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Gear Up and Throttle Down — Saving Fuel

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"Gear Up and Throttle Down" is a fuel-saving practice suitable for light drawbar loads (less than 65 percent of full power) when reduced PTO speed is not a problem.

For the most efficient operation, a tractor's engine should be operated near its rated capacity. However, there are many field operations (such as light tillage, planting, cultivating, and hay raking) that do not require full tractor power. This is especially true when older implements, which were sized for a smaller tractor, are used with higher horsepower tractors. Also, many operations should be performed at a fixed field speed.

For these lighter operations, a substantial amount of fuel can be saved by shifting to a faster gear and slowing the engine speed to maintain the desired field speed, or "Gear Up and Throttle Down." An example of this procedure is shifting a manual transmission car or truck from second to third gear while reducing the throttle setting to maintain travel speed.

General Operating Guidelines for "Gear Up and Throttle Down"

1. Consider "Gear Up and Throttle Down" on light load operations (typically those requiring less than 65 percent of full engine power).

2. Stay within the engine RPM working range specified in the operator's manual.

3. Select a faster gear to maintain travel speed and implement productivity while reducing engine RPM.

4. Do not overload the engine. Check the engine response to the throttle setting and drawbar load.

Work, Power, Energy, and Efficiency

The fundamental definition of work is moving a weight or a force over a distance. "Foot-pound" (abbreviated ft-lbf) is a common unit of measurement for work. For example, to lift a 55 pound object 10 feet would require 550 ft-lbf of work. In the case of a tractor, if a force (ie. drawbar pull) of 3,300 pounds is needed to pull a disk and the disk is pulled 10 feet, then 33,000 ft-lbf of work would be done.

Power is the amount of work done in a given period of time. If the 55 pound object was lifted 10 feet in one second, the power required would be 550 ft-lbf/sec. Similarly, if it takes one minute to pull the disk 10 feet, the power required is 33,000 ft-lbf/min. The unit of measurement for power is horsepower. One horsepower equals 550 ft-lbf/sec or 33,000 ft-lbf/min. Both of the examples required 1 horsepower to complete the task.

Energy is the capacity to do work. For tractors, gallons of fuel consumed is a measure of the amount of energy used.

A measure of efficiency is the amount of work done divided by the amount of energy used. For tractors, horsepower-hour (hp-hr) is the standard measure of work done. One hp-hr is one horsepower expended over one hour, which is equivalent to 1,980,000 ft-lbf of work. Horsepower-hours per gallon (hp-hr/gal) of fuel is a common measure of tractor engine efficiency. Hp-hr/gal can be calculated from either PTO (power-take-off) or drawbar power. The hp-hr/gal values from the PTO tests will be higher than the drawbar observations due to transmission inefficiencies.

Specific fuel consumption (hp-hr/gal) is not generally affected by engine size and can be used to compare the fuel efficiency of different sizes of tractors. Higher

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values of hp-hr/gal indicate greater fuel efficiency in the same way that higher miles per gallon indicate a better fuel economy for highway vehicles. For diesel tractor engines, 13.5 hp-hr/gal would be an average fuel efficiency for drawbar loads while a very efficient tractor can achieve 18.5 hp-hr/gal for loads on the PTO. Increased fuel efficiency is the advantage of "Gear Up and Throttle Down" practice.

DRAWBACK — PTO Operations

There are a few drawbacks with "Gear Up and Throttle Down." When engine speed is reduced, reaction time of the tractor hydraulics will be slower, and PTO speed is correspondingly reduced. When PTO speed is reduced, the PTO-driven device may have unacceptable performance and/or reduced productivity. For some load conditions, reduced PTO speeds can reduce the PTO-driven unit's life and cause failure of drive lines.

Tractor Test Data

The fuel saving benefit of the "Gear Up and Throttle Down" practice is confirmed by the University of Nebraska Tractor Tests. Information on fuel efficiency is given in five of the drawbar performance tests (see two examples in Figures 1 and 2).

- Test-1: Maximum Available Drawbar Power. In a gear selected by the manufacturer, the pull and travel speed are measured and used to determine maximum available power. This test is performed at full throttle.

- Test-2: 75 Percent of Pull at Maximum Drawbar Power. In the same gear and at full throttle, the tractor is operated at 75 percent of the pull measured in Test-1.

- Test-3: 75 Percent of Pull at Reduced Engine Speed. The tractor is operated in a faster gear with a reduced throttle setting. Pull and travel speeds are maintained about the same as in Test-2.

- Test-4: 50 Percent of Pull at Maximum Drawbar Power. In the same gear as Test-1 and at full throttle, the tractor is operated at half of the pull measured in Test-1.

- Test-5: 50 Percent of Pull at Reduced Engine Speed. The tractor is operated in a faster gear with a reduced throttle setting. Pull and travel speeds are about the same as in Test-4.

During Test-3, most tractors use between 5 and 15 percent less fuel than during Test-2, while during Test-5, most tractors use between 15 and 30 percent less fuel than during Test-4. Only the throttle setting and operating gear changed between each of these two tests.

Test data from more than 700 diesel tractors are summarized in Tables 1 and 2. These tractors were tested at the University of Nebraska Tractor Test Lab or tested from other OCED (Organization of Economic Cooperation and Development) test stations during the last 20 years. Comparing the results of Tests 4 and 5, the advantage of using the "Gear Up and Throttle Down" practice is illustrated. Remember, travel speed, drawbar pull, and drawbar horsepower were the same for these two tests. Only a change in throttle and gear settings occurred. In Test-5, engine speed was reduced by an average of 27 percent; fuel consumption dropped an average of 18 percent and fuel efficiency increased 23 percent over the full throttle setting of Test-4.

Normally, "Gear Up and Throttle Down" can be used when loads require less than 65 percent of a tractor's power. It is generally safe to reduce engine RPM by 20 to 30 percent of the rated RPM. Check the Operator's Manual for specific recommendations for your tractor.

There is no justification for operating either turbocharged or naturally aspirated engines at full throttle when full drawbar horsepower is not required. Most tractor manufacturers indicate that the "Gear Up and Throttle Down" practice is suitable for their tractors and recommend the practice for fuel savings. Further, this practice could decrease maintenance, downtime, and expenses generally incurred from over-speeding mechanical equipment.

CAUTION — Do Not Overload the Tractor

When using the practice of "Gear Up and Throttle Down," the most important thing to remember is NOT to overload or lug the engine. Overloading the engine requires the engine to produce more torque at a low engine speed than it is designed for. Excessive black exhaust smoke is one indication of an overloaded diesel engine. To check the engine for overloading, work the tractor for a short time at the desired speed and throttle setting. Then, rapidly open the throttle. If the engine readily picks up speed, it is not overloaded, and the original throttle setting is suitable. If the engine does not respond quickly, shift down a gear or increase the engine speed. Again, check for engine overload at the new settings.

EXAMPLE —
Tractor Selection and Sizing

Suppose an operation requires 165 drawbar horsepower. You have a choice between two tractors. The first is rated at 165 drawbar horsepower (Figure 1) and the second at 314 drawbar horsepower (Figure 2). Should you use the small tractor at full throttle and full load, the large tractor at full throttle and 50 percent load, or the large tractor at 50 percent load but using "Gear Up and Throttle Down?"

Table 3 shows that the small tractor has good fuel efficiency (15.5 hp-hr/gal). The savings is over 2 gal/hr compared to the full throttle operation of the large tractor. But note that a significant savings (1 gal/hr) exists between the fuel used by the small tractor (10.66 gal/hr) and the large tractor (9.69 gal/hr) using the "Gear Up and Throttle Down" procedure. So in this comparison using "Gear Up and Throttle Down" procedures the larger tractor is more fuel efficient than the smaller. This example shows that a large tractor sized properly for a light load will use about the same amount or less fuel as a tractor half the size operating at full load. An added gain is the increased annual usage of the large tractor which helps spread the costs of owning a large tractor over more annual hours of use.

Remember, fuel consumption and specific fuel consumption can vary widely for individual tractor models. Consult the University of Nebraska Tractor Test Reports for your specific tractors when making an efficiency selection. Keep accurate records of the fuel usage of all tractors under a variety of operating conditions. With accurate records, an equipment system manager will be able to select the most economical tractor for a specific operation.

Remove Extra Ballast

Extra weight is used to properly ballast a tractor for field operations to achieve the optimum tractive conditions. Heavy draft loads require more ballast than lighter loads. If it is convenient for light loads, remove extra ballast to reduce rolling resistance and improve fuel economy as well as reduce the potential for soil compaction.

Summary

The fuel saving practice of "Gear Up and Throttle Down" involves reducing engine speed to 70 to 80 percent of rated engine speed, and shifting to a faster gear to maintain the desired field speed and implement productivity. This practice is suitable for light drawbar loads (less than 65 percent of full power) when reduced PTO speed is not a problem. Remember, DO NOT overload the engine.

If you "Gear Up and Throttle Down" whenever possible, you will be on your way toward getting the most for your fuel dollars.

For Tractor Test Information Contact:
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Table 3. Typical tractor size and operation comparison.

	Small[1] MFWD tractor	Large[2] 4WD tractor	Large[2] 4WD tractor
Throttle setting	Full	Full	Reduced
Percent load	100%	50%	50%
Drawbar Power (hp)	165.0	165.03	165.54
Fuel Consumption (gal/hr)	10.66	12.75	9.69
Fuel Efficiency (hp-hr/gal)	15.5	12.94	17.08

[1]John Deere 8210 (NTTL 1773-Summary 308), PTO-hp = 187.29 hp (Figure 1)
[2]Case IH STX 375 (NTTL 1783-Summary 335), PTO-hp = 337.93 hp (Figure 2)

Table 1. Average performance of two-wheel-drive (2WD) and mechanical-front-wheel-drive (MFWD) diesel tractors.

	Range of PTO Power (hp)				
Average	**<40**	**40-80**	**80-120**	**120-160**	**>160**
2WD					
PTO-Horsepower	28.1	58.6	98.9	137.0	172.4
Drawbar Horsepower (Concrete)	23.5	48.7	84.9	118.6	148.5
Test-1, Fuel Consumption (gal/hr)	2.0	3.7	6.3	8.4	10.6
Test-1, Fuel Efficiency (hp-hr/gal)	11.6	13.1	13.6	14.2	14.0
Test-4, Drawbar Power (hp)	13.2	27.1	46.4	65.6	81.0
Test-4, Fuel Consumption (gal/hr)	1.4	2.6	4.3	6.0	7.2
Test-5, Drawbar Power (hp)	13.2	27.0	46.5	65.6	81.2
Test-5, Fuel Consumption (gal/hr)	1.1	2.0	3.5	4.8	5.9
Reduction of Engine Speed (%)[1]	32.7	30.3	29.7	29.0	27.4
Decrease in Fuel Consumption (%)[1]	20.7	19.6	18.9	20.0	18.0
Increase in Fuel Efficiency (%)[1]	26.5	24.5	24.3	26.0	23.0
Number of Tractors	23	55	52	29	19
MFWD-Disengaged					
PTO-Horsepower	26.1	59.1	97.8	136.1	170.6
Drawbar Horsepower (Concrete)	21.1	49.2	81.6	118.4	143.8
Test-1, Fuel Consumption (gal/hr)	1.8	3.7	5.9	8.4	10.4
Test-1, Fuel Efficiency (hp-hr/gal)	11.5	13.2	13.7	14.2	13.9
Test-4, Drawbar Power (hp)	11.9	27.3	44.5	64.0	78.7
Test-4, Fuel Consumption (gal/hr)	1.3	2.5	4.1	5.8	7.1
Test-5, Drawbar Power (hp)	12.0	27.3	44.5	63.9	78.6
Test-5, Fuel Consumption (gal/hr)	1.0	2.0	3.3	4.7	5.7
Reduction of Engine Speed (%)[1]	32.3	30.1	27.5	25.4	27.7
Decrease in Fuel Consumption (%)[1]	17.9	18.3	19.4	18.5	19.6
Increase in Fuel Efficiency (%)[1]	22.1	22.9	24.7	23.0	24.5
Number of Tractors	22	69	45	35	6
MFWD - Engaged					
PTO-Horsepower	37.3	60.7	96.8	138.3	189.8
Drawbar Horsepower (Concrete)	30.4	51.1	82.7	121.2	163.4
Test-1, Fuel Consumption (gal/hr)	2.5	3.8	5.9	8.4	11.2
Test-1, Fuel Efficiency (hp-hr/gal)	12.4	13.3	14.1	14.5	14.7
Test-4, Drawbar Power (hp)	16.6	27.6	44.0	65.2	88.6
Test-4, Fuel Consumption (gal/hr)	1.8	2.7	4.1	5.8	7.5
Test-5, Drawbar Power (hp)	16.5	27.6	44.1	65.1	88.6
Test-5, Fuel Consumption (gal/hr)	1.5	2.2	3.4	4.8	6.3
Reduction of Engine Speed (%)[1]	27.4	23.0	20.7	22.4	21.7
Decrease in Fuel Consumption (%)[1]	17.2	15.7	16.0	16.8	15.6
Increase in Fuel Efficiency (%)[1]	20.6	19.4	19.8	20.6	19.1
Number of Tractors	4	60	86	55	51

[1]Comparison of the results from Test-4 and Test-5.

Table 2. Average performance of four-wheel-drive (4WD) and rubber-belted tracks diesel tractors.

	Range of PTO Power (hp)					
Average	**80-120**	**120-160**	**160-200**	**200-240**	**240-280**	**>280**
PTO-Horsepower	98.6	144.2	181.3	217.0	261.6	330.8
Drawbar Horsepower (Concrete)	70.5	121.7	157.7	192.1	233.4	297.5
Test-1, Fuel Consumption (gal/hr)	6.4	9.2	11.3	13.0	15.5	19.1
Test-1, Fuel Efficiency (hp-hr/gal)	11.1	13.2	14.1	14.8	15.1	15.6
Test-4, Drawbar Power (hp)	40.4	67.6	85.8	104.2	127.8	162.6
Test-4, Fuel Consumption (gal/hr)	4.7	6.7	8.0	8.9	10.9	13.1
Test-5, Drawbar Power (hp)	40.2	67.6	85.7	104.1	127.9	162.7
Test-5, Fuel Consumption (gal/hr)	3.9	4.8	6.2	7.3	8.6	10.7
Reduction of Engine Speed (%)[1]	26.4	43.4	31.4	27.3	31.5	28.4
Decrease in Fuel Consumption (%)[1]	18.7	27.6	21.6	17.4	20.3	18.0
Increase in Fuel Efficiency (%)[1]	23.0	38.4	28.9	21.7	26.5	22.7
Number of Tractors	4	3	19	29	23	44

[1]Comparison of the results from Test-4 and Test-5.

Figure 1. The Power-Take-Off and Drawbar Performance Results from John Deere 8210 (NTTL Summary #308).

Nebraska OECD Tractor Test 1773-Summary 308
John Deere 8210 Diesel
16 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-1109 rpm)					
187.29 *(139.66)*	2200	10.73 *(40.63)*	0.405 *(0.246)*	17.45 *(3.44)*	
Maximum Power (2 hours)					
214.65 *(160.07)*	2000	11.47 *(43.41)*	0.378 *(0.230)*	18.72 *(3.69)*	
Varying Power and Fuel Consumption					
187.29 *(139.66)*	2200	10.73 *(40.63)*	0.405 *(0.246)*	17.45 *(3.44)*	Air temperature
162.8 *(121.40)*	2253	9.81 *(37.12)*	0.426 *(0.259)*	16.60 *(3.27)*	78°F *(26°C)*
122.78 *(91.56)*	2264	7.98 *(30.21)*	0.459 *(0.279)*	15.38 *(3.03)*	Relative humidity
82.26 *(61.34)*	2274	6.24 *(23.62)*	0.536 *(0.326)*	(3.03) *(2.60)*	39%
41.36 *(30.85)*	2284	4.46 *(16.87)*	0.762 *(0.463)*	9.28 *(1.83)*	Barometer
1.00 *(0.75)*	2291	2.76 *(10.45)*	19.489 *(11.855)*	0.36 *(0.07)*	28.55" Hg *(96.68 kPa)*

Maximum Torque 667 lb.-ft. *(905 Nm)* at 1100 rpm
Maximum Torque Rise 49.4%
Torque rise at 1800 engine rpm 36%

Drawbar Performance
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 Gear									
Test - 1	165 *(123.18)*	14419 *(64.14)*	4.30 *(6.91)*	2199	5.22	0.456 *(0.277)*	15.50 *(3.05)*	195 *(91)*	65 *(18)*	28.95 *(98.04)*
	75% of Pull at Maximum Power-7th Gear									
Test - 2	129.15 *(96.31)*	10802 *(48.05)*	4.48 *(7.22)*	2258	3.53	0.499 *(0.303)*	14.17 *(2.79)*	190 *(88)*	73 *(23)*	28.96 *(98.07)*
	75% of Pull at Reduced Engine Speed-9th Gear									
Test - 3	129.18 *(96.33)*	10817 *(48.11)*	4.48 *(7.21)*	1773	3.80	0.430 *(0.262)*	16.43 *(3.24)*	191 *(88)*	72 *(22)*	28.96 *(98.07)*
	50% of Pull at Maximum Power-7th Gear									
Test - 4	87.78 *(65.45)*	7211 *(32.08)*	4.56 *(7.35)*	2268	2.53	0.571 *(0.347)*	12.37 *(2.44)*	187 *(86)*	72 *(22)*	28.95 *(98.04)*
	50% of Pull at Reduced Engine Speed-9th Gear									
Test - 5	87.62 *(65.34)*	7211 *(32.08)*	4.56 *(7.33)*	1779	2.47	0.480 *(0.292)*	14.74 *(2.90)*	187 *(86)*	71 *(22)*	28.95 *(98.04)*

Figure 2. The Power-Take-Off and Drawbar Performance Results from Case IH 375 (NITL Summary #335).

Nebraska OECD Tractor Test 1783-Summary 335
Case IH STX 375 Diesel
16 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-1006 rpm)					
337.93 *(252.00)*	2000	19.07 *(72.17)*	0.396 *(0.241)*	17.73 *(3.49)*	
Maximum Power (2 hours)					
386.64 *(288.32)*	1600	19.06 *(72.15)*	0.346 *(0.210)*	20.28 *(4.00)*	
Varying Power and Fuel Consumption					
337.93 *(252.00)*	2000	19.07 *(72.17)*	0.396 *(0.241)*	17.73 *(3.49)*	Air temperature
293.69 *(219.00)*	2042	17.44 *(66.03)*	0.417 *(0.254)*	16.84 *(3.32)*	75°F *(24°C)*
222.37 *(165.82)*	2065	14.41 *(54.54)*	0.455 *(0.277)*	15.43 *(3.04)*	Relative humidity
149.15 *(111.22)*	2079	11.46 *(43.37)*	0.539 *(0.328)*	13.02 *(2.56)*	22%
75.50 *(56.30)*	2111	8.42 *(31.88)*	0.783 *(0.476)*	8.96 *(1.77)*	Barometer
1.02 *(0.76)*	2134	5.43 *(20.55)*	37.472 *(22.793)*	0.19 *(0.04)*	29.21" Hg *(98.82 kPa)*

Maximum Torque 1325 lb.-ft. *(1797 Nm)* at 1198 rpm
Maximum Torque Rise 49.5%
Torque rise at 1600 engine rpm 43%

Drawbar Performance
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 5th Gear										
Test - 1	313.95 *(234.12)*	23889 *(106.26)*	4.93 *(7.93)*	1997	2.89	0.428 *(0.260)*	16.41 *(3.23)*	187 *(86)*	63 *(17)*	29.08 *(98.48)*
75% of Pull at Maximum Power 5th Gear										
Test - 2	242.79 *(181.05)*	17857 *(79.43)*	5.10 *(8.21)*	2052	2.16	0.472 *(0.287)*	14.86 *(2.93)*	185 *(85)*	66 *(19)*	29.05 *(98.37)*
75% of Pull at Reduced Engine Speed 8th Gear										
Test - 3	243.17 *(181.33)*	17843 *(79.37)*	5.11 *(8.22)*	1555	2.16	0.371 *(0.225)*	18.93 *(2.73)*	179 *(82)*	66 *(19)*	29.05 *(98.37)*
50% of Pull at Maximum Power 5th Gear										
Test - 4	165.03 *(123.06)*	11901 *(52.94)*	5.20 *(8.37)*	2081	1.61	0.542 *(0.330)*	12.94 *(2.55)*	181 *(83)*	65 *(18)*	29.05 *(98.37)*
50% of Pull at Reduced Engine Speed 8th Gear										
Test - 5	165.54 *(123.44)*	11903 *(52.94)*	5.22 *(8.39)*	1574	1.52	0.411 *(0.250)*	17.08 *(3.36)*	179 *(82)*	64 *(18)*	29.05 *(98.37)*