Matching Tractor Horsepower and Farm Implement Size
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FARMING KNOW-HOW

Guidelines to Better Family Farming

Matching Tractor Horsepower and Farm Implement Size

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Obtaining a satisfactory match between tractor horsepower and implement size is an important phase of farm machinery management on both large and small farms. Implements that are too large for the horsepower available will cause tractor overloading, excessive tire slippage, a higher incidence of tractor breakdowns, and unsatisfactory performance in general. Implements that are too small will result in inefficient operation, low production, and increased costs — and may encourage the operator to use a ground speed too high for either good machine performance or safety.

Due to the wide range of implements found on any one farm, it is seldom possible to match all implements perfectly to the tractor horsepower available. The objective should be to match as effectively as possible the tractor horsepower available and the power requirements of the majority of the "heavy-draft" machines. Obviously, some of the lighter-draft machines will not utilize all of the tractor power available. With light-draft machines, select an implement size that is convenient to use, or adequate for the job to be done, recognizing that there may be a distinct mismatch between the horsepower of the tractor and the power requirements of the machine. If more than one tractor is available, plan to use those machines with low power requirements with a smaller tractor.

TRACTOR HORSEPOWER

Currently, most farm tractors are rated powerwise according to the maximum observed power-take-off (PTO) horsepower, as determined by the Nebraska Tractor Tests. Therefore, when one casually states that he owns a 100-horsepower tractor, he usually means that the tractor is capable of delivering 100 horsepower at the PTO outlet. It should be pointed out, however, that a significant part of this 100 horsepower **is not** available for drawbar use in the field. The question then becomes, where does this part of the horsepower go, and **how much** is actually left available for use in field operations?

It should be pointed out that some of the larger four-wheel-drive tractors do not have a PTO outlet and, therefore, do not have a maximum observed PTO horsepower rating in the Nebraska Tractor Test Reports. For these units, multiplying the maximum observed **drawbar** horsepower by a factor of 1.2 will give a very close approximation of the maximum observed PTO horsepower potential.

HORSEPOWER LOSSES

Drawbar horsepower is the horsepower actually available to be transmitted by traction through the tractor drawbar to the implement. Drawbar horsepower is always less than the PTO horsepower. This is due to a combination of power losses through the transmission train and "rolling resistance" and slippage losses of the tires when operating on a traction surface.

At the Nebraska Tractor Test site, the traction surface for drawbar tests is always concrete. According to Nebraska Tractor Test figures, these losses average approximately 15 percent, leaving roughly 85 percent of the maximum observed PTO horsepower available for use at the tractor drawbar, when operating on concrete. But since we are dealing with **maximum** observed PTO horsepower, it is neither practical nor advisable to load the tractor to the **maximum** for normal field operations.

Variations in soil and soil moisture conditions, slopes, safety requirements, etc., make it mandatory to hold some horsepower in reserve to take care of fluctuating load situations which **always** occur in normal field operations. Standard practice indicates that a power reserve of 17 percent of the original 100 per-

Table 1—Where the PTO Horsepower Goes.

Power Application	Traction condition			
	Concrete	Firm Soil*	Tilled Soil†	Loose Soil‡
	Percent	Percent	Percent	Percent
Maximum observed PTO horsepower (Nebraska Tractor Test Data expressed as a percent)	100.0	100.0	100.0	100.0
Less losses in transmitting power to wheels, and rolling resistance and slippage losses on concrete	−15.0	−15.0	−15.0	−15.0
Maximum potential horsepower available at tractor drawbar	85.0	85.0	85.0	85.0
Deductions for overload reserve, emergency, and safety	−17.0	−17.0	−17.0	−17.0
Potential usable drawbar horsepower	68.0	68.0	68.0	68.0
Power losses due to rolling resistance and tire slippage, as affected by the traction surface	− 0.0	− 5.5	−13.0	−20.5
Drawbar horsepower actually available to the implement	68.0	62.5	55.0	47.5

**Firm, undisturbed soil, such as corn stubble, wheat stubble, hay fields.*

†Soil that has been tilled and worked down to seed bed condition ready for planting.

‡Soil that has been recently tilled with a moldboard plow or similar soil-loosening tool.

cent (or 20 percent of the remaining 85 percent) should be held in reserve to meet these situations. Deducting this 17 percent now leaves 68 percent of the original 100 percent available for use at the tractor drawbar **when operating on concrete** (Table 1).

In the field, however, soil conditions vary widely—from firm, compact soil to very loose, freshly tilled soil. It may also be very dry or at times very wet. These factors and others all affect the "rolling resistance," or the amount of power required just to move the tractor over the traction surface. They also affect tire slippage, which tends to increase as the drawbar load increases. Roughly speaking, approximately 5.5 percent of the total maximum observed PTO horsepower is required to overcome these losses when the tractor is moving over firm soil, 13 percent over tilled soil (prepared seed bed) and 20.5 percent over loose, freshly plowed soil. What is left is **usable drawbar horsepower** (DBHP)—the horsepower that is actually available at the tractor drawbar for use by an implement. As shown in Table 1, there will be approximately 62.5 percent of the original maximum observed PTO horsepower available for implement use when operating on firm soil, 55.0 percent on tilled soil, and 47.5 percent on loose soil.

These are the horsepower figures that must be used when selecting the size of implement to go with a given tractor. This information is shown graphically in Figure 1.

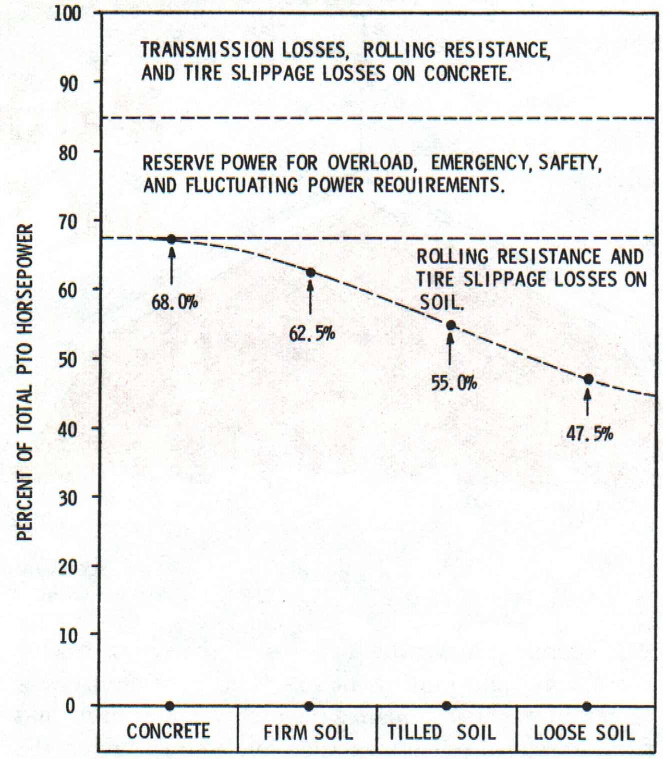

Figure 1. Where the PTO horsepower goes. Net drawbar horsepower available for use at the tractor drawbar on four surface conditions.

POWER REQUIREMENTS OF IMPLEMENTS

"Horsepower" is a measure of the rate at which work is being performed. By definition, one horsepower is equal to 33,000 foot-pounds of work per minute. Continuing to work at this rate for one hour is equal to one horsepower-hour. Thus, if one knows the approximate pounds of pull per unit of width required to move an implement through the soil, and knows the operating speed in miles per hour, the drawbar horsepower required can be calculated from this simplified equation:

$$\frac{\text{Pounds pull}^1 \times \text{speed (MPH)}}{375} = \text{Drawbar horsepower required}^1$$

In most instances, the unit of width will be one foot, but in some cases it may be one inch or one row.

The drawbar horsepower (DBHP) requirements per foot of width (or per row) for some of the more common farming operations are shown in Table 2.

MATCHING TRACTOR AND IMPLEMENT

It is now possible to select the proper implement size for a tractor of a given horsepower, or to select a tractor of the proper horsepower output for use with an implement of a given size. We will use two examples: **Example 1,** to select a moldboard plow size

[1]*Per unit of implement width.*

Table 2 — Drawbar Horsepower Requirements per Foot of Implement Width for Selected Farm Machines.*

Operation	Draft	Speed	DBHP
	(lbs. per foot of width)	(miles per hour)	(per foot of width)
Shred stalks	200	5.0	2.7
Moldboard plow (8-in. plowing depth):			
Coarse-textured soils (sandy)	450	4.5	5.4
Medium-textured soil (loam)	750	4.5	9.0
Fine-textured soils (clay loam)	1,050	4.5	12.6
Tiller behind plow	260	4.5	3.1
Chisel plow	720	4.5	8.6
Heavy-duty disk	620	4.5	7.5
Tandem disk harrow:			
1st pass, plowed ground	340	4.0	3.6
2nd pass, plowed ground	280	4.5	3.4
Stalk ground	250	4.5	3.0
Spring-tooth harrow	270	5.0	3.6
Field cultivator	240	5.5	3.5
Roller-packer	140	6.0	2.4
Mulcher-packer	280	5.0	3.7
Row crop planting:			
Conventional tillage	385†	4.5	4.6†
No-till tillage	540†	3.0	4.3†
Grain drill	115	4.0	1.3
Rotary hoe	110	7.0	2.3
Cultivator	150	3.5	1.4
Sprayer	40	6.5	.7
Bean puller	375†	3.0	3.0†
Bean windrower	100†	3.0	.8†
Beet topper	600†	3.5	5.6†
Beet harvester	3,200†	3.0	25.6†
Potato harvester	2,800†	2.5	18.7†

**For machines not listed in this table, select one from the list that is most comparable with the one in question and make any adjustments up or down, as judgment or experience seems to dictate.*

†Per row, not per foot of machine width.

for use with a 60 PTO horsepower tractor; and **Example 2,** to determine the tractor PTO horsepower size required to handle an 8-foot tandem disk on freshly plowed soil.

EXAMPLE 1

How large a moldboard plow can a 60-PTO horsepower tractor handle in medium-textured soil when plowing at a depth of 8 inches, at a speed of 4.5 miles per hour?

From Table 1, we find that on firm soil, a tractor can be expected to deliver approximately 62.5 percent of its maximum observed PTO horsepower to the tractor drawbar for use by the implement. Thus:

$$60\text{-PTO HP} \times 62.5\% = 37.5 \text{ DBHP available for the plow.}$$

From Table 2, we find that when plowing at a depth of 8 inches in medium-textured soil at a speed of 4.5 miles per hour, approximately 9.0 drawbar horsepower per foot of plow width is required.

$$\frac{37.5 \text{ DBHP}}{9.0 \text{ DBHP per foot}} = 4.17 \text{ feet, or } 50.0 \text{ inches of plow width.}$$

From this it appears that a 3-bottom, 16-inch plow (48 inches of plow width) would be the most appropriate plow size. Certainly, a 4-bottom, 14-inch plow (56 inches of plow width) would overload the tractor under the stated operating conditions.

EXAMPLE 2

How large a tractor would be required to handle an 8-foot tandem disk when disking freshly plowed ground (first disking) at a speed of 4.0 miles per hour?

From Table 2, we find that on freshly plowed soil, a tandem disk requires a drawbar pull of approximately 340 pounds per foot of width, when operating at 4.0 miles per hour. Using the Horsepower Equation mentioned earlier, we find:

$$\frac{340 \text{ pounds pull} \times 4.0 \text{ mph}}{375} = 3.63 \text{ DBHP per foot of disk width.}$$

It then follows that for an 8-foot disk:

$$3.63 \text{ DBHP/ft} \times 8.0 \text{ ft} = 29.0 \text{ DBHP for the 8-foot tandem disk.}$$

From Table 1, we find that only approximately 47.5 percent of the maximum observed tractor PTO horsepower is available for implement use when the tractor is operating on freshly plowed soil. Thus:

$$\frac{29.0 \text{ DBHP}}{47.5\%} = 61.1 \text{ PTO horsepower.}$$

Thus, we find that a 61.1-PTO horsepower tractor is the size that should be used to pull an 8-foot tandem disk when operating under the stated conditions. Due to the fact that we have allowed for a 17-percent power reserve, a 60.0-PTO horsepower tractor would, undoubtedly, substitute satisfactorily in this situation.

By following these examples, it should be fairly easy to match tractor power and implement size for a wide range of farming operations. It should be possible to determine implement size for a given tractor horsepower or to determine the tractor horsepower required for an implement of a given size.

GENERAL

As seen in the above examples, it is seldom possible to obtain a "perfect" match between tractor power and implement size. Variables such as soil variations from one part of a field to another, soil moisture variations, soil compaction, tractor engine wear, tire wear, and a host of other things make this impossible. It is possible, however, to match tractor power and implement power requirements sufficiently close for satisfactory performance of both the tractor and the implement.

The following suggestions should be used as guidelines in making final decisions on matching tractor power to implement size:

1. Calculations for implement sizes seldom come out in whole units. For example, you cannot use a 4.6-bottom plow or a 6.3-row corn planter. As a rough rule of thumb, unless circumstances dictate otherwise, go to the nearest whole unit.
2. Abnormally high operating speeds **may** affect implement performance, and **do** affect power requirements. A 10-percent increase in ground speed will cause **more** than a 10-percent increase in horsepower requirements.
3. Do not match power and implements for the toughest part of your farm. Aim to match for average conditions, and reduce ground speed or call on the 17-percent power reserve to handle the tougher areas.
4. Do not deliberately plan to under-power your equipment. This will cause excessive engine wear and tire slippage, and will increase fuel consumption.
5. Wherever possible, make minor adjustments in operating speed to utilize the available tractor horsepower efficiently.
6. Where two or more tractor sizes are available, plan to use light-draft implements with the smaller tractor.
7. It is sometimes not practical to purchase a light-draft implement that is large enough to utilize all of the potential tractor horsepower. With these light loads, plan to throttle back and shift to a higher gear to maintain the desired ground speed. (This cannot be done where the PTO is in use, and a constant PTO speed is required.) Never throttle back to the point where the tractor engine is lugging, or operating at less than 50 percent of the rated engine speed (full-load, governed RPM).

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