar testing results rather than for the maximum achievable lifting capacity. Drawbar ballasting required more of the weight added to the main drive axle, whereas, maximum achievable lifting capacity requires more of the ballast on the front axle.

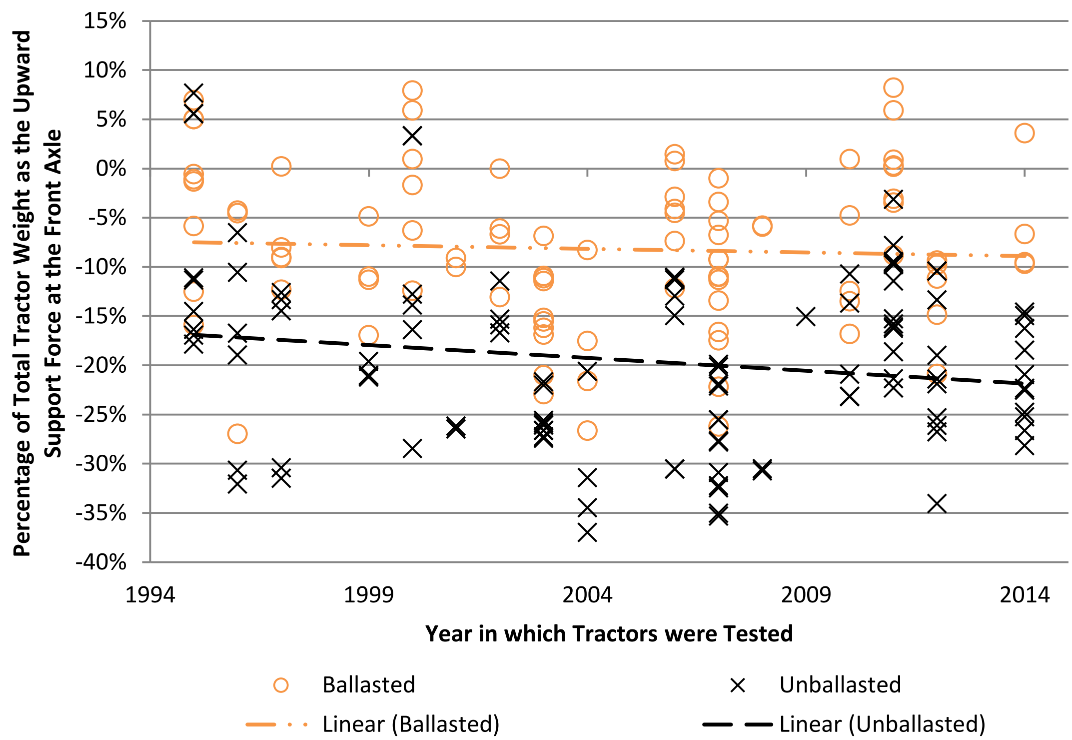

Figure 5.1. Percent of total tractor weight as the upward support force at the front axle of 2WD and MFWD tractors greater than 112 kW (150 HP) tested at NTTL when the lower links of the hydraulic lift were in a horizontal position with the maximum corrected lift force on the coupled frame.

5.2.2 Articulated 4WD tractors

Over the last decade articulated 4WD tractors have maintained an average of

20% of the total tractor weight as the upward support force at the front axle when full lift was present in an unballasted configuration (fig. 5.2). The data used for Figure 5.2 were listed in Appendix E, which contains published lift data for 4WD tractors tested at the NTTL, and calculated front axle reaction forces using equation 6. While most of these tractors have maintained sufficient weight on the front drive wheels of the tractors to be able to steer even when full lift force was present some unballasted 4WD tractors have not maintained at least a 20% front axle weight distribution. Ballasted 4WD tractor lifting capacity trends were also shown in Figure 5.2. Only 13 of the 55 4WD tractors analyzed were ballasted.

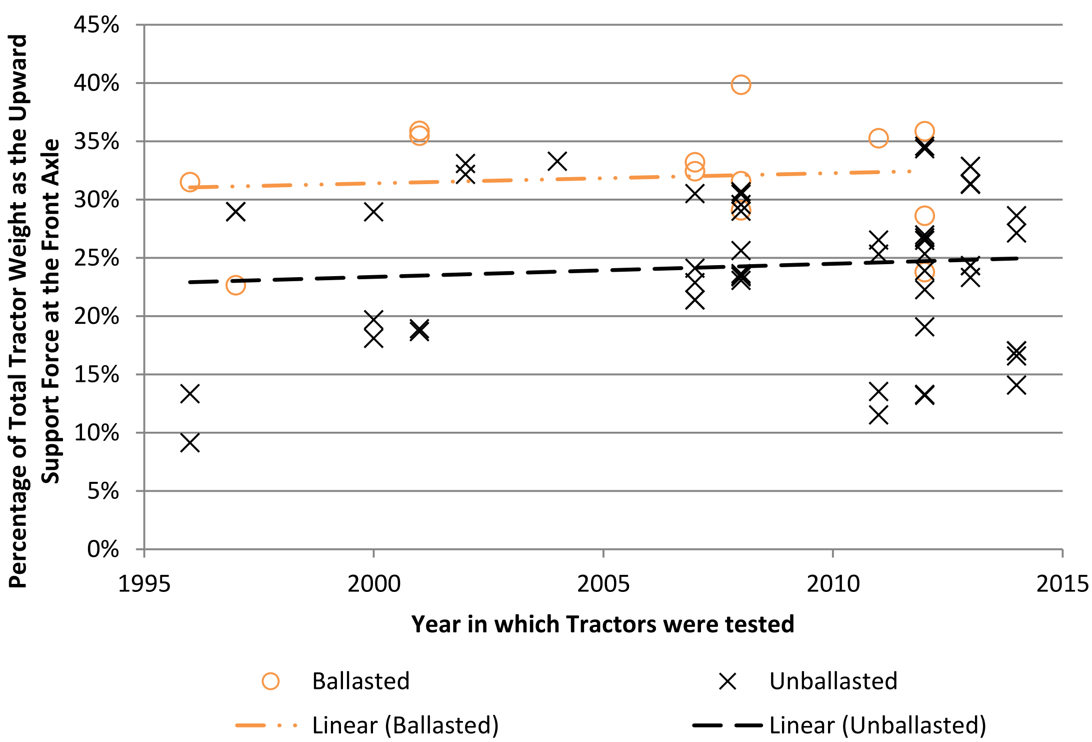

Figure 5.2. Percent of total tractor weight as the upward support force at the front axle of 4WD tractors tested at NTTL when the lower links of the hydraulic lift were in a horizontal position with the maximum corrected lift force on the coupled frame.

5.2.3 2-TRACK TRACTORS

No lifting trends were shown for 2-track tractors since existing test report data only include the total tractor mass. Therefore there was insufficient available data to calculate the moment about the rear track-laying drive wheel.

2-track tractors steer by increasing or decreasing one track velocity relative to the other. For example, if the operator of a 2-track tractor wanted to turn right, either the right track would have to slow down, the left track would have to speed up, or a combination of the two would have to happen simultaneously. Because of this steering mechanism, 2-track tractors are steerable as long as enough of both tracks have sufficient contact with the ground to provide the required traction forces without a rear tip over of the tractor.

5.3 AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS COMMITTEE RECOMMENDATIONS

This research was presented at the 2015 American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting to the machinery systems committees MS-23/2 (Ag Mach. – Common Tests and US TAG ISO TC23/SC2), and MS 23/4/5 (Tractor Implement Interface/PTO). Both of these committees include members that are representatives of the agricultural machinery industry from leading manufacturers. These committee members recommended that the existing OECD Code 2 hydraulic lift test procedure continue to be utilized and that in addition, a maximum realistic achievable lifting capacity following equation 6 be published. They recommended a minimum of 0% front axle weight distribution for 2-track tractors, and 20% for 2WD, MFWD, and 4WD tractors. These committee members suggested reporting results for additional ballast configurations to be able to show the realistic achievable lifting capacities for common tractor configurations. Some of the manufacturers also suggested reporting lifting capacities at other distances behind the rear of the tractor in addition to the current 610 mm lifting frame distance to better represent larger lifted implements.

5.4 Realistic Achievable Lifting Capacity Example Tractor Calculation

The next two sections describe the calculations for the realistic achievable lifting capacity at the hitch point, and at a point 610 mm rear of the hitch point. The John Deere 6150M was selected using the raw data shown in Tables 4.1 and 4.2 and tractor data from Appendices G and H.

5.4.1 Lift at Hitch Point

The data given in Table 4.1 showed that the highest point reached by the hydraulic three-point occurred when the hitch points were 296 mm (row 26 in table 4.1) above the lower link pivot point. Following row 26 across reveals the calculated link angle, ϕ, at the top position was 17.5 degrees (cell E26 in table 4.1). Next, the length of the lower links (B) and the horizontal distance of the lower link pivot from the rear axle (e) were determined to be 975 mm, and 160 mm respectively from table 1.1.1 in Appendix H. The distance w was zero since the lifting force was applied at the hitch point in this situation. The tractor masses were obtained in the tractor mass sub-section of the test conditions section, 2.3, page 16 of Appendix H. Taking the unballasted static mass with the driver on the front axle (2390 kg) and total mass (6493 kg) times the acceleration of gravity, 9.81 m s^{-2}, yields static weight at the front axle of 23.4 kN, and total tractor weight of 63.7 kN. The wheelbase was obtained from page 13 of Appendix H section 1.12 to be 2765 mm. Now, inserting these variables into equation 6 and using 20% for $\%_W$:

$$F_L = \frac{(F_{Fs} - (W_T * \%_W)) * W_B}{e + [\cos(\phi) * B] + [\cos(\Theta) * w]} \quad (6)$$

$$F_L = \frac{(23.4\ \text{kN} - (63.7\ \text{kN} * 0.20)) * 2765\ \text{mm}}{160\ \text{mm} + [\cos(17.5°) * 975\ \text{mm}] + [0\ \text{mm}]}$$

$$F_L = 27.0\ \text{kN}$$

This unballasted John Deere 6150M can achieve a lift of 27.0 kN directly on the hitch points while still maintaining 20% of the unballasted weight of the tractor as the upward support force at the front axle. This value was 52.0% of the 52.1 kN maximum corrected force exerted through the full range of lift that was published in the OECD Code 2 test report for the 6150M (section 4.5, page 29, Appendix H).

5.4.2 Lift at 610 mm behind Hitch Point

The top position occurred when the point of application of the lifting force on the coupled frame was 391 mm high relative to the lower link pivot points, (row 26 in table 4.2). Using the same procedure as for the lift at the hitch point, follow row 26 across to determine the calculated mast angle, θ, at the top position to be 8.7 degrees (cell D26 in table 4.2). The calculated link angle, ϕ, at the top position was 17.8 degrees (cell E26 in table 4.2). Since this lift occurs on a coupled frame that was 610 mm long, w becomes 610 mm. As determined in the lift at the hitch point section, the static force on the front axle of the tractor and the total static force of the tractor were 23.4 kN and 63.7 kN respectively. Also, the length of the lower links (B) was 975 mm, and the horizontal distance of the lower link pivot point from the rear wheel axis horizontally (e) was 160 mm. Finally the wheelbase was 2765 mm. Inserting all of this data into equation 6, and setting $\%_W$ to 20%:

$$F_L = \frac{(F_{Fs} - (W_T * \%_W)) * W_B}{e + [\cos(\phi) * B] + [\cos(\Theta) * w]} \quad (6)$$

$$F_L = \frac{(23.4\text{ kN} - (63.7\text{ kN} * 0.20)) * 2765\text{ mm}}{160\text{ mm} + [\cos(17.8°) * 975\text{ mm}] + [\cos(8.7°) * 610\text{ mm}]}$$

$$F_L = 17.4\text{ kN}$$

The maximum realistic achievable lifting force of this unballasted John Deere 6150M tractor at a point of lift 610 mm rear of the hitch point was 17.4 kN while still maintaining a 20% upward support force on the front axle. This value was 38.5% of the 45.2 kN of lift the tractor achieved in the maximum corrected vertical force section as shown in the Official OECD Code 2 test report (section 4.5, page 29, Appendix H). This force was also shown in the NTTL Tractor Summary for the John Deere 6150M (Hydraulic performance section, Appendix G).

CHAPTER 6. CONCLUSIONS

The test for the effect of weight distribution on steering control supports a conclusion that 20% of the total tractor weight as the upward support force at the front axle was sufficient to provide adequate steering control for 2WD, MFWD and 4WD drive tractors. This was based on the operator's responses to survey question

1 having a significantly higher quality of steering control at 20% front axle weight distribution compared to 15% front axle weight distribution at all speeds. This was further supported by the drawbar testing requirement shown in equation (1).

Current trends show that on average 2WD and MFWD tractors do not maintain a sufficient percentage of total tractor weight as the upward support force at the front axle to sustain the maximum corrected lifting force exerted through the full range as determined with the current OECD Code 2 and still be steerable in an unballasted condition. On average, 4WD tractors do maintain a sufficient percentage of total tractor weight as the upward support force at the front axle to allow for adequate steering control. 2-track tractor lifting trends were not determined because only the total weight of the tractor was measured, and not the amount of weight on each individual axle. As a result, there is no way to determine the upward support force on the front track-laying wheel of 2-track tractors.

A proposal for a revision to the hydraulic lift portion of OECD Code 2 has been drafted that identifies usable achievable lifting forces which allow adequate steering control of tractors. This proposal utilizes equation 6 based on data measured during testing.

These research results allow for a method for tractor buyers to select appropriate tractors if information about the implement mass and center of mass are known. These future changes to the hydraulic lift test reporting procedures could lead to the determination of realistic achievable lifting capacity at different lengths behind the hitch points that match implement center of mass locations.

6.1 Proposal

The proposed revision to the OECD Code 2 section for the hydraulic lift test consists of making a few additions to the current test. A value that should be calculated and added to the report for 2WD, MFWD, and 4WD tractors is the lifting force at which the upward support force at the front axle is equal to 20% of the total unballasted tractor weight. For 2-track tractors, this maximum realistic achievable lift capacity should be based on 0% of the total unballasted tractor weight as the upward support force at the front track-laying wheel since steering is possible as long as the tracks are on the traveling surface. These percentages were based on the weight distribution test performed in this research project, and feedback from industry professionals with numerous years of experience. In addition, the heights of the lower link hitch points relative to the lower link pivot point and the point of application of the lifting force on the coupled frame relative to the height of the lower link pivot point should be published at each height during the lift with a coupled frame. Length G, the vertical distance of the rear wheel axis above the ground, should also be measured and included in OECD Code 2 test reports.

The major change in the publication of the new OECD Code 2 hydraulic lift testing procedure was to add a new reported value, the realistic achievable lift capacity. This new value was more representative of the maximum implement weight that farmers can expect their tractors to be capable of lifting with the three-point hydraulic lift while still maintaining adequate steering control with the front wheels during normal operations. All of the theoretical lifts calculated in the maximum realistic achievable lift section need to be determined for the hydraulic lift geometry with the lift in its uppermost position. The realistic achievable lift value shall be the lesser of the maximum corrected vertical force and the value calculated with the appropriate percentage for the $\%_w$ variable using equation 6.

Since most tractors are ballasted during normal three-point operations additional optional lift forces can be included for selected ballasted configurations. The publication of ballasted information will allow users to consider planned ballast with respect to usable hydraulic lift capacity. For each selected ballasting configuration, front and rear axle static loads must be measured and reported.

These optional ballasted lift values will be published at the discretion of the manufacturer so long as the ballasted tractor was statically weighed at an accredited test facility and the ballast was added in accordance with the manufacturer's instructions. With these additional weight distributions, the same procedures for determining the maximum achievable lift values can be followed as those for reporting with the unballasted weight distribution. To accomplish these changes, section 4.3.4 needs to be modified according to the proposal presented in Appendix B. A sample of how future publications will appear if this proposal is accepted was calculated for the John Deere 6150M and shown in Appendix C.

6.2 Suggestions for Future Work

Future research is needed to develop a procedure for determining the static weight distributions of 2-track tractors. One possible solution to determine the weight distribution of 2-track tractors is to place blocks on the scale and drive the front track-laying wheels onto the blocks, and drive the rear track-laying wheels on other blocks high enough so that the tractor is level and the tracks do not touch the ground. Then repeat this procedure reversing the tractor to weigh the rear track-laying wheels. For these processes, test engineers need to make sure to subtract the weight of the block from the total weight on the front and rear track-laying wheels.

Currently tractors are tested at 610 mm behind the rear three-point linkage. In the future there might be a need to calculate a lift at a point further behind the three-point linkage. This calculation will be accomplished by setting w, in equation 11, equal to the length behind the three-point linkage that was desired.

References

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Appendix A: Current OECD Code 2 Section 4.3

Current OECD Code 2 publication for section 4.3 dealing with hydraulic lift (OECD, 2014 a):

4.3 Hydraulic Lift

4.3.1 Test Requirements

The tractor shall be so secured that the reactive force of the hydraulic power lift deflects neither tyres nor suspension. The linkage shall be adjusted in the same way both with and without the coupled frame to achieve typical arrangements as follows:

– the linkage shall be adjusted in accordance with the tables in ISO 730:2009. For those tractors which do not achieve the standard power range, the lift force will be measured at the maximum achievable power range;

– the upper link shall be adjusted to the length necessary to bring the mast of the frame vertical when the lower links are horizontal;

– where more than one upper or lower link point is available on the tractor, the points used shall be those specified by the manufacturer and shall be included in the test report;

– where there is more than one attachment point to connect the lift rods to the lower links, the connection points used shall be those specified by the manufacturer and shall be included in the test report;

– these initial adjustments, as far as possible, shall cause the mast to turn through a minimum of 10° from the vertical to the angle at which the frame is in the uppermost position. If this is not possible, the fact shall be stated in the test report;

- the oil pressure shall be checked during the test.

4.3.2 Lift at the lower hitch points

An external vertical downward force shall be applied to a horizontal bar connecting the lower hitch points. This force shall remain as vertical as possible in the median plane of the tractor throughout the lift range. If necessary, the values of measurement will have to be corrected.

The lifting force available and the corresponding pressure of the hydraulic fluid shall be determined at a minimum of six points approximately equally spaced throughout the range of movement of the lift, including one at each extremity. At each point the force shall be the maximum which can be exerted against a static load. Additionally, the range of movement shall be reported. The pressure recorded during the test must exceed the minimum relief valve pressure setting.

The values of force measured shall be corrected to correspond to a hydraulic pressure equivalent to 90 per cent of the actual relief valve pressure setting of the hydraulic lift system. The corrected value of the lowest lifting force constitutes the maximum vertical force which can be exerted by the hydraulic power lift throughout its full range of movement.

4.3.3 Lift on a coupled frame

A frame having the following characteristics shall be attached to the three-point linkage:

The mast height and the distance from the hitch points to the centre line of the tractor shall be appropriate to the linkage category (as defined by ISO 730 in 4.3.1 above). Where more than one category is specified, that chosen for the test shall be at the manufacturer's option.

The centre of gravity shall be at a point 610 mm to the rear of the lower hitch points, on a line at right angles to the mast and passing through the middle of the line joining the lower hitch points.

Testing conditions and procedure shall be as in 4.3.2 above. The weight of the frame shall be added to the force applied.

4.3.4 Test results

The following results shall be reported:

- the maximum corrected vertical force at the lower hitch points and at the centre of gravity of the standard frame as a function of the lifting heights measured with respect to the horizontal lower links for the whole range of movement of the lift;
- the full range of vertical movement of the respective points of application of the force (see 4.3.2);
- the pressure equivalent to 90 per cent of the actual relief valve pressure setting;
- the pressure corresponding to maximum power delivered by the hydraulic system;

– the height of the lower hitch points above the ground in their lowermost position and without load;

– the angle through which the mast turns from the vertical to the uppermost position;

– the main linkage dimensions and the mast height of the frame relative to the centre line of the rear wheels as tested;

– the temperature of the hydraulic fluid at the start of each test;

– the calculated moment around the rear wheel axis, resulting from the maximum external lift force at the frame which can be exerted through the full range of movement.

APPENDIX B: PROPOSED REVISIONS TO OECD CODE 2 SECTION 4.3.4

Sample revised OECD Code 2 section 4.3.4 with everything that is underlined was added or changed:

4.3.4 Required Test results

The following results shall be reported:

4.3.4.1 The maximum corrected vertical force at the lower hitch points and at the centre of gravity of the standard frame as a function of lifting heights measured with respect to the horizontal lower links for the whole range of movement of the lift;

4.3.4.2 <u>The maximum corrected realistic achievable lift vertical force when the three-point is at the maximum height, for the unballasted weight distribution with the lift force applied at the following points:</u>

4.3.4.2.1 <u>Hitch point</u>

4.3.4.2.2 <u>On the coupled frame, 610 mm to the rear of the hitch points</u>

<u>Using the lesser of the two following values at each point:</u>

- <u>The force determined in part 4.3.4.1</u>
- <u>The force determined using the following equation with the hydraulic lift in its uppermost lifting position:</u>

$$\mathbf{F_L} = \frac{(\mathbf{F_{Fs}} - (\mathbf{W_T} * \%_{\mathbf{w}})) * \mathbf{W_B}}{(\mathbf{e} + [\mathbf{B} * \mathbf{cos}(\boldsymbol{\phi})] + [\mathbf{w} * \mathbf{cos}(\boldsymbol{\Theta})])}$$

<u>Where:</u>

<u>**F_L** – the vertical lifting force exerted by the hydraulic lift through the whole range</u>

of motion of the hydraulic power lift to achieve the desired force exerted as the upward support at the front axle of the tractor in order to maintain reasonable steering control

F_{Fs} is the weight measured at the front wheels during static weighing (kN)

W_T is the total static weight of the tractor (kN)

$\%_W$ – the percent of total tractor weight, either ballasted or unballasted, that must be exerted as the upward support force at the front axle in order to maintain reasonable steering control and equals 0.0 for 2-track tractors, and 0.20 for all other 2WD, MFWD, and 4WD tractors

W_B – the wheelbase of the tractor

e – horizontal longitudinal distance between the lower three-point link pivot point and the center of the rear axle

B – longitudinal component of the length of lower three-point links

ϕ – angle of the lower links of the hydraulic lift relative to the horizontal at the given z height measured during testing

w – distance between the lower link hitch points and the point of application of the lifting force on the coupled frame

Θ – angle of the lower portion of the coupled frame relative to the horizontal at the given z height measured during testing

– The full range of vertical movement of the respective points of application of the force (see 4.3.2);

- The pressure equivalent to 90 per cent of the actual relief valve pressure setting;
- The height of the lower hitch points above the ground in their lowermost position and without load;
- The angle through which the mast turns from the vertical to the uppermost position;
- The main linkage dimensions and the mast height of the frame relative to the centre line of the rear wheels as tested;
- The temperature of the hydraulic fluid at the start of each test;
- The calculated moment around the rear wheel axis, resulting from the maximum external lift force at the frame which can be exerted through the full range of movement.

4.3.5 Optional Test results

4.3.5.1 Additional weight distributions may be reported; however, weight distributions must be in accordance with the manufacturer's instructions in the operator's manual;

  - Must be physically weighed at an accredited test facility following section 2.12;
  - State the mass in the specimen test report under the Hydraulic Power Lift Test report section;
  - Report the lift capacity following the same procedures as in 4.3.4.2.

APPENDIX C: SAMPLE OECD CODE 2 HYDRAULIC LIFT PUBLICATION

The following sample publication demonstrates what the new hydraulic lift section of the test report for OECD Code 2 will look like. All of these calculated values were shown in the new adaptation of the OECD Code 2 hydraulic lift test report for the John Deere 6150M, Figure C.2. In comparison, Figure C.1 shows what was issued for the OECD Code 2 hydraulic lift portion of the John Deere 6150M test report.

CODE 2 - *July 2012*

4.5 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Categoy 3N, 2 x 85mm cylinders, Top Link in Top Hole
Date of test: 14-Nov-13

	at the hitch point	on the frame
Height of lower hitch points above ground in down position	230 mm	229 mm
Vertical movement - without load	738 mm	810 mm
with load	682 mm	778 mm
Maximum corrected force exerted through full range	52.1 kN	45.2 kN
Corresponding pressure of hydraulic fluid	18.3 MPa	18.3 MPa
Moment about rear-wheel axis	59 kNm	79 kNm
Maximum tilt angle of mast from vertical	----- °	* 8.7 °

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-386	-302	-206	-104	-4	99	197	259	296			
Corrected lift forces at the Hitch points:												
kN	52.1	52.6	53.6	54.7	55.7	57.0	58.3	58.6	57.9			
Corresponding pressure: 18.3												
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-387	-308	-203	-95	17	135	252	339	391			
Corrected lift forces at the frame:												
kN	53.6	51.8	51.1	50.6	49.8	49.7	47.9	46.4	45.2			
Corresponding pressure: 18.3												

*Maximum observed tilt angle with settings used

Figure C.1. Current hydraulic lift test results as published in OECD Code 2 Final Test report for John Deere 6150M (OECD, 2013).

4.5 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Categoy 3N, 2 x 85mm cylinders, Top Link in Top Hole
Date of test: 14-Nov-13

	at the hitch point		on the frame	
Height of lower hitch points above ground in down position	230	mm	229	mm
Vertical movement - without load	738	mm	810	mm
with load	682	mm	778	mm
Maximum corrected force exerted through full range	52.1	kN	45.2	kN
Corresponding pressure of hydraulic fluid	18.3	MPa	18.3	MPa
Moment about rear-wheel axis	59	kNm	79	kNm
Maximum tilt angle of mast from vertical	-----	°	* 8.7	°

4.5.1 LIFT AT THE HITCH POINT

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-389	-305	-209	-107	-7	96	194	256	293			
Corrected lift forces at the Hitch points:												
kN	52.1	52.6	53.6	54.7	55.7	57.0	58.3	58.6	57.9			
Corresponding pressure: 18.3												

4.5.2 LIFT ON THE FRAME

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-390	-309	-207	-109	-8	94	189	257	295			
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-390	-311	-206	-98	14	132	249	336	388			
Corrected lift forces at the frame:												
kN	53.6	51.8	51.1	50.6	49.8	49.7	47.9	46.4	45.2			
Corresponding pressure: 18.3												

*Maximum observed tilt angle with settings used

4.5.3 TRACTOR MASS

	Unballasted		Ballasted for lift option #1		Ballasted for lift option #2	
	With driver	Without driver	With driver	Without driver	With driver	Without driver
	kg	kg	kg	kg	kg	kg
Front	2390	2370				
Rear	4103	4048				
Total	6493	6418				

4.5.4 BALLAST FOR LIFT

	Option #1			Option #2		
	Weights		Water	Weights		Water
	Number	Total mass		Number	Total mass	
		kg	kg		kg	kg
Front						
Rear						
Optional						

4.5.5 ACHIEVABLE LIFT CAPACITY **

	Hitch Point	610 mm rear hitch point
Unballasted	27.2 kN	17.5 kN
Lift ballast condition Option #1	0.0 kN	0.0 kN
Lift ballast condition Option #2	0.0 kN	0.0 kN

**For 2WD, MFWD, and 4WD tractors, 20% of total vehicle weight as the upward support force at the front axle for adequate steering control
**For 2-track tractors, 0% of total vehicle weight as the upward support force at the front axle for adequate steering control

Figure C.2. Proposed hydraulic power lift section for OECD Code 2 for John Deere 6150M.

APPENDIX D: DATA FOR 2WD AND MFWD TRACTORS

Data from 2WD, and MFWD tractors that were tested at the Nebraska Tractor Test Lab.

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	NTTL Test #	Brand	Model	kW	[W_B]-mm	[F_{Fs}]-kN	[W_T]-kN	[F_{Fs}]-kN	[W_T]-kN	[e]-mm	[B]-mm	[Θ]-(°)	[ϕ]-(°)	[F_L]-kN
1993	1664	John Deere	7600	83	2799	22	66			193	1013	0	0	52
1993	1665	John Deere	7600	84	2799	23	67			193	1013	0	0	52
1993	1666	John Deere	7700	94	2799	23	67	23	76	193	1013	0	0	52
1993	1667	John Deere	7700	94	2799	24	69	24	77	193	1013	0	0	52
1993	1668	John Deere	7800	110	2799	24	68	23	84	193	1013	0	0	52
1993	1669	John Deere	7800	110	2799	24	69	24	85	193	1013	0	0	52
1995	1688	John Deere	8100	122	2949	34	85	34	95	274	1057	-1.9	0.1	67
1995	1689	John Deere	8200	136	2949	34	85	42	105	274	1057	-1.9	0.1	67
1995	1690	John Deere	8300	151	2949	34	85	46	117	274	1057	-2.4	0.1	74
1995	1691	John Deere	8400	170	2949	34	86	48	131	274	1057	-2.4	0.1	74
1995	1692	AGCO	9435	101	2959	25	70	25	78	224	975	-1	-0.1	62
1995	1693	AGCO	9455	116	2959	25	71	25	79	224	975	-1	-0.1	62
1995	1694	White	6124	93	2692	24	66	27	77	224	975	-1	-0.1	62
1995	1695	White	6144	107	2692	23	67	27	78	224	975	-1	-0.1	62
1995	1696	Massey Ferguson	9240	157	2921	30	89	31	100	262	892	0.3	-0.2	72
1995	1697	AGCO	9635	101	2946	27	78	27	86	267	884	0.5	-1.2	35
1995	1698	AGCO	9655	116	2946	27	79	27	87	267	884	0.5	-1.2	35
1995	1699	AGCO	9675	131	2946	30	84	30	93	267	884	0.5	-1.2	42
1995	1700	AGCO	9695	147	2946	30	83	30	92	267	884	0.5	-1.2	42
1995	1705	Ford	7740	65	2362	17	45	18	50	104	912	-0.5	0	42
1996	1709	CaseIH	7220	117	3005	24	78	12	76	445	861	0	0	51
1996	1710	CaseIH	7230	128	3005	25	80			445	861	0	0	48
1996	1711	CaseIH	7240	147	3005	25	80			452	965	-1	0.5	75
1996	1712	CaseIH	7250	162	3005	26	81			452	965	-1	0.5	75
1996	1715	Belarus	532	41	2451	11	32			184	813	-1	0	23
1996	1716	Belarus	925	69	2451	13	39			184	813	-1	0	23
1996	1717	John	5500	55	2177	11	26	13	43	160	836	1.4	3.3	16

Test Year	NTTL Test #	Brand	Model	kW	[W_B]-mm	Unballasted [F_{Fs}]-kN	Unballasted [W_T]-kN	Ballasted [F_{Fs}]-kN	Ballasted [W_T]-kN	[e]-mm	[B]-mm	Horizontal (frame) [Θ]-(°)	Horizontal (frame) [ϕ]-(°)	Horizontal (frame) [F_L]-kN
		Deere												
1996	1718	AGCO	9815	161	2921	32	88	41	114	262	917	-0.2	-0.2	76
1996	1719	White	6215	160	2921	30	87	41	114	262	917	-0.2	-0.2	76
1997	1724	John Deere	7610	87	2799	23	65			193	1013	0	0	52
1997	1725	John Deere	7610	87	2799	23	67			193	1013	0	0	52
1997	1726	John Deere	7710	98	2799	24	68	24	80	193	1013	0	0	52
1997	1727	John Deere	7710	98	2799	25	69	25	81	193	1013	0	0	52
1997	1728	John Deere	7810	113	2799	24	68	26	86	193	1013	0	0	52
1997	1729	John Deere	7810	112	2799	25	70	27	87	193	1013	0	0	52
1997	1734	CaseIH	8910	102	3005	25	77	25	84	445	861	-1	0.2	46
1997	1735	CaseIH	8930	136	3005	25	80	35	99	445	861	0	0	55
1997	1736	CaseIH	8940	154	3005	25	82	38	106	452	965	-1	0.5	75
1997	1737	CaseIH	8950	169	3005	25	82	40	110	452	965	-1	0.5	75
1997	1738	John Deere	7210	72	2624	20	57			160	963	-1.7	0	40
1997	1739	John Deere	7210	72	2624	20	62			160	963	-1.7	0	40
1997	1740	John Deere	7410	79	2624	20	57			160	963	-1.7	0	40
1997	1741	John Deere	7410	79	2624	20	58			160	963	-1.7	0	40
1997	1742	Belarus	8345	56	2451	13	39			183	805	-0.2	0	30
1997	1743	Belarus	9345	69	2451	13	39			183	805	-0.2	0	30
1998	271	White	8410	109	2751	27	75	27	84	254	991	-1	0.5	71
1998	1752	AGCO	9745	109	2985	26	75	27	84	254	991	-1	0.5	71
1998	1753	White	8410	109	2751	27	75	27	84	254	991	-1	0.5	71
1998	1754	John Deere	5210	34	2050	9	23			160	836	1.4	3.3	16
1998	1755	John Deere	5310	42	2050	9	24			160	836	1.4	3.3	16
1998	1756	John Deere	5410	48	2177	12	26			160	836	1.4	3.3	16
1998	1757	John Deere	5510	57	2177	12	29			160	836	1.4	3.3	16
1998	1758	AGCO	9735	94	2985	25	72	25	80	254	991	-1	0.5	71
1998	1759	White	8310	94	2751	26	73	26	81	254	991	-1	0.5	71
1999	1760	CaseIH	MX 240	154	3005	37	93	43	120	201	1087	0.3	0.1	89
1999	1761	CaseIH	MX 270	177	3005	37	94	50	136	201	1087	0.3	0.1	89
1999	1762	White	6510	63	2347	14	38			-18	1067	-3.3	-0.1	29
1999	1763	White	6710	72	2738	20	50			99	940	-2.6	0	37

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L] -kN**
1999	1764	CaseIH	MX 180	110	3005	33	86	33	93	201	1077	-1.1	-0.2	58
1999	1765	CaseIH	MX 200	124	3005	33	88	35	98	201	1087	-0.4	-0.1	82
1999	1766	CaseIH	MX 220	139	3005	34	90	39	109	201	1087	-0.4	-0.1	82
2000	1767	AGCO	8745	53	2510	14	35			-18	1067	-3.3	-0.1	29
2000	1768	AGCO	8765	63	2512	16	39			-18	1067	-3.3	-0.1	29
2000	1769	White	6410	52	2438	14	36			-18	1067	-3.3	-0.1	29
2000	1770	John Deere	5105	31	1951	8	21			160	759	0	0	16
2000	1771	John Deere	5205	37	1951	9	21			160	759	0	0	16
2000	1772	John Deere	8110	123	2949	35	87	39	103	274	559	-1.9	0.1	67
2000	1773	John Deere	8210	139	2949	35	87	41	109	274	559	-1.9	0.1	67
2000	1775	John Deere	8310	154	2949	36	89	46	121	274	1057	-2.4	0.1	74
2000	1777	John Deere	8410	177	2949	37	92	50	139	274	1057	-2.4	0.1	74
2000	1779	AGCO	8775	72	2860	20	50			99	940	-2.6	0	37
2000	1780	White	6810	83	2860	21	57			99	940	-1.6	0.2	48
2000	1781	White	8510	122	3073	31	85	39	100	249	975	-0.4	-0.5	75
2000	1782	White	8610	137	3073	31	87	42	112	249	975	-0.5	0.3	94
2000	1787	John Deere	7610	90	2799	22	65	25	75	193	1013	0	0	52
2000	1788	John Deere	7710	103	2799	23	68	30	84	193	1013	0	0	52
2001	1792	Massey Ferguson	2210	35	2007	11	25			119	759	-0.2	-1	24
2001	1793	Massey Ferguson	2220	43	1996	10	23			119	759	-0.2	-1	24
2001	1794	White	8710	152	3073	33	88	44	120	249	975	-0.5	0.3	94
2001	1795	White	8810	170	3073	33	89	45	127	249	975	-0.5	0.3	94
2002	392	John Deere	7320	82	2649	24	59			135	945	-0.1	-0.1	49
2002	1798	John Deere	8320	163	2969	36	90	44	113	274	1082	2.3	0	78
2002	1800	John Deere	8420	175	2949	44	107	44	125	274	1082	2	0	91
2002	1801	John Deere	8520	191	2949	43	107	60	150	274	1082	2	0	91
2002	1807	John Deere	7810	113	2799	26	73	29	88	193	1013	0	0	52
2002	1808	John Deere	6403	65	2309	14	40	23	51	175	963	0.5	0	25
2002	1809	John Deere	6603	72	2637	16	43	23	54	175	963	0.5	0	25

Test Year	NTTL Test #	Brand	Model	kW	$[W_B]$-mm	Unballasted $[F_{Fs}]$-kN	Unballasted $[W_T]$-kN	Ballasted $[F_{Fs}]$-kN	Ballasted $[W_T]$-kN	[e]-mm	[B]-mm	Horizontal (frame) [Θ]-(°)	Horizontal (frame) [ϕ]-(°)	Horizontal (frame) $[F_L]$-kN
2003	1816	John Deere	7220	72	2649	19	53			135	945	-0.1	-0.1	49
2003	1817	John Deere	7420	87	2649	21	58	25	70	183	980	-3.3	-1.4	47
2003	1818	John Deere	7520	94	2649	22	62	26	75	183	980	-3.3	-1.4	47
2003	1819	John Deere	8120	128	2969	37	90	38	100	274	1082	2	0	92
2003	1820	John Deere	8220	142	2969	36	90	43	109	274	1082	2	0	92
2003	1825	CaseIH	MX 210	129	3005	34	91	36	101	201	1204	-1.2	0	86
2003	1826	CaseIH	MX 230	143	3005	34	90	39	111	201	1204	-1.2	0	86
2003	1827	CaseIH	MX 255	163	3002	40	97	45	128	201	1204	-1	-0.5	97
2003	1828	CaseIH	MX 285	180	3005	40	97	50	140	201	1204	-1	-0.5	97
2003	1829	New Holland	TG 210	144	3284	33	92	37	104	201	1204	-1.2	0	86
2003	1830	New Holland	TG 230	160	3284	32	91	40	113	201	1204	-1.2	0	86
2003	1831	New Holland	TG 255	183	3284	34	95	46	127	201	1204	-1	-0.5	97
2003	1832	New Holland	TG 285	205	3284	34	95	50	139	201	1204	-1	-0.5	97
2004	1833	John Deere	7720	113	2858	27	74	31	90	180	1120	-0.8	0.1	82
2004	1834	John Deere	7820	127	2858	28	77	34	96	180	1120	-0.8	0.1	82
2004	1835	John Deere	7920	139	2858	30	81	37	104	180	1120	-0.8	0.1	82
2004	1836	New Holland	48DA	31	1900	8	20			79	798	1	-1.8	15
2004	1837	CaseIH	DX55	36	1900	8	22			79	798	1	-1.8	15
2004	1838	John Deere	5105	35	1951	7	19			160	759	0	0	16
2004	1839	John Deere	5205	39	1951	9	22			160	759	0	0	16
2004	1840	AGCO	LT75	59	2553	17	43			102	945	-1	0	52
2004	1841	AGCO	LT90	66	2553	18	44			102	945	-1	0	52
2004	1842	AGCO	RT135	106	2891	27	70	32	83	145	1031	0.5	0	68
2004	1843	AGCO	RT150	116	2891	27	74	35	88	145	1031	0.5	0	68
2005	1849	AGCO	GT55 A	44	2055	12	28			160	762	0.7	1.7	17
2005	1850	AGCO	GT75 A	57	2187	12	30			160	762	0.7	1.7	17

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**$[W_B]$-mm**	**$[F_{Fs}]$-kN**	**$[W_T]$-kN**	**$[F_{Fs}]$-kN**	**$[W_T]$-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**$[F_L]$-kN**
2005	1851	Massey Ferguson	491	63	2291	14	34			-36	762	-0.7	0	18
2005	1852	Massey Ferguson	492	69	2291	16	38			-36	762	-0.7	0	18
2005	1853	John Deere	4320	31	1816	7	18			137	699	0.1	-1.6	14
2005	1854	John Deere	4520	35	1816	7	18			137	699	0.1	-2.1	14
2005	1855	John Deere	4720	39	1816	7	18			137	699	0.1	-2.1	14
2005	1856	McCor-mick	MTX 120	79	2700	23	57			224	892	-0.2	0	48
2005	1857	McCor-mick	MTX 135	84	2700	23	57			224	892	-0.2	0	48
2005	1858	McCor-mick	MTX 150	99	2700	23	58			224	892	-0.2	0	48
2005	1863	Massey Ferguson	451	36	1999	11	25			-38	871	-1	0	15
2005	1864	Massey Ferguson	471	49	2291	10	28			-36	958	-1.2	0	17
2005	1865	Massey Ferguson	481	55	2291	10	27			-36	958	-1.2	0	17
2005	1866	John Deere	5225	36	2177	11	26			160	836	-2.6	1.5	18
2005	1867	John Deere	5325	43	2177	12	31			160	836	-2.6	1.5	18
2005	1868	John Deere	5425	51	2177	12	31			160	836	-2.6	1.5	18
2005	1869	John Deere	5525	58	2177	13	34			160	836	-2.6	1.5	18
2006	1870	John Deere	5103	33	2040	8	22			150	828	-1.4	0.1	19
2006	1871	John Deere	5203	36	2040	8	22			150	828	-1.4	0.1	19
2006	1872	John Deere	5303	42	2040	8	22			150	828	-1.4	0.1	19
2006	1873	John Deere	8430	204	3020	46	111	59	150	231	1161	-0.6	0	95
2006	1874	John Deere	8430	204	3020	48	114	57	151	231	1161	-0.6	0	95
2006	1880	McCor-mick	XTX 185	130	2873	25	72			99	1003	-1.7	0	80
2006	1881	McCor-mick	XTX 200	136	2873	25	72			99	1003	-1.7	0	80
2006	1882	McCor-mick	XTX 215	152	2873	25	72	36	90	99	1003	-1.7	0	80
2006	1883	AGCO	LT75A	65	2675	18	45			102	945	-1	0	52
2006	1884	John Deere	8130	148	3051	40	96	42	111	277	1082	-2.1	0	78
2006	1885	John Deere	8230	164	3051	40	96	45	121	277	1082	-2.1	0	78

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L] -kN**
2006	1887	John Deere	8330	186	3051	40	96	51	135	277	1082	-2.1	0	78
2006	1890	John Deere	8530	225	3020	50	120	65	165	231	1161	-0.6	0	95
2006	1891	Kubota	L5030	42	1915	8	18			86	749	-0.8	0	15
2007	1893	John Deere	7630	118	2858	28	77	31	90	180	1120	-0.8	0.1	82
2007	1894	John Deere	7730	114	2858	28	77	34	96	180	1120	-0.8	0.1	82
2007	1895	John Deere	7830	136	2858	29	80	38	104	180	1120	-0.8	0.1	82
2007	1896	John Deere	7930	150	2858	29	80	42	113	180	1120	-0.8	0.1	82
2007	1897	John Deere	7930	148	2858	30	82	42	114	180	1120	-0.8	0.1	82
2007	1898	CaseIH	MX 215	161	3005	37	94	39	107	201	1204	-1.2	0	86
2007	1899	CaseIH	MX 245	181	3005	36	94	44	122	201	1204	-1.2	0	86
2007	1900	New Holland	TG 215	159	3284	33	95	38	108	201	1204	-1.2	0	86
2007	1901	New Holland	TG 245	183	3284	33	95	44	122	201	1204	-1.2	0	86
2007	1902	AGCO	TL90A	70	2675	19	47			102	945	-1	0	52
2007	1905	John Deere	5603	63	2177	13	33			160	836	-2.6	1.5	17
2007	1906	John Deere	5625	62	2177	12	28			160	836	-2.6	1.5	17
2007	1912	CaseIH	MX 275	169	3005	38	97	53	135	201	1204	-1	-0.5	97
2007	1913	CaseIH	MX 305	192	3005	38	97	60	149	201	1204	-1	-0.5	97
2007	1914	New Holland	TG 275	169	3284	35	97	53	134	201	1204	-1	-0.5	97
2007	1915	New Holland	TG 305	192	3284	35	97	58	148	201	1204	-1	-0.5	97
2007	1916	CaseIH	Mag-num 275	171	3005	38	97	53	135	201	1204	-1	-0.5	97
2008	1917	FarmTr-ac	675	50	2050	12	28			74	919	-6.9	4.9	21
2008	1918	New Holland	TT 50A	33	1976	7	18			-20	826	-1.8	-0.1	11
2008	1919	New Holland	TT 60A	37	2075	8	21			36	846	-0.9	-1.8	11
2008	1920	New Holland	TT 75A	46	2149	8	23			10	848	-0.4	0.8	13
2008	1921	John	7130	76	2649	21	56			135	945	-0.3	-0.1	48

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L]-kN**
		Deere												
2008	1922	John Deere	7230	84	2649	22	58	27	67	135	945	-0.3	-0.1	48
2008	1923	John Deere	7430	105	2685	24	68	30	85	165	1001	-0.7	-0.2	56
2008	1932	AGCO	LT95A	74	2753	21	50			102	945	-1	0	52
2008	1933	Massey Ferguson	5480	90	2753	20	51			102	945	-1	0	52
2008	1936	CaseIH	Mag-num 335	207	3005	41	110	65	164	201	1153	-2.1	-0.5	114
2008	1937	New Holland	T8050	205	3284	35	108	59	153	201	1153	-2.1	-0.5	114
2008	1938	CaseIH	DX 50	33	1867	6	16			25	813	-1	-0.4	14
2008	1939	CaseIH	DX 60	39	1900	8	19			79	800	-2.6	0	20
2008	1944	Kubota	M108 S	76	2436	14	39			114	899	1.2	-3.1	32
2008	1945	John Deere	4520	41	1816	7	18			137	699	0.1	-2.1	14
2008	1946	John Deere	4720	44	1816	8	18			137	699	0.1	-2.1	14
2009	1947	John Deere	5083E	49	2177	14	33			160	836	-2.6	1.5	17
2009	1948	John Deere	5093E	57	2177	14	34			160	836	-2.6	1.5	17
2009	1949	John Deere	6115D	74	2350	16	42	27	55	175	945	-0.6	0	36
2009	1950	John Deere	6130D	81	2350	17	45	23	55	175	945	-0.6	0	36
2009	1951	John Deere	6140D	87	2350	17	45	28	58	175	945	-0.6	0	36
2009	1952	John Deere	7330	96	2649	22	60	31	78	160	980	-1.2	0.4	51
2009	1954	John Deere	5055D	35	1951	8	22			157	759	-0.7	3	15
2009	1955	John Deere	5055E	36	2040	10	25			150	828	-1.4	0.1	19
2009	1956	John Deere	5065E	42	2050	10	25			150	828	-1.4	0.1	19
2009	1957	John Deere	5075E	46	2050	10	25			150	828	-1.4	0.1	19
2009	1958	John Deere	5065 M	38	2177	11	31			221	841	-0.8	0.1	23
2009	1959	John Deere	5075 M	45	2177	12	35			221	841	-0.8	0.1	23
2009	1960	John Deere	5085 M	52	2177	13	34			221	841	-0.8	0.1	23
2009	1961	John Deere	5095 M	60	2177	14	37			221	841	-0.8	0.1	23
2009	1962	John Deere	5105 M	61	2177	14	38			221	841	-0.8	0.1	23

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[F_{Fs}] -kN**	**[W_T] -kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L] -kN**
2009	1963	John Deere	8320R	204	3020	46	115			231	1161	-0.6	0	95
2010	1966	John Deere	8225R	142	3020	40	98	43	119	231	1161	-0.6	0	95
2010	1967	John Deere	8245R	156	3020	41	97	46	123	231	1161	-0.6	0	95
2010	1968	John Deere	8270R	171	3020	41	106	46	138	231	1161	-0.6	0	95
2010	1969	John Deere	8295R	187	3020	47	115	56	150	231	1161	-0.6	0	95
2010	1972	John Deere	8345R	213	3020	50	121	65	173	231	1161	-0.6	0	95
2010	1974	John Deere	6100D	65	2350	16	41	19	48	175	945	-0.6	0	36
2010	1975	Massey Ferguson	2560	47	2286	11	29			-36	958	-1.2	0	17
2010	1976	Massey Ferguson	2660	53	2370	15	35			-36	958	-1.2	0	17
2010	1977	Massey Ferguson	2670	60	2360	16	38			-36	762	-0.7	0	18
2010	1978	Massey Ferguson	2680	64	2360	16	39			-36	762	-0.7	0	18
2010	1981	New Holland	TS 6020	71	2520	12	34			117	1036	-1	0	32
2010	1982	New Holland	TS 6030	73	2520	15	39			117	1036	-1	0	32
2011	1983	Bobcat	CT450	28	1880	8	18			79	729	-1.9	-2.1	11
2011	1984	John Deere	6100D	63	2350	16	44			175	945	-0.6	0	36
2011	1985	John Deere	6230	61	2400	18	47			135	945	-1	0	26
2011	1986	John Deere	6330	69	2400	18	46			135	945	-0.3	0	37
2011	1987	John Deere	6430	76	2400	17	44			135	945	-1	0	26
2011	1988	John Deere	6430	79	2400	18	47			135	945	-0.3	0	37
2011	1989	John Deere	7130	78	2649	20	55			135	945	-0.3	-0.1	48
2011	1990	John Deere	8335R	229	3020	51	123			231	1161	-0.6	0	95
2011	1991	John Deere	8360R	240	3020	53	126	78	178	231	1161	-0.6	0	95
2011	1992	CaseIH	Mag-num 180	130	3005	35	85	35	94	249	958	-0.5	0.5	71
2011	1993	CaseIH	Mag-num 190	142	3005	35	85	40	104	249	958	-0.5	0.5	71

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L]-kN**
2011	1994	CaseIH	Mag-num 210	151	3005	35	85	44	110	249	958	-0.5	0.5	71
2011	1995	CaseIH	Mag-num 225	152	3005	40	92	44	122	249	958	-0.5	0.5	71
2011	1997	Versatile	305	190	3185	34	99	58	137	409	1057	-1.4	0	76
2011	2001	John Deere	8235R	154	3020	45	114			231	1161	-0.6	0	95
2011	2002	John Deere	8260R	173	3020	45	113			231	1161	-0.6	0	95
2011	2003	John Deere	8285R	192	3020	45	113			231	1161	-0.6	0	95
2011	2004	John Deere	8310R	203	3020	49	120			231	1161	-0.6	0	95
2011	2005	John Deere	7215R	142	2926	33	96			277	1102	1	0	79
2011	2006	CaseIH	Mag-num 340	220	3056	47	119	67	165	201	1095	2	0.3	116
2011	2007	New Holland	T8.39 0	219	3454	42	119	64	166	201	1095	2	0.3	116
2011	2012	CaseIH	Farm-all 55A	34	2210	8	20			119	765	0	-0.1	13
2011	2013	CaseIH	Farm-all 65A	45	2210	11	26			10	848	-0.7	-0.1	14
2011	2014	CaseIH	Farm-all 75A	50	2210	11	27			10	848	-0.7	-0.1	14
2012	2017	CaseIH	Mag-num 235	148	3056	38	103	41	119	201	1095	-0.8	0.6	83
2012	2018	CaseIH	Mag-num 260	164	3056	37	104	45	132	201	1095	2	0.3	116
2012	2019	CaseIH	Mag-num 290	185	3056	45	108	51	142	201	1095	2	0.3	116
2012	2020	CaseIH	Mag-num 315	202	3056	47	119	55	154	201	1095	2	0.3	116
2012	2021	John Deere	7200R	127	2926	33	95			277	1102	1	0	79
2012	2022	John Deere	7230R	144	2926	35	98			277	1102	1	0	79
2012	2023	John Deere	7260R	164	2926	36	106			320	1102	0.5	0	93
2012	2024	John Deere	7280R	177	2926	37	106	51	139	320	1102	0.5	0	93
2012	2025	John Deere	5083E	52	2177	14	33			160	836	-2.6	1.5	18
2012	2026	John Deere	5093E	61	2177	14	33			160	836	-2.6	1.5	18

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L]-kN**
2012	2027	John Deere	5101E	67	2177	14	33			160	836	-2.6	1.5	18
2012	2028	John Deere	6230	58	2400	17	44			135	945	-1	0	26
2012	2029	John Deere	6330	65	2400	17	44			135	945	-1	0	26
2012	2031	Challen-ger	MT 585B	135	3007	32	79			145	1031	0.5	0	68
2012	2032	Challen-ger	MT 595B	147	3007	32	79			145	1031	0.5	0	68
2012	2036	John Deere	5085 M	53	2301	14	36			221	841	0.3	-0.2	29
2012	2037	John Deere	5100 M	63	2301	15	39			221	841	0.3	-0.2	29
2012	2038	John Deere	5115 M	74	2301	15	40			221	841	0.3	-0.2	29
2012	2050	CaseIH	Farm-all 140A	87	2642	20	50			107	1036	-1	0	32
2012	2051	CaseIH	Farm-all 125A	81	2642	20	48			107	1036	-1	0	32
2012	2052	CaseIH	Farma ll 120A	72	2520	18	44			107	1036	-1	0	32
2012	2053	CaseIH	Farma ll 110A	69	2520	18	44			107	1036	-1	0	32
2013	2055	John Deere	6105D	67	2350	17	44			348	841	0.3	0.1	37
2013	2056	John Deere	6115D	71	2350	17	44			348	841	0.3	0.1	37
2013	2057	John Deere	6130D	78	2451	17	45			348	841	0.3	0.1	37
2013	2058	John Deere	6140D	87	2451	17	45			348	841	0.3	0.1	37
2013	2059	John Deere	6140R	85	2766	24	66			160	1054	0.2	0	45
2013	2060	John Deere	6150R	92	2766	24	67			160	1054	1.6	-0.1	51
2013	2063	Kubota	M110 GX	73	2436	15	42			114	899	-0.3	-0.6	42
2013	2064	Kubota	M135 GX	89	2690	19	50	27	67	114	899	-0.3	-0.6	42
2013	2065	Kubota	M996 0	68	2250	12	30			185	805	-0.3	-0.2	31
2013	2074	John Deere	5085E	54	2301	15	35			160	836	-2.6	1.5	18
2013	2075	John Deere	5100E	65	2301	15	35			160	836	-2.6	1.5	18
2013	2076	John Deere	6105 M	65	2581	19	49			135	945	-0.8	-0.1	36
2013	2077	John Deere	6115 M	72	2581	19	49			135	945	-0.8	-0.1	41
2013	2078	John Deere	6125 M	78	2581	19	49			135	945	-0.8	-0.1	41

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L]-kN**
2013	2079	John Deere	6140 M	87	2766	21	54			135	945	-0.9	-0.1	46
2013	2080	John Deere	6150 M	92	2766	23	64			160	975	2	-0.3	50
2013	2081	John Deere	6170 M	108	2799	24	68			196	1011	1.5	-0.2	57
2014	2082	John Deere	7210R	133	2926	33	98			277	1102	1	0	79
2014	2083	John Deere	7290R	183	2926	38	109	51	137	320	1102	0.5	0	93
2014	2084	John Deere	7270R	169	2926	36	108			320	1102	0.5	0	93
2014	2085	John Deere	7250R	160	2926	35	105			320	1102	0.5	0	93
2014	2086	CaseIH	Mag-num 370	228	3155	50	135	59	177	201	1095	2	0.3	116
2014	2090	John Deere	7230R	148	2926	35	102			277	1102	1	0	79
2014	2091	John Deere	7290R	186	2926	37	108	52	136	320	1102	0.5	0	93
2014	2098	John Deere	8245R	161	3081	46	113			320	1168	-0.4	0.2	104
2014	2099	John Deere	8270R	177	3081	46	112			320	1168	-0.4	0.2	104
2014	2100	John Deere	8295R	194	3081	46	113			320	1168	-0.4	0.2	104
2014	2101	John Deere	8320R	210	3081	51	122			320	1168	-0.4	0.2	104
2014	2102	John Deere	8370R	241	3081	53	125	77	180	320	1168	-0.4	0.2	104

(NTTL, 93-05) (NTTL, 06-14) Some of the data above are available to the public, upon request but not published.

APPENDIX E: DATA FOR 4WD ARTICULATED TRACTORS

Data from 4WD tractors that were tested at the Nebraska Tractor Test Lab.

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	NTTL Test #	Brand	Model	kW	$[W_B]$-mm	$[F_{Fs}]$ -kN	$[W_T]$ -kN	$[F_{Fs}]$ -kN	$[W_T]$ -kN	[e]-mm	[B]-mm	[Θ]-(°)	[ϕ]-(°)	$[F_L]$-kN
1996	1708	CaseIH	9370	240	3658	82	151			310	1181	0	0	108
1996	1713	CaseIH	9330	150	3058	55	106			259	1194	-1	2.2	68
1997	1732	John Deere	9300	239	3528	91	166			287	1260			70
1997	1733	John Deere	9400	233	3528	91	166	101	184	287	1260			70
2000	1783	CaseIH	STX 375	252	3912	97	168			434	1181	-0.8	0	118
2000	1784	CaseIH	STX 440	298	3912	101	176	112	198	434	1181	-0.8	0	118
2000	1785	CaseIH	STX 440	298	3912	128	229			434	1181	-2.5	0	109
2001	1796	CaseIH	STX 275	178	3531	80	142			434	1181	-0.1	0	84
2001	1797	CaseIH	STX 325	218	3531	80	143			434	1181	-0.1	0	84
2002	1803	John Deere	9320	248	3500	96	163			287	1260			70
2002	1805	John Deere	9520	248	3500	100	171	114	199	287	1260			70
2004	1844	John Deere	9620	277	3500	101	175	123	223	287	1260			70
2007	1907	CaseIH	STX 330	213	3912	81	144			434	1181	-0.1	0	84
2007	1908	CaseIH	STX 380	259	3912	107	186			434	1181	-0.8	0	118
2007	1909	CaseIH	STX 430	287	3912	107	186			434	1181	-0.8	0	118
2007	1910	CaseIH	STX 480	320	3912	115	199			434	1181	-0.8	0	118
2007	1911	CaseIH	STX 530	353	3912	133	234			434	1181	-2.5	0	109
2008	1924	John Deere	9530	292	3498	105	178	121	217	287	1303			80
2008	1926	John Deere	9630	318	3498	104	176	130	241	287	1303			80
2008	1928	Challenger	MT 945C	271	3950	127	225			470	1080	-0.3	0.2	136
2008	1929	Challenger	MT 955C	302	3950	127	225	150	240	470	1080	-0.3	0.2	136
2008	1930	Challenger	MT 965C	328	3950	128	226	181	267	470	1080	-0.3	0.2	136
2008	1934	CaseIH	Steiger 485	331	3912	112	195			434	1181	-0.8	0	118
2008	1940	John Deere	9230	198	3498	89	154			287	1283			80
2008	1941	John Deere	9330	248	3498	98	166			287	1283			80
2008	1942	John Deere	9430	252	3498	101	172	108	200	287	1283			80
2011	2008	CaseIH	Steiger 350	230	3759	97	171			394	1278	-2	0	127
2011	2009	CaseIH	Steiger 450	304	3759	101	178			394	1278	-2	0	127

						Unballasted		Ballasted				Horizontal (frame)		
Test Year	**NTTL Test #**	**Brand**	**Model**	**kW**	**[W_B]-mm**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[F_{Fs}]-kN**	**[W_T]-kN**	**[e]-mm**	**[B]-mm**	**[Θ]-(°)**	**[ϕ]-(°)**	**[F_L]-kN**
2011	2010	CaseIH	Steiger 500	340	3912	120	211			434	1181	-0.8	0	118
2011	2011	CaseIH	Steiger 600	356	3912	127	227	170	294	434	1181	-0.8	0	118
2012	2015	New Holland	T9.560	335	3759	101	178			394	1278	-2	0	127
2012	2016	New Holland	T9.615	353	3912	119	205			434	1181	-0.8	0	118
2012	2030	John Deere	9360R	230	3500	99	168			183	1331			110
2012	2039	John Deere	9410R	245	3500	105	173			183	1331			110
2012	2040	John Deere	9460R	248	3500	111	186	117	211	183	1331			110
2012	2042	John Deere	9510R	239	3500	119	198	134	237	183	1331			110
2012	2044	John Deere	9560R	240	3500	118	194	159	257	183	1331			110
2012	2046	CaseIH	Steiger 400	265	3759	101	179			394	1278	-2	0	127
2012	2047	CaseIH	Steiger 550	354	3912	129	231			434	1181	-0.8	0	118
2012	2048	CaseIH	Steiger 550	353	3912	152	262			434	1181	-2.5	0	109
2012	2049	CaseIH	Steiger 600	356	3912	153	264			434	1181	-2.5	0	109
2013	2066	Versatile	375	226	3429	102	167			442	1092	0.4	0	75
2013	2067	Versatile	400	247	3429	102	167			442	1092	0.4	0	75
2013	2068	Versatile	450	272	3866	116	202			500	1156	-0.8	-0.4	90
2013	2069	CaseIH	Steiger 350	228	4064	125	232			394	1278	-2	0	127
2013	2070	CaseIH	Steiger 400	261	4064	132	249			394	1278	-2	0	127
2013	2071	CaseIH	Steiger 450	300	4064	132	249			394	1278	-2	0	127
2013	2072	CaseIH	Steiger 450	300	3912	138	242			434	1181	-2.5	0	109
2013	2073	CaseIH	Steiger 500	336	3912	138	242			434	1181	-2.5	0	109
2014	2092	CaseIH	Steiger 370	241	3759	102	179			394	1278	-2	0	127
2014	2093	CaseIH	Steiger 420	274	3759	109	189			394	1278	-2	0	127
2014	2094	CaseIH	Steiger 470	311	3759	109	189			394	1278	-2	0	127
2014	2095	CaseIH	Steiger 500	336	3912	125	214			434	1181	-0.8	0	118
2014	2096	CaseIH	Steiger 540	356	3912	130	220			434	1181	-0.8	0	118
2014	2097	New Holland	T9.565	335	3759	112	211			394	1278	-2	0	127

(NTTL, 96-07) (NTTL, 08-14) Some of the data above are available to the public, upon request but not published.

APPENDIX F: DATA FOR 2-TRACK TRACTORS

Data from 2-track tractors that were tested at the Nebraska Tractor Test Lab.

Test Year	NTTL Test #	Brand	Model	kW	[W_B]-mm	Unballasted [W_T]-kN	[e]-mm	[B]-mm	Horizontal (frame) [Θ]-(°)	[ϕ] -(°)	[F_L] -kN
1998	1744	JD	8100T	121	2261	110	175	1057	-0.9	0	72
1998	1745	JD	8200T	136	2261	109	175	1057	-0.9	0	72
1998	1746	JD	8300T	152	2261	112	175	1057	-0.9	0	72
1998	1747	JD	8400T	169	2261	112	175	1057	-0.9	0	72
1998	1748	Caterpillar	65E	207	2720	153	267	765	-0.4	0	90
1998	1749	Caterpillar	75E	224	2720	156	267	765	-0.4	0	90
2000	1774	JD	8210T	140	2261	114	175	1057	-0.9	0	72
2000	1776	JD	8310T	154	2261	116	175	1057	-0.9	0	72
2000	1778	JD	8410T	177	2261	118	175	1057	-0.9	0	72
2001	1790	JD	9300T	226	2819	187	287	1273	-1.1	0	73
2001	1791	JD	9400T	223	2819	190	287	1273	-1.1	0	73
2002	1799	JD	8320T	163	2261	120	274	1082	1.6	-0.2	79
2002	1802	JD	8520T	191	2261	122	274	1082	1.6	-0.2	79
2002	1804	JD	9320T	248	2819	191	287	1273	-1.1	0	73
2002	1806	JD	9520T	248	2819	194	287	1273	-1.1	0	73
2002	1812	Challenger	MT755	177	2601	131	226	1006	0.1	0	95
2002	1813	Challenger	MT765	194	2601	131	226	1006	0.1	0	95
2002	1814	Challenger	MT855	299	3157	195	439	930	0.3	0	137
2002	1815	Challenger	MT865	331	3109	197	439	930	0.3	0	137
2003	1821	Challenger	MT735	139	2601	125	226	1006	0.1	0	95
2003	1822	Challenger	MT745	155	2601	125	226	1006	0.1	0	95
2003	1823	Challenger	MT835	227	3157	184	439	930	0.3	0	137
2003	1824	Challenger	MT845	252	3157	186	439	930	0.3	0	137
2004	1845	JD	9620T	271	2819	194	287	1273	-1.1	0	73
2005	1846	Challenger	MT765B	220	2601	139	226	1006	0.1	0	95
2005	1847	Challenger	MT865B	374	3109	197	439	930	0.3	0	137
2005	1859	Challenger	MT755B	207	2601	135	226	1006	0.1	0	95
2005	1860	Challenger	MT835B	254	3157	194	439	930	0.3	0	137
2005	1861	Challenger	MT845B	289	3157	192	439	930	0.3	0	137
2005	1862	Challenger	MT855B	331	3157	189	439	930	0.3	0	137
2006	1886	JD	8230T	163	2261	122	231	1082	-1.5	0.1	82
2006	1888	JD	8330T	191	2261	126	231	1082	-1.5	0.1	82
2006	1889	JD	8430T	212	2261	128	231	1082	-1.5	0.1	82

Test Year	NTTL Test #	Brand	Model	kW	[W_B]-mm	Unballasted [W_T]-kN	[e]-mm	[B]-mm	Horizontal (frame) [Θ]-(°)	[ϕ] -(°)	[F_L] -kN
2008	1925	JD	9530T	273	2819	196	287	1455	-0.3	0	82
2008	1927	JD	9630T	300	2819	196	287	1455	-0.3	0	82
2008	1943	JD	9430T	239	2819	197	287	1455	-0.3	0	82
2009	1953	Challenger	MT845C	292	3157	194	439	930	0.3	0	137
2009	1964	Challenger	MT865C	350	3109	193	439	930	0.3	0	137
2010	1970	JD	8295RT	181	2515	151	201	1511	-0.1	0.1	99
2010	1971	JD	8320RT	195	2515	151	201	1511	-0.1	0.1	99
2010	1973	JD	8345RT	208	2515	155	201	1511	-0.1	0.1	99
2011	1998	JD	8310RT	201	2515	156	201	1511	-0.1	0.1	99
2011	1999	JD	8335RT	217	2515	156	201	1511	-0.1	0.1	99
2011	2000	JD	8360RT	227	2515	159	201	1511	-0.1	0.1	99
2012	2041	JD	9460RT	236	2819	209	287	1293	-0.5	-0.1	110
2012	2043	JD	9510RT	233	2819	208	287	1295	-0.4	0.7	110
2012	2045	JD	9560RT	231	2819	210	287	1295	-0.4	0.7	110
2013	2061	Challenger	MT755D	210	2601	140	226	1006	0.1	0	95
2013	2062	Challenger	MT765D	224	2601	138	226	1006	0.1	0	95
2014	2087	Challenger	MT755E	213	2601	149	226	1006	0.1	0	95
2014	2088	Challenger	MT765E	233	2601	149	226	1006	0.1	0	95
2014	2089	Challenger	MT775E	250	2601	151	226	1006	0.1	0	95
2014	2103	JD	8345RT	218	2515	162	201	1311	-0.7	-0.7	102

(NTTL, 98) (NTTL, 00-14) Some of the data above are available to the public, upon request but not published.

APPENDIX G: NEBRASKA NTTL TRACTOR TEST 2080-SUMMARY 896

Current NTTL publication for John Deere 6150M.

NEBRASKA OECD TRACTOR TEST 2080–SUMMARY 896
JOHN DEERE 6150M POWRQUAD-PLUS DIESEL
20 SPEED

POWER TAKE-OFF PERFORMANCE

Power HP (kW)	Crank shaft speed rpm	Gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Mean Atmospheric Conditions
MAXIMUM POWER AND FUEL CONSUMPTION					
Rated Engine Speed—(PTO speed—1049 rpm)					
124.43 (*92.79*)	2100	7.62 (*28.84*)	0.430 (*0.262*)	16.33 (*3.22*)	Fuel used during active exhaust regeneration - 0.76 gal (*2.87 l*) (see note 1 p.2)
Standard Power Take-off Speed (1000 rpm)					
131.26 (*97.88*)	2000	7.81 (*29.55*)	0.418 (*0.254*)	16.81 (*3.31*)	
Maximum Power (1 hour)					
137.13 (*102.26*)	1850	7.82 (*29.61*)	0.401 (*0.244*)	17.53 (*3.45*)	
VARYING POWER AND FUEL CONSUMPTION					
124.43 (*92.79*)	2100	7.62 (*28.84*)	0.430 (*0.262*)	16.33 (*3.22*)	Air temperature
108.88 (*81.19*)	2163	7.19 (*27.21*)	0.464 (*0.282*)	15.15 (*2.98*)	73°F (*23°C*)
82.85 (*61.78*)	2194	6.11 (*23.13*)	0.518 (*0.315*)	13.56 (*2.67*)	Relative humidity
55.95 (*41.72*)	2221	4.89 (*18.52*)	0.614 (*0.374*)	11.44 (*2.25*)	26%
28.00 (*20.88*)	2231	3.88 (*14.67*)	0.973 (*0.592*)	7.22 (*1.42*)	Barometer
0.91 (*0.68*)	2246	2.89 (*10.94*)	22.355 (*13.598*)	0.31 (*0.06*)	28.88" Hg (*97.80 kPa*)

Maximum torque - 452 lb.-ft. (*612 Nm*) at 1450 rpm
Maximum torque rise - 45.3%
Torque rise at 1680 engine rpm - 37%
Power increase at 1850 engine rpm - 10.2%

DRAWBAR PERFORMANCE
UNBALLASTED - FRONT DRIVE ENGAGED
FUEL CONSUMPTION CHARACTERISTICS

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr (kg/kW.h)	Fuel Consumption Hp.hr/gal (kW.h/l)	Temp.°F (°C) cooling med	Temp.°F (°C) Air dry bulb	Barom. inch Hg (kPa)
Maximum Power—7th (B8) Gear									
113.23 (*84.44*)	8883 (*39.51*)	4.78 (*7.69*)	2100	4.2	0.476 (*0.289*)	14.78 (*2.91*)	190 (*88*)	47 (*8*)	28.54 (*96.65*)
75% of Pull at Maximum Power—7th (B8) Gear									
90.17 (*67.24*)	6688 (*29.75*)	5.06 (*8.14*)	2194	3.1	0.534 (*0.325*)	13.17 (*2.59*)	189 (*87*)	59 (*15*)	28.58 (*96.78*)
50% of Pull at Maximum Power—7th (B8) Gear									
61.20 (*45.63*)	4447 (*19.78*)	5.16 (*8.30*)	2215	2.0	0.630 (*0.383*)	11.16 (*2.20*)	189 (*87*)	58 (*14*)	28.58 (*96.78*)
75% of Pull at Reduced Engine Speed—11th (C3) Gear									
90.06 (*67.15*)	6680 (*29.71*)	5.06 (*8.14*)	1379	3.1	0.442 (*0.269*)	15.91 (*3.13*)	189 (*87*)	58 (*14*)	28.58 (*96.78*)
50% of Pull at Reduced Engine Speed—11th (C3) Gear									
61.25 (*45.67*)	4443 (*19.76*)	5.17 (*8.32*)	1395	2.0	0.480 (*0.292*)	14.64 (*2.88*)	189 (*87*)	59 (*15*)	28.57 (*96.75*)

Location of tests: Nebraska Tractor Test Laboratory, University of Nebraska, Lincoln, Nebraska 68583-0832

Dates of tests: October 28 to November 14, 2013

Manufacturer: John Deere Werke Mannheim, John- Deere- StraBe 90, Mannheim, Germany

FUEL, OIL and TIME: Fuel No. 2 Diesel **Specific gravity converted to 60°/60°F** (*15°/15°C*) 0.8442 **Fuel weight** 7.029 lbs/gal (*0.842 kg/l*) **Oil SAE** 10W-30 **API service classification** CJ-4 **Transmission and hydraulic lubricant** John Deere Hy-Gard II fluid **Front axle lubricant** John Deere Hy-Gard II fluid **Total time engine was operated:** 23.5 hours

ENGINE: Make John Deere Diesel **Type** six cylinder vertical with turbocharger and air to air intercooler **Serial No.** *CD6068R029001* **Crankshaft** lengthwise **Rated engine speed** 2100 **Bore and stroke** 4.19"x 5.00" (*106.5 mm x 127.0 mm*) **Compression ratio** 16.5 to 1 **Displacement** 414 cu in (*6788 ml*) **Starting system** 12 volt **Lubrication** pressure **Air cleaner** two paper elements and aspirator **Oil filter** one full flow cartridge **Oil cooler** engine coolant heat exchanger for crankcase oil, radiator for hydraulic and transmission oil **Fuel filter** one paper element and one paper cartridge with water separator **Fuel cooler** radiator for pump return fuel **Exhaust** regenerative particulate filter integrated within a vertical muffler **Cooling medium temperature control** two thermostats and variable speed fan

ENGINE OPERATING PARAMETERS: Fuel rate: 52.7 - 57.1 lb/h (*23.9 - 25.9 kg/h*) **High idle:** 2225 - 2275 rpm **Turbo boost:** nominal 13.1 - 16.0 psi (*90 - 110 kPa*) as measured 14.9 psi (*103 kPa*)

CHASSIS: Type front wheel assist **Serial No.***1L06150MADG763757* **Tread width** rear 61.3" (*1558 mm*) to 109.1" (*2771 mm*) front 65.0" (*1650 mm*) to 83.2" (*2084 mm*) **Wheelbase** 108.9" (*2765 mm*) **Hydraulic control system** direct engine drive **Transmission** selective gear fixed ratio with partial (4) range operator controlled power shift **Nominal travel speeds mph (km/h)** first 1.60 (*2.57*) second 1.93 (*3.10*) third 2.31 (*3.71*) fourth 2.83 (*4.55*) fifth 3.39 (*5.46*) sixth 4.08 (*6.57*) seventh 4.89 (*7.87*) eighth 5.39 (*8.68*) ninth 5.99 (*9.64*) tenth 6.50 (*10.46*) eleventh 7.78 (*12.52*) twelfth 9.53 (*15.34*) thirteenth 9.99 (*16.08*) fourteenth 12.03 (*19.36*) fifteenth 14.40 (*23.18*) sixteenth 14.43 (*23.22*) seventeenth 17.37 (*27.96*) eighteenth 17.65 (*28.40*) nineteenth 20.81 (*33.49*) twentieth 25.49 (*41.02*)

DRAWBAR PERFORMANCE

UNBALLASTED - FRONT DRIVE ENGAGED-2100 RPM
MAXIMUM POWER IN SELECTED GEARS

Power Hp (*kW*)	Drawbar pull lbs (*kN*)	Speed mph (*km/h*)	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr (*kg/kW.h*)	Fuel Consumption Hp.hr/gal (*kW.h/l*)	Temp.°F (°C) cool-ing med	Temp.°F (°C) Air dry bulb	Barom. inch Hg (*kPa*)
					4th(A4)Gear				
92.25 (*68.79*)	13374 (*59.49*)	2.59 (*4.17*)	2183	14.5	0.571 (*0.347*)	12.31 (*2.42*)	190 (*88*)	51 (*11*)	28.59 (*96.82*)
					5th(B1)Gear				
106.38 (*79.33*)	12637 (*56.21*)	3.16 (*5.09*)	2120	9.6	0.509 (*0.310*)	13.81 (*2.72*)	189 (*87*)	51 (*11*)	28.63 (*96.95*)
					6th(B2) Gear				
111.03 (*82.80*)	10633 (*47.30*)	3.92 (*6.30*)	2100	6.0	0.487 (*0.296*)	14.44 (*2.84*)	190 (*88*)	49 (*10*)	28.56 (*96.72*)
					7th(B3)Gear				
113.23 (*84.44*)	8883 (*39.51*)	4.78 (*7.69*)	2100	4.2	0.476 (*0.289*)	14.78 (*2.91*)	190 (*88*)	47 (*8*)	28.54 (*96.65*)
					8th(C1)Gear				
112.47 (*83.87*)	7957 (*35.39*)	5.30 (*8.53*)	2099	3.7	0.480 (*0.292*)	14.66 (*2.89*)	189 (*87*)	51 (*10*)	28.56 (*96.72*)
					9th (B4)Gear				
111.31 (*83.00*)	7056 (*31.38*)	5.92 (*9.52*)	2100	3.2	0.485 (*0.295*)	14.48 (*2.85*)	189 (*87*)	48 (*9*)	28.54 (*96.65*)
					10th(C2)Gear				
112.55 (*83.93*)	6560 (*29.18*)	6.43 (*10.35*)	2100	2.9	0.480 (*0.292*)	14.63 (*2.88*)	189 (*87*)	54 (*12*)	28.57 (*96.75*)
					11th (C3)Gear				
112.05 (*83.55*)	5421 (*24.11*)	7.75 (*12.47*)	2101	2.4	0.483 (*0.294*)	14.54 (*2.86*)	189 (*87*)	55 (*13*)	28.56 (*96.72*)
					12th (C4)Gear				
107.75 (*80.35*)	4232 (*18.82*)	9.55 (*15.37*)	2100	1.8	0.501 (*0.305*)	14.03 (*2.76*)	189 (*87*)	56 (*13*)	28.57 (*96.75*)

TRACTOR SOUND LEVEL WITH CAB	Front Wheel Drive Engaged dB(A)	Front Wheel Drive Disengaged dB(A)
At no load in 7th (B3) gear	66.8	66.1
Transport speed - no load - 20th (E4) gear		74.2
Bystander in 19th (E3) gear		80.5

TIRES AND WEIGHT	Tested Without Ballast
Rear Tires - No., size, ply & psi(*kPa*)	Two 460/85R42;***;12(*85*)
Front Tires - No., size, ply & psi(*kPa*)	Two 420/85R28;***;12(*85*)
Height of Drawbar	21.5 in (*545 mm*)
Static Weight with operator - Rear	9045 lb (*4103 kg*)
- Front	5270 lb (*2390 kg*)
- Total	14315 lb (*6493 kg*)

reverse 1.67 (*2.69*), 2.01 (*3.23*), 2.40 (*3.87*), 2.95 (*4.75*), 3.54 (*5.69*), 4.26 (*6.86*), 5.10 (*8.21*), 5.63 (*9.06*), 6.25 (*10.06*), 6.77 (*10.91*), 8.12 (*13.07*), 9.95 (*16.01*), 10.42 (*16.77*), 12.55 (*20.20*), 15.03 (*24.19*), 15.06 (*24.23*), 18.13 (*29.18*), 18.42 (*29.64*), 21.71 (*34.94*), 26.60 (*42.81*) **Clutch** wet multiple disc hydraulically actuated by foot pedal **Brakes** wet multiple disc hydraulically operated by two foot pedals that can be locked together **Steering** hydrostatic **Power take-off** 540 rpm at 1987 engine rpm or 1000 rpm at 2000 engine rpm **Unladen tractor mass** 14140 lb (*6414 kg*)

NOTE 1: The manufacturer declares that the average time between active regenerations is 100 hours, while operated in Auto Filter Cleaning Mode, at rated speed, full load, under steady state conditions.

REPAIRS AND ADJUSTMENTS: No repairs or adjustments.

REMARKS: All test results were determined from observed data obtained in accordance with official OECD, SAE and Nebraska test procedures. For the maximum power tests the fuel temperature at the injection pump inlet was maintained at 121°F (*50°C*). The performance figures on this summary were taken from a test conducted under the OECD Code 2 test code procedure.

We, the undersigned, certify that this is a true and correct report of official Tractor Test No. 2080, Nebraska Summary 896, January 13, 2014.

Roger M. Hoy
Director

M.F. Kocher
S. Pitla
J.D. Luck
Board of Tractor Test Engineers

DRAWBAR PERFORMANCE
UNBALLASTED - FRONT DRIVE ENGAGED - 1850 RPM
MAXIMUM POWER IN SELECTED GEARS

Power Hp *(kW)*	Drawbar pull lbs *(kN)*	Speed mph *(km/h)*	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr *(kg/kW.h)*	Fuel Consumption Hp.hr/gal *(kW.h/l)*	Temp. °F(°C) cool-ing med	Temp. °F(°C) Air dry bulb	Barom. inch Hg *(kPa)*
					4th(A4)Gear				
92.28	13381	2.59	2183	14.5	0.568	12.37	191	51	28.60
(68.81)	*(59.52)*	*(4.17)*			*(0.346)*	*(2.44)*	*(88)*	*(11)*	*(96.85)*
					5th (B1)Gear				
106.38	12637	3.16	2119	9.6	0.509	13.81	189	51	28.63
(79.33)	*(56.21)*	*(5.09)*			*(0.310)*	*(2.72)*	*(87)*	*(11)*	*(96.95)*
					6th(B2)Gear				
115.35	12060	3.59	1976	8.6	0.482	14.59	190	53	28.66
(86.01)	*(53.64)*	*(5.78)*			*(0.293)*	*(2.87)*	*(88)*	*(12)*	*(97.05)*
					7th (B3)Gear				
122.19	11139	4.12	1850	6.5	0.452	15.54	191	47	28.54
(91.12)	*(49.55)*	*(6.62)*			*(0.275)*	*(3.06)*	*(88)*	*(8)*	*(96.65)*
					8th (C1)Gear				
122.42	9988	4.60	1850	5.2	0.455	15.45	191	51	28.56
(91.29)	*(44.43)*	*(7.40)*			*(0.277)*	*(3.04)*	*(88)*	*(10)*	*(96.72)*
					9th (B4)Gear				
123.19	8973	5.15	1850	4.4	0.450	15.61	191	48	28.54
(91.86)	*(39.91)*	*(8.29)*			*(0.274)*	*(3.08)*	*(88)*	*(9)*	*(96.65)*
					10th (C2)Gear				
124.23	8305	5.61	1850	4.0	0.448	15.70	191	54	28.57
(92.64)	*(36.94)*	*(9.03)*			*(0.272)*	*(3.09)*	*(88)*	*(12)*	*(96.75)*
					11th (C3)Gear				
125.24	6932	6.78	1850	3.1	0.444	15.84	192	56	28.57
(93.39)	*(30.83)*	*(10.91)*			*(0.270)*	*(3.12)*	*(89)*	*(13)*	*(96.75)*
					12th (C4)Gear				
122.17	5480	8.36	1851	2.5	0.455	15.46	191	57	28.57
(91.10)	*(24.37)*	*(13.45)*			*(0.277)*	*(3.05)*	*(88)*	*(14)*	*(96.75)*

DRAWBAR PERFORMANCE

UNBALLASTED - FRONT DRIVE DISENGAGED

FUEL CONSUMPTION CHARACTERISTICS

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr (kg/kW.h)	Fuel Consumption Hp.hr/gal (kW.h/l)	Temp.°F (°C) cool-ing med	Temp.°F (°C) Air dry bulb	Barom. inch Hg (kPa)
					Maximum Power—7th (B3) Gear				
109.53 *(81.67)*	8939 *(39.76)*	4.60 *(7.39)*	2100	6.9	0.493 *(0.300)*	14.25 *(2.81)*	189 *(87)*	48 *(9)*	28.55 *(96.68)*
					75% of Pull at Maximum Power—7th(B3) Gear				
88.56 *(66.04)*	6708 *(29.84)*	4.95 *(7.97)*	2195	4.1	0.545 *(0.331)*	12.90 *(2.54)*	190 *(88)*	58 *(15)*	28.58 *(96.78)*
					50% of Pull at Maximum Power—7th (B3) Gear				
60.81 *(45.35)*	4489 *(19.97)*	5.08 *(8.18)*	2216	2.5	0.633 *(0.385)*	11.10 *(2.19)*	189 *(87)*	58 *(15)*	28.58 *(96.78)*
					75% of Pull at Reduced Engine Speed—11th(C3) Gear				
88.49 *(65.98)*	6706 *(29.83)*	4.95 *(7.97)*	1378	4.0	0.446 *(0.271)*	15.76 *(3.10)*	190 *(88)*	60 *(16)*	28.57 *(96.75)*
					50% of Pull at Reduced Engine Speed—11th(C3) Gear				
60.66 *(45.23)*	4460 *(19.84)*	5.10 *(8.21)*	1397	2.4	0.481 *(0.292)*	14.63 *(2.88)*	189 *(87)*	60 *(15)*	28.57 *(96.75)*

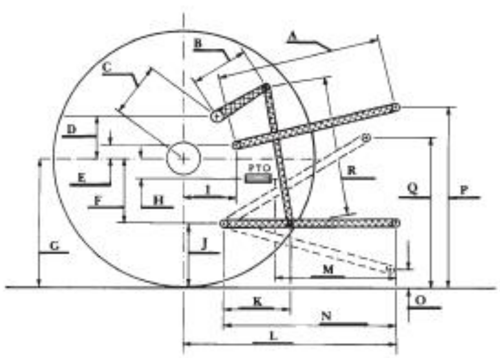
MAXIMUM POWER IN SELECTED GEARS

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr (kg/kW.h)	Fuel Consumption Hp.hr/gal (kW.h/l)	Temp.°F (°C) cool-ing med	Temp.°F (°C) Air dry bulb	Barom. inch Hg (kPa)
					5th(B1) Gear				
85.09 *(63.45)*	10472 *(46.58)*	3.05 *(4.91)*	2186	14.6	0.589 *(0.359)*	11.92 *(2.35)*	189 *(87)*	52 *(11)*	28.64 *(96.99)*
					6th(B2) Gear				
101.94 *(76.01)*	10169 *(45.23)*	3.76 *(6.05)*	2169	11.7	0.533 *(0.324)*	13.18 *(2.60)*	189 *(87)*	53 *(11)*	28.65 *(97.02)*
					7th(B3) Gear				
109.53 *(81.67)*	8939 *(39.76)*	4.60 *(7.39)*	2100	6.9	0.493 *(0.300)*	14.25 *(2.81)*	189 *(87)*	48 *(9)*	28.55 *(96.68)*
					8th(C1) Gear				
109.02 *(81.30)*	7922 *(35.24)*	5.16 *(8.30)*	2100	5.3	0.495 *(0.301)*	14.19 *(2.79)*	189 *(87)*	51 *(11)*	28.56 *(96.72)*
					9th(B4) Gear				
109.23 *(81.45)*	7087 *(31.52)*	5.78 *(9.30)*	2100	4.4	0.495 *(0.301)*	14.20 *(2.80)*	189 *(87)*	49 *(9)*	28.56 *(96.72)*
					10th(C2) Gear				
111.53 *(83.16)*	6633 *(29.50)*	6.31 *(10.15)*	2100	4.0	0.484 *(0.295)*	14.51 *(2.86)*	188 *(87)*	55 *(13)*	28.56 *(96.72)*
					11th(C3) Gear				
111.24 *(82.95)*	5475 *(24.35)*	7.62 *(12.26)*	2100	3.2	0.484 *(0.294)*	14.53 *(2.86)*	189 *(87)*	56 *(13)*	28.57 *(96.75)*
					12th(C4) Gear				
107.95 *(80.50)*	4304 *(19.14)*	9.41 *(15.14)*	2101	2.2	0.501 *(0.305)*	14.04 *(2.77)*	189 *(87)*	57 *(14)*	28.58 *(96.78)*

HYDRAULIC PERFORMANCE

CATEGORY: IIIN
Quick Attach: No

	Lift cylinders
Maximum force exerted through whole range:	8986 lbs *(40.0 kN)* 2 x 80 mm 10167 lbs *(45.2 kN)* 2 x 85 mm
i) Maximum observed pressure:	2908 psi *(200 bar)*
	two outlet sets combined
ii) Pump delivery rate at minimum pressure and rated engine speed:	31.1 GPM *(117.8 l/min)*
iii) Pump delivery rate at maximum hydraulic power:	30.8 GPM *(116.6 l/min)*
Delivery pressure:	2577 psi *(178 bar)*
Power:	46.3 HP *(34.5 kW)*
	single outlet set
ii) Pump delivery rate at minimum pressure and rated engine speed:	31.0 GPM *(117.3 l/min)*
iii) Pump delivery rate at maximum hydraulic power:	31.2 GPM *(118.2 l/min)*
Delivery pressure:	2174 psi *(150 bar)*
Power:	39.6 HP *(29.5 kW)*



HITCH DIMENSIONS AS TESTED—NO LOAD

	inch	*mm*
A	25.2	*640*
B	15.7	*400*
C	22.1	*562*
D	20.9	*531*
E	13.2	*336*
F	9.8	*250*
G	34.2	*870*
H	3.1	*80*
I	18.1	*460*
J	24.4	*620*
K	21.9	*555*
L	44.7	*1135*
M	21.7	*550*
N	38.4	*975*
O	9.1	*230*
P	51.4	*1305*
Q	38.1	*968*
R	37.4	*950*

JOHN DEERE 6150M DIESEL

Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln

(NTTL, 2014)

APPENDIX H: OECD TRACTOR TEST SUMMARY FOR JOHN DEERE 6150M

Selected pages from the current OECD test report for John Deere 6150M, approval No. 821.

CODE 2 - *July 2012*

OECD APPROVAL NO. 2/2 821
CODE 2
DATE OF APPROVAL: 26 March 2014

NEBRASKA TRACTOR TEST LABORATORY
DEPARTMENT OF BIOLOGICAL SYSTEMS ENGINEERING
INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
UNIVERSITY OF NEBRASKA - EAST CAMPUS
LINCOLN, NEBRASKA 68583-0832, USA

REPORT ON TEST IN ACCORDANCE WITH OECD STANDARD CODE 2
FOR THE OFFICIAL TESTING OF AGRICULTURAL TRACTORS

John Deere 6150M
Mechanical Front Wheel Drive (MFWD)

MANUFACTURED BY:	**John Deere Werke Mannheim** **John-Deere-Straße 90** **D-68163 Mannheim, Germany**
NEBRASKA TEST NO.	**2080**
TEST DATES:	**October – November 2013**

TABLE OF CONTENTS

This test report provides the results of the tests conducted in accordance with the OECD Standard Test Code for the Official Testing of Agricultural Tractor Performance - C(87)53 Final, Code 2.

This report has been approved by the OECD Coordinating Centre in ENAMA, Italy on the 26th of March 2014 for the John Deere 6150M, MFWD **tractor with OECD Number** 2/2 821**.**

Dr. Roger M. Hoy, Director
Nebraska Tractor Test Laboratory

Justin Geyer, Test Engineer
Nebraska Tractor Test Laboratory

Date: 27 March 2014

1.6 Three point linkage

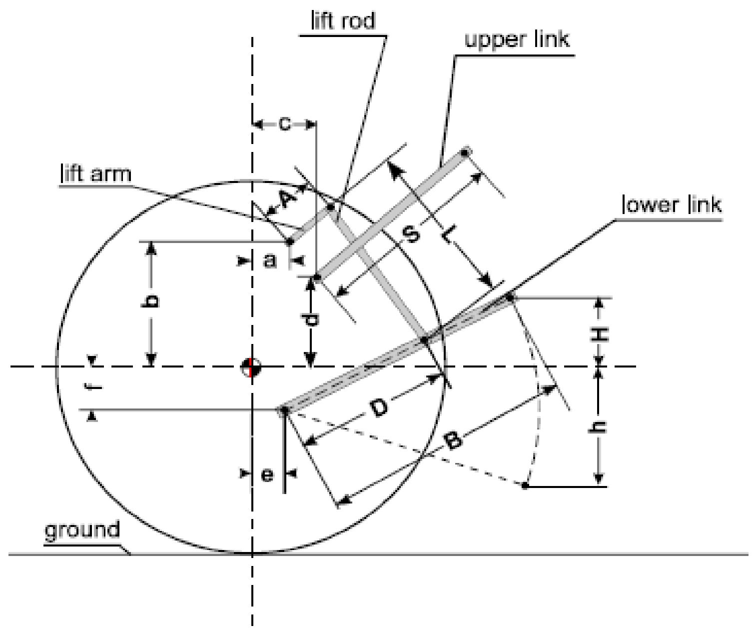


Figure 1.1
Lift Test – Linkage geometry

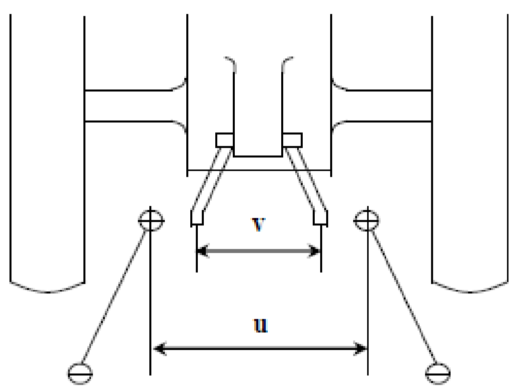


Figure 1.2
Lift Test – Linkage geometry

C	- Category: • *Conformity with categories 1, 2, 3, 4, or 1N, 2N, 3N, 4N of ISO 730:2009*	3N, in conformity of ISO 730:2009
C	- Category adapter:	N/A

		Figures 1.1 and 1.2	Dimension or range	Settings used in test(s)
			mm	mm
	Length of arms:	**(A)**	400	400
C	Length of lower links:	**(B)**	975	975
C	Distance of lift arm pivot point from rear wheel axis			
	- horizontally:	**(a)**	185	185
C	- vertically:	**(b)**	531	531
C	Horizontal distance between the 2 lower link points:	**(u)**	500	500
C	Horizontal distance between the 2 lift arm end points:	**(v)**	630	630
C	Length of upper arm link:	**(S)**	587 to 782	640
C	Distance of upper link pivot point from rear wheel axis			
	- horizontally:	**(c)**	460	460
C	- vertically:	**(d)**	Top hole – 336 Middle hole – 270 Bottom hole – 218	336, 270
C	Distance of lower link pivot point from rear wheel axis			
	- horizontally:	**(e)**	160	160
C	- vertically:	**(f)**	250	250
C	Distance of lower link pivot points to lift rod pivot points on lower links:	**(D)**	555	555
C	Length of lift rods:	**(L)**	875 to 1035	950
C	Height of lower hitch points relative to the rear wheel axis			
	- in low position:	**(h)**	495 to 815	645
C	- in high position:	**(H)**	-100 to 218	93
C	Height above ground of lower hitch points when locked in transport position (*):		775 to 1093	968
C	(*) Assuring r = 875 Tyre dynamic radius index of ISO 4251-1:2005 (pneumatic tyred tractors only)			

Table 1.1.1

Dimensions of linkage geometry when connected to the standard frame

	1.10	Steering			
D		- Make / Model / Type:	Rexroth Bosch Group / AL177633 / LAGU		
		- Method of operation			
D		- Pump(s):	Same as main hydraulic pump		
D		- Rams(s):	Integrated symmetrical design		
D		- Working pressure (MPa):	20.2 +/- 0.5		
	1.11	**Brakes**			
	1.11.1	Service brake			
D		- Make / Model / Type:	Borg Warner / AL171954 / John Deere oil immersed		
C		- Method of operation:	Hydraulic, operated by two pedals which can be locked together		
C		- Trailer braking take-off (hydraulic or air brakes):	Optional with hydraulic or / and air trailer brake		
	1.11.2	Parking brake			
C		- Type:	Spring applied		
C		- Method of operation:	Gear selector lever		
	1.12	**Wheels**			
		- Number			
C		- Front (driving / steering):	2/2		
C		- Rear (driving / steering):	2/0		
C		- Wheelbase (mm):	2765		
		- Track width adjustment:			
			Minimum mm	Maximum mm	Adjustment method
D		Front	1650	2084	Reversing wheels and offset lug rims
D		Rear	1558	2771	Rack and pinion axle; reversing wheels and offset lug rims
	1.13	**Protective structure**			
C		- Make / Model / Type:	John Deere / CG703 / Cab		
C		- Manufacturer's name and address:	John Deere Bruchsal, Bruchsal, Baden-Württemberg, Germany		
		- Protective device			
C		- Cab / frame / rollguard / other:	Cab		
C		- Tiltable / not tiltable:	Not tiltable		
		- OECD approval			
C		- approval number:	4/1 360		
C		- Date of approval:	March 20, 2012		
C		- Nos. of minor modification certificates, if any:	N/A		

2. TEST CONDITIONS

Separate tables may be added to report other test conditions or equipments.

2.1 Overall dimensions

	Length	Width		Height at top of:	
		minimum	maximum	protective structure	exhaust pipe
	mm	mm	mm	mm	mm
Ballasted	N/A	N/A	N/A	N/A	N/A
Unballasted	4868	1650	2084	2963	2883

2.2 Ground clearance (unballasted tractor)

(mm): 455

- Clearance – limiting part: Sway block

2.3 Tractor mass

- Mass (with cab):

	Ballasted		Unballasted	
	With driver	Without driver	With driver	Without driver
	kg	kg	kg	kg
Front	N/A	N/A	2390	2370
Rear	N/A	N/A	4103	4048
Total	N/A	N/A	6493	6418

2.4 Ballast

	Weights		Water
	Number	Total mass	
		kg	kg
Front	N/A	N/A	N/A
Rear	N/A	N/A	N/A
Optional	N/A	N/A	N/A

3.2.2 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Category 3N, 2 x 80 mm cylinders, Top Link in Middle Hole
Date of test: 13-Nov-13

	at the hitch point	on the frame
Height of lower hitch points above ground in down position	229 mm	194 mm
Vertical movement - without load	738 mm	885 mm
with load	684 mm	842 mm
Maximum corrected force exerted through full range	46.5 kN	36.3 kN
Corresponding pressure of hydraulic fluid	18.4 MPa	18.3 MPa
Moment about rear-wheel axis	53 kNm	63 kNm
Maximum tilt angle of mast from vertical	---- °	11.1 °

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-387	-302	-207	-103	1	96	195	260	272	281	292	297
Corrected lift forces at the Hitch points:												
kN	46.5	46.9	47.7	48.6	49.6	50.7	51.9	52.2	52.3	52.2	51.7	51.7
Corresponding pressure: 18.4												
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-422	-335	-228	-106	9	135	268	359	375	392	403	421
Corrected lift forces at the frame:												
kN	43.9	43.4	42.8	42.2	41.5	40.6	39.3	38.1	37.8	37.4	37.2	36.3
Corresponding pressure: 18.3												

4.3 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Category 3N, 2 x 80 mm cylinders, Top Link in Top Hole
Date of test: 13-Nov-13

	at the hitch point	on the frame
Height of lower hitch points above ground in down position	229 mm	229 mm
Vertical movement - without load	738 mm	810 mm
with load	684 mm	785 mm
Maximum corrected force exerted through full range	46.5 kN	40.0 kN
Corresponding pressure of hydraulic fluid	18.4 MPa	18.3 MPa
Moment about rear-wheel axis	53 kNm	70 kNm
Maximum tilt angle of mast from vertical	---- °	* 8.9 °

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-387	-302	-207	-103	1	96	195	260	272	281	292	297
Corrected lift forces at the Hitch points:												
kN	46.5	46.9	47.7	48.6	49.6	50.7	51.9	52.2	52.3	52.2	51.7	51.7
Corresponding pressure: 18.4												
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-387	-305	-199	-91	15	133	254	339	356	382	392	398
Corrected lift forces at the frame:												
kN	48.5	46.8	46.2	45.6	44.9	43.9	42.6	41.4	41.0	40.3	40.2	40.0
Corresponding pressure: 18.3												

*Maximum observed tilt angle with settings used

4.4 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Categoy 3N, 2 x 85mm cylinders, Top Link in Mid Hole
Date of test: 14-Nov-13

	at the hitch point	on the frame
Height of lower hitch points above ground in down position	230 mm	195 mm
Vertical movement - without load	738 mm	885 mm
with load	682 mm	837 mm
Maximum corrected force exerted through full range	52.1 kN	41.3 kN
Corresponding pressure of hydraulic fluid	18.3 MPa	18.3 MPa
Moment about rear-wheel axis	59 kNm	72 kNm
Maximum tilt angle of mast from vertical	--- °	11.3 °

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-386	-302	-206	-104	-4	99	197	259	291	296		
Corrected lift forces at the Hitch points:												
kN	52.1	52.6	53.6	54.7	55.7	57.0	58.3	58.6	58.3	57.9		
Corresponding pressure: 18.3												
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-421	-332	-223	-108	13	141	274	362	407	417		
Corrected lift forces at the frame:												
kN	48.5	47.5	47.5	47.3	46.6	45.7	44.2	42.7	41.7	41.3		
Corresponding pressure: 18.3												

4.5 POWER LIFT TEST

Tractor tested: John Deere 6150M
Tractor Setup: Categoy 3N, 2 x 85mm cylinders, Top Link in Top Hole
Date of test: 14-Nov-13

	at the hitch point	on the frame
Height of lower hitch points above ground in down position	230 mm	229 mm
Vertical movement - without load	738 mm	810 mm
with load	682 mm	778 mm
Maximum corrected force exerted through full range	52.1 kN	45.2 kN
Corresponding pressure of hydraulic fluid	18.3 MPa	18.3 MPa
Moment about rear-wheel axis	59 kNm	79 kNm
Maximum tilt angle of mast from vertical	---- °	* 8.7 °

Lifting heights at hitch point relative to the horizontal plane including the lower link pivot points:												
mm	-386	-302	-206	-104	-4	99	197	259	296			
Corrected lift forces at the Hitch points:												
kN	52.1	52.6	53.6	54.7	55.7	57.0	58.3	58.6	57.9			
Corresponding pressure: 18.3												
Lifting heights at frame relative to the horizontal plane including the lower link pivot points:												
mm	-387	-308	-203	-95	17	135	252	339	391			
Corrected lift forces at the frame:												
kN	53.6	51.8	51.1	50.6	49.8	49.7	47.9	46.4	45.2			
Corresponding pressure: 18.3												

*Maximum observed tilt angle with settings used

OECD. (2013)