Fast Sled Propulsion (7/30/2023 by FSP Staff)

Hydrostatic Transmission Attributes

HYBRID EXAMPLE WITH INFINITELY VARIABLE TRANSMISSION

Note: ***Click on the superscript notations in the paragraphs below to bring up the respective Bibliography segment. To return to that specific paragraph section, click on the same enlarged notation within the Bibliography.***

TWO PARTS

For this Compound Electric Hybrid application, The Hydrostatic Transmission (HST) would consist of two integral components: a Hydraulic *Infinitely Variable Displacement Motor*, and an *Infinitely Variable Displacement Pump*. These should be high-efficiency rotary actuators with low inertia moving parts. Notably, the Pump would also be equipped with integrated reverse flow capability.[A1]

SPIN FROM INFINITY

The HST Motor is in a direct link with the vehicle axles by connection through the final drive gearing.[B1] Its operation is always synchronized with the wheel axle's RPM, turning in precise relationship with these axles. This means that if the vehicle attains a speed of 60mph, then the HST motor will correspondingly spin at a rate proportional to that – and change in direct proportion as the vehicle goes faster or slower.

Conversely, the HST Pump is directly connected to the Prime Mover power source,[B2] so it will always rotate at the same RPM as the Prime Mover (the fuel engine & electric motor combination). However, within the framework of this Hydrostatic Transmission, the Motor and the Pump do not maintain, or are in any way required to have, an absolute fixed RPM relationship between them. Instead, their essential synchronization revolves around aligning their flow rates (e.g., Gallons Per Minute), for the hydraulic fluid circulating between them.

This synchronization of flow rate is achieved by independently varying the displacement of these two units, just as their RPMs also vary independently. This capability ensures that the requisite flow rate matches, regardless of RPM at either end of the transmission. (Matching even if there is no rotation at either end.) Under pressure this approach makes possible the transmission of power and the associated Torque in an infinitely variable range of ratios between rpms of the Pump's input shaft and the Motor's output shaft.

And all that infinite & continuous flexibility can be started from a neutral zero displacement (or undefined infinity, following infinitely smaller displacement steps).

THE FORCE IS WITH US

Any Hydraulic Motor with a capacity of 334cc possesses the remarkable capability to generate 1,460 lb/ft. of Torque while operating at a working pressure of 5,400 psi. Furthermore, when the output shaft is also turning 1,800 RPM it seamlessly transmits 500 HP at full displacement.[C1] This output is similar to that of large Diesel Truck engines[C2], except for one crucial distinction: the Hydraulic Motor delivers the full 1,460 lb/ft of Torque instantly at a standstill of zero RPM's. This is a most important functional capability - eliminating the need to rev up to 900+ RPM for the start of maximum torque, as is typically required by a Diesel Engine. In this practice, Diesel engines not only waste fuel but also overheat and wear out the clutch, eventually leading to its failure.

This one of its many features truly distinguishes the HST. Its ability to sustain exceptional peak Torque even when the vehicle remains at an ongoing standstill or moves at a slow crawl, is a testament to the inherent smoothness of hydraulic systems. This function surpasses the performance of typical vehicle electric motors, which are prone to overheating and potential burnout under such demanding low speed conditions (e.g., Locked Rotor).[C3]

WIDE FULL POWER RATIO

A truly viable *"Infinitely Variable Hydrostatic Motor"* has the capability to increase RPM while proportionally decreasing displacement. This means that, under a constant psi working pressure, it can maintain the maximum power output consistently as described in the following example box below.

This remarkable feature ingeniously enables continuous transmission of a consistent power level while rpms are fluctuating. So, the power output can remain steadfast even as the vehicle's speed undergoes fluctuations affecting HST motor rpm - simply by corresponding displacement changes in both the HST pump & motor.

The ultimate objective is to attain the highest possible duty cycle horsepower output whenever needed, across a very broad range of RPM's. This pursuit attains the realization of a "Wide Full Power Ratio" unique to this system's versatility and effectiveness. And thereby delivering exceptional economy and efficiency for any Heavy Truck application.

Example Using the Previous Hydraulic Motor

Reaching 1,800 RPM's and operating at full displacement, while maintaining 5,400 psi working pressure, the motor throughput is at 500 horsepower. And as the vehicle accelerates to its top highway speed, the HST motor also increases to 9,000 RPM, while simultaneously decreasing its displacement in direct proportion.

This is an 80% displacement reduction above – but since pressure stays the same and so does the fluid flow due to increased RPM's – then the power throughput also stays the same at 500HP.

This dynamic displacement adjustment ensures that the power going out to the axles remains consistent throughout the transition to higher speeds, effectively modulating Torque and RPM in the same proportions. Seamlessly without steps or variations.

In this example, it has resulted in a remarkable *5:1 Full Power* ratio, showcasing an exceptionally "Wide Full Power Ratio" for an infinitely variable output. This method is used so the system can consistently apply the full needed horsepower while navigating tough highways, surmounting hills, or in any difficult scenario, regardless of vehicle speed, exemplifying its adaptability and performance.

(See also below in "Heavy Duty" about incredible Torque abilities)

THE BALANCING GAME

With the current realm of hydrostatic actuators having high inertia rotating groups, achieving the wide power ratio described above becomes an insurmountable challenge, necessitating innovation on these moving components. Analogous to a combustion engine, where the crankshaft incorporates lobes to mitigate forces during rotation and enable higher RPMs, the quest for a higher RPM range to achieve a "Wide Full Power Ratio" for the HST motor and HST pump - calls for both infinitely variable and harmoniously balanced rotating groups.

With such a configuration in place, it becomes possible to maintain consistent hydraulic pressure and fluid flow over this "Wide Full Power Ratio," thereby preserving the desired high-power output dispersed over this broad range of RPM fluctuations.

As an intriguing aside, even extremely diminutive Hydraulic motors, like those with a 19cc capacity, can achieve 14,000 RPM, despite their inherent imbalance—although their tiny size plays a crucial role in this exceptional achievement.[E1]

Pumping It Out

This HST would also feature an "Infinitely Variable Displacement Hydraulic Pump," characterized by a balanced rotation and a 223cc displacement, so it exhibits the impressive capability to transmit 582HP. This remarkable output is achieved while utilizing 57% of its displacement, maintaining a constant 5,400 PSI working pressure, and the shaft is rotating at 5,500 RPM.

It is directly connected to a featured Prime Mover power source operating at the same rpm's, which is the "Sweet Spot" for this engine. This implies that more efficient fuel engines and electrical motors, operating at higher RPMs, can be employed as the Prime Mover for use as the force creator behind a truck's drivetrain.

The pump as typical would have an integral reverse flow for backing up, unless for certain vocational applications the reverse function is in the 2-speed final drive as a selection off of the lower range.

Furthermore, since the HST easily adjusts and manages the production of all necessary torque, there's no requisite for a specific Torque curve from the Prime Mover. This further underscores the HST system's adaptability and efficacy to work with high efficiency, higher rpm, lower torque Prime Movers.

HEAVY DUTY

The HST's "Infinitely Variable Displacement Motor" has its connection with the drive axles through a final drive gear set meticulously chosen to suit the specific truck application type, payload, differential gearing, top speed, and duty cycle requirements.

For all these heavy trucks and demanding vocational applications there is a 2-speed final drive. This final drive low-speed is the included underdrive gear, which proves ideally pivotal for leveraging the "Wide Full Power Ratio". In this setup it will elevate Torque output by over fourfold, resulting in a Torque multiplying Ratio that can exceed 22:1.[G1] This 22:1 Ratio, in turn, empowers the HST to match the high-level working torque output typically demanded by super-duty manual transmissions essential for heavy truck hauling—which now by switching to HST would no longer be burdened with having to navigate shifting through 18 gears. (And still be able to obtain 115,000+ lb/ft of start-up torque at the axles[G1] – even in the Electric only mode!).

Incredibly, the HST Compound Electric Hybrid unlocks the same potential for highest torque in Electric-only mode operation (e.g., Zero Emissions), and most importantly, the HST electric hybrid system possesses the capability to simultaneously generate electricity on the fly, recharging batteries, while also putting out the energy for propelling a truck down the road, combining any one or all engine components of the Prime Mover—an embodiment of unparalleled versatility and efficiency.

All the while keeping the Hybrid ethos, as this system also captures brake energy, channeling it for regeneration into batteries or accumulators. Amazingly, even a Flywheel for regeneration use can be seamlessly accomplished.

SWEET SPOT

Most Importantly, the Prime Mover engine combination can maintain continuous operation within its optimal RPM range, known as the efficiency Sweet Spot*. Any surplus power generated by the engine while operating within this Sweet Spot[H1] can seamlessly flow into the Electric Motor for battery charging. This ingenious setup allows the engine to remain within its efficiency Sweet Spot while concurrently making a dual contribution to the loads as computed at any moment of time.

Moreover, this Infinitely Variable HST, when integrated into a Compound Electric Hybrid arrangement, affords the remarkable capability to operate the Prime Mover engine at the lowest possible RPMs for maximum cruising efficiency, regardless of how low that RPM might be. This flexibility ensures peak efficiency in diverse operational scenarios when operating outside Electric-Only mode.

Picture harnessing the electricity stored in batteries to assist in ascending a hill, then in turn, replenishing those batteries while descending the other side, only to repeat this cycle with each subsequent incline. So, when seamlessly integrated with advanced Topography-aware Smart GPS Route planning technology, this synergy will significantly enhance long-haul efficiency (i.e., fuel savings!).

ADVANTAGES OF HYDROSTATICS FOR TRANSMISSION MANUFACTURERS

Heavy Truck Transmission Manufacturers have developed a wide array of sizes and options for the geared transmissions they offer OEMs to use in a multitude of truck applications. This requires substantial resources to provide numerous gear ratio combinations and power take-off choices – to meet diverse customer requirements. In many cases, the options and variables extend into hundreds of choices, and with add-ons as well as controls it can be a thousand variations to stock parts for. [J1]

* "Sweet Spot" is that Engine RPM point where the engine is operating at its highest efficiency also known as the Best Efficiency Point on a fuel consumption map.

However, by including Hydrostatic Infinitely Variable transmissions in their repertoire, then a great many of these geared variations can be eliminated. Since by electronic controls, a multitude of application requirements, for a mix of power and torque ratios, can be accommodated by one HST unit. And any group of applications can use the same final drive this way - so there are far less parts to make or stock.

Virtually a “one size fits almost all concept”. **Greatly enhancing sustainability!**

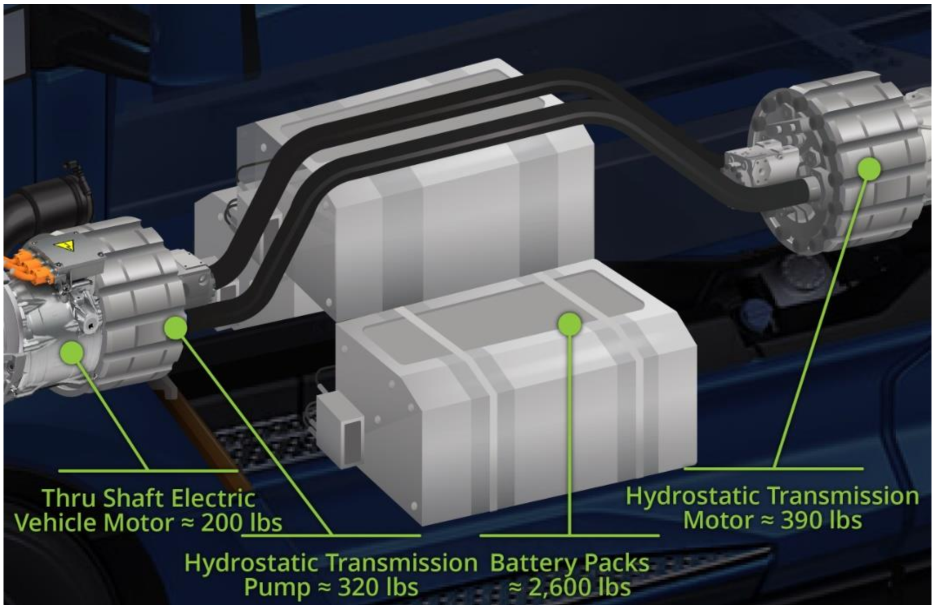
And most importantly, these transmission manufacturers would have a Zero Emissions option for their customers in heavy trucking and long-haul applications to fulfill that need.

(**Bonus**: without waiting for infrastructure changes)

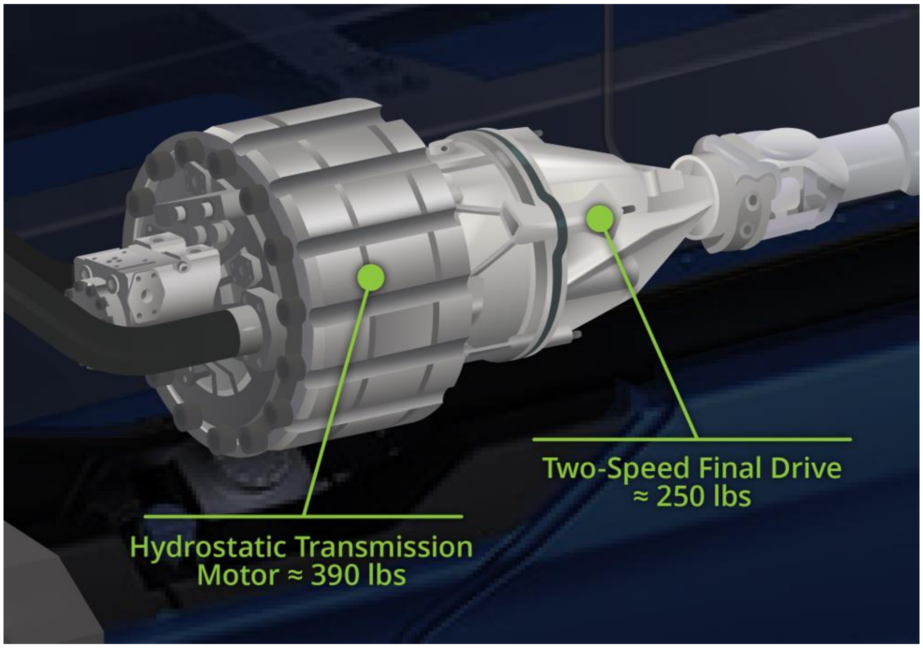
The top 10 heavy truck transmission manufacturers:

1. Allison Transmission - Indianapolis, Indiana, USA
2. Eaton Corporation - Dublin, Ireland
3. ZF Friedrichshafen AG - Friedrichshafen, Germany
4. Dana Incorporated - Maumee, Ohio, USA
5. Volvo Group - Gothenburg, Sweden
6. Voith Turbo GmbH & Co. KG - Heidenheim an der Brenz, Germany
7. Meritor, Inc. - Troy, Michigan, USA
8. MAN SE - Munich, Germany
9. Scania AB - Södertälje, Sweden
10. PACCAR, Inc. - Bellevue, Washington, USA

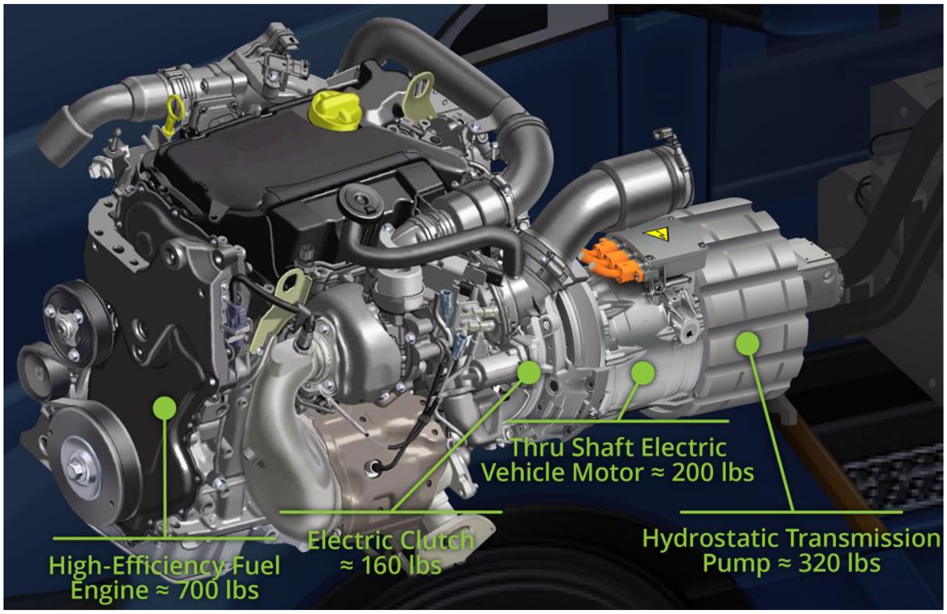
A1


Thru Shaft Electric
Vehicle Motor ≈ 200 lbs
Hydrostatic Transmission
Pump ≈ 320 lbs
Battery Packs
≈ 2,600 lbs
Hydrostatic Transmission
Motor ≈ 390 lbs

B1


Two-Speed Final Drive
≈ 250 lbs
Hydrostatic Transmission
Motor ≈ 390 lbs

B2



C1

1,460	Torque lb./ft	TQ from 334cc HST motor at full displacement
		and while at full operational pressure of 5,400psi
4.07	High gear ratio	Final Drive high-gear-ratio for output to the Axle differential gearing
		(max HST rpm / axle rpm / differential ratio)
4.58	Low gear ratio	Final Drive compounding low gear (drop gear ratio)
		For the Final Drive 2 speed low gear compounding option
1,800	HST RPM low	RPM minimum for Hydrostatic motor to achieve full power output
9,000	HST RPM high	Top HST RPM at full power output and reduced displacement
		resulting in HST overall ratio
20.0%	min-disp %	HST motor minimum displacement % at full power output
		(minimum rpm's / max rpm's ... at full power output)
5.00	HST ratio	HST motor full power output ratio from min. to max. displacement
		Full displacement @ high RPM's to the rated min. displacement @ RPM's.
		(HST highest RPM / Minimum RPM while staying at full power output)
22.9		Wide Ratio Full Power using 2 speed final drive
	22.9	(top speed full power / lowest speed at full power) or (HST ratio * final drive low gear ratio)
13.0	MPH high gear b	Lowest speed of Truck using the top gear of 2 speed final drive
		while maintaining full power output
		(top speed @ full output HP / ratio of HST motor)
14.2	MPH low gear top	Top speed in underdrive low gear of 2 speed final drive
		(top MPH / lower gear ratio)
1.19	overlap MPH	MPH overlap between Low Gear and High gear of 2 speed final drive
		during shifting between the 2 gears at maximum output & speed
2.8	MPH low gear bot	Speed of truck using Low Gear selection from 2 speed final drive
		While still maintaining maximum breakaway torque below
		And from here starts full horsepower throughput applied from HST
		(Top gear full power low speed / low gear ratio specified)
500	HPm	Horsepower output of 334cc HST motor operating at this full power ratio
		HP= (RPM * TQ) / 5252

C2

https://www.cummins.com/engines/x12-2024?v=4641&application=Heavy-Duty%20Truck

https://docplayer.net/95501628-Cummins-x12-sep-2018.html

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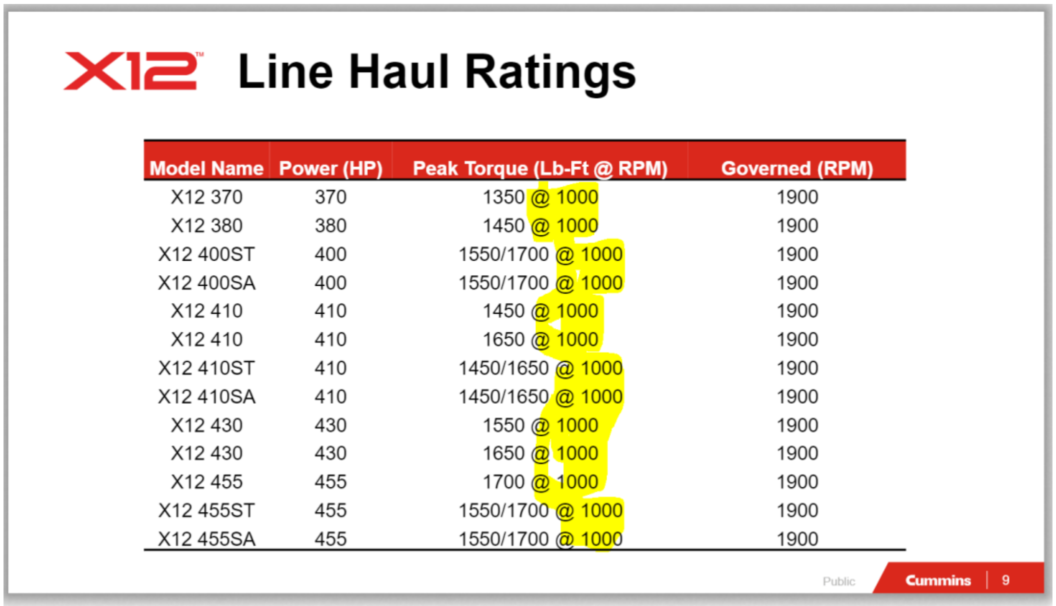


X12 Line Haul Ratings

Model Name	Power (HP)	Peak Torque (Lb-Ft @ RPM)	Governed (RPM)
X12 370	370	1350 @ 1000	1900
X12 380	380	1450 @ 1000	1900
X12 400ST	400	1550/1700 @ 1000	1900
X12 400SA	400	1550/1700 @ 1000	1900
X12 410	410	1450 @ 1000	1900
X12 410	410	1650 @ 1000	1900
X12 410ST	410	1450/1650 @ 1000	1900
X12 410SA	410	1450/1650 @ 1000	1900
X12 430	430	1550 @ 1000	1900
X12 430	430	1650 @ 1000	1900
X12 455	455	1700 @ 1000	1900
X12 455ST	455	1550/1700 @ 1000	1900
X12 455SA	455	1550/1700 @ 1000	1900

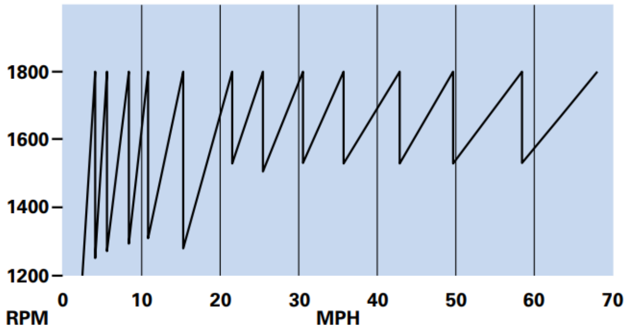
Public Cummins | 9

https://www.eaton.com/content/dam/eaton/products/transmissions/vehicle-transmissions/rt-13/low-intertia-rtlo-13-speed-trsl0249-en-us.pdf

(page 2: **EATON FULLER RT-13, 13 speed Transmission**

(shifting rpm & mph pattern)

Performance Chart: RTLO-18913A



Based on 1800 RPM engine operating at 1636 RPM/62 MPH [100 kph].

Ratios and Steps:

GEAR	RATIO	% STEP
8th H	0.73	
		17
8th L	0.86	
		17
7th H	1.00	
		17
7th L	1.17	
		18
6th H	1.38	
		17
6th L	1.62	
		19
5th H	1.94	
		17
5th L	2.28	
Range Shift		41
4th	3.23	
		37
3rd	4.43	
		38
2nd	6.11	
		40
1st	8.59	
		42
Low 1	12.31	
Reverse-HI	3.50	
Reverse-Low	13.22	
Overall Ratio: 16.9 to 1		

C3

Failures in Three-Phase Stator Windings (easa.com)

https://easa.com/resources/failures-in-three-phase-stator-windings

Damage caused by locked rotor

Severe thermal deterioration of the insulation in all phases of the motor normally is caused by very high currents in the stator winding due to a locked rotor condition. It may also occur as a result of excessive starts or reversals.

E1

https://econfig.parker.com/?lang=&mfgDivision=&parentCatId=&uom=&currcode=&productURL=&productId=&ControlAndValueString=C6348C107D2096149752117008F31D36

Product Description

The high efficient Parker bent axis design motors, with unique spherical piston concept gives thermal shock resistance. The motors are rated up to 420bar pressure levels, and speeds up to 14000rpm. The well proven gear synchronization and double tapered bearing concept gives a very robust and reliable motor in demanding applications, applicable for both open and closed loop systems. Combined with our well proven track record of durable motors, we have an outstanding uptime. Sizes from 5-19cc.

G1

4.25	Dif-ratio	Differential drive ratio for end of truck drivetrain to Axle output
42.0	dia. inches	Tire diameter size from radius
480.2	turns/mile	# of revolutions the axle makes with these tires for each mile of travel
		(5280 feet per mile / circumference of tire in feet)
65.0	top MPH	Truck top speed spec'd limit for passing on highway
		while maintaining full HP output through HST
520.2	RPMa	Axle RPM to achieve this top passing speed as specified
		(Top MPH * turns per mile / 60)
1,460	Torque lb./ft	TQ from 334cc HST motor at full displacement
		and while at full operational pressure of 5,400psi
4.07	High gear ratic	Final Drive high-gear-ratio for output to the Axle differential gearing
		(max HST rpm / axle rpm / differential ratio)
4.58	Low gear ratio	Final Drive compounding low gear (drop gear ratio)
		For the Final Drive 2 speed low gear compounding option
1,700	HST RPM low	RPM minimum for Hydrostatic motor to achieve full power output
9,000	HST RPM high	Top HST RPM at full power output and reduced displacement
		resulting in HST overall ratio
18.9%	min-disp %	HST motor minimum displacement % at full power output
		(minimum rpm's / max rpm's ... at full power output)
5.29	HST ratio	HST motor full power output ratio from min. to max. displacement
		Full displacement @ high RPM's to the rated min. displacement @ RPM's.
		(HST highest RPM / Minimum RPM while staying at full power output)
24.2		Wide Ratio Full Power using 2 speed final drive
	24.2	(top speed full power / lowest speed at full power) or (HST ratio * final drive low gear ratio)
12.3	MPH high gear b	Lowest speed of Truck using the top gear of 2 speed final drive
		while maintaining full power output
		(top speed @ full output HP / ratio of HST motor)
14.2	MPH low gear top	Top speed in underdrive low gear of 2 speed final drive
		(top MPH / lower gear ratio)
1.91	overlap MPH	MPH overlap between Low Gear and High gear of 2 speed final drive
		during shifting between the 2 gears at maximum output & speed
2.7	MPH low gear bott	Speed of truck using Low Gear selection from 2 speed final drive
		While still maintaining maximum breakaway torque below
		And from here starts full horsepower throughput applied from HST
		(Top gear full power low speed / low gear ratio specified)
473	HPm	Horsepower output of 334cc HST motor operating at full power ratio
		HP= (RPM * TQ) / 5252
115,687	Torque lb./ft	Axle Torque output maximum at startup through MPH of bottom speed low gear above
		with Final Drive compounding in low gear for max breakaway & startup force
		using the 2 speed final drive lower ratio to compound with upper ratio
		(HST tq * ratio final high gear * ratio underdrive compound gear * ratio rear end)

H1

Sweet spot refinement (techno-fandom.org)

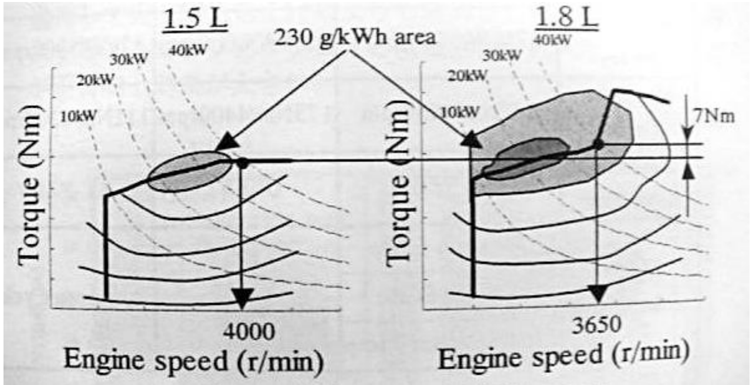


Fig. 3 Engine Efficiency and Displacement

This is called a brake specific fuel consumption or BSFC graph, and here two of them are shown together comparing the second-generation and third-generation Prius engines respectively. The "brake" part simply implies a somewhat idealized laboratory power measurement, often done with some means of applying a braking force to a test engine and letting it push against that to generate heat, electricity, or whatever while measurements are taken. The key part here is "fuel consumption", and that has an interesting relationship to torque and speed. Almost all BSFC charts have this general appearance, with torque plotted against RPM and a set of roughly concentric regions, similar to how elevation contour lines are indicated on a topo map, indicating the fuel consumed per unit power/energy output under differing sets of running conditions. This is often given in fuel grams per kilowatt-hour, all units of energy. The higher one climbs on the topological "mound" represented by the fuel consumption lines, the less fuel is burned to obtain a certain power. The top of the mound represents the most ideal conditions, e.g. the theoretical "sweet spot" for an engine. The mound's location varies a bit depending on engine design; some other examples for different production engines can be found at Ecomodder, a good general explanation from Autospeed, and more about the theory may reside in a Wikipedia article.

Boosting Fuel Economy With the "Sweet Spot" | Go By Truck Global News (gobytrucknews.com)

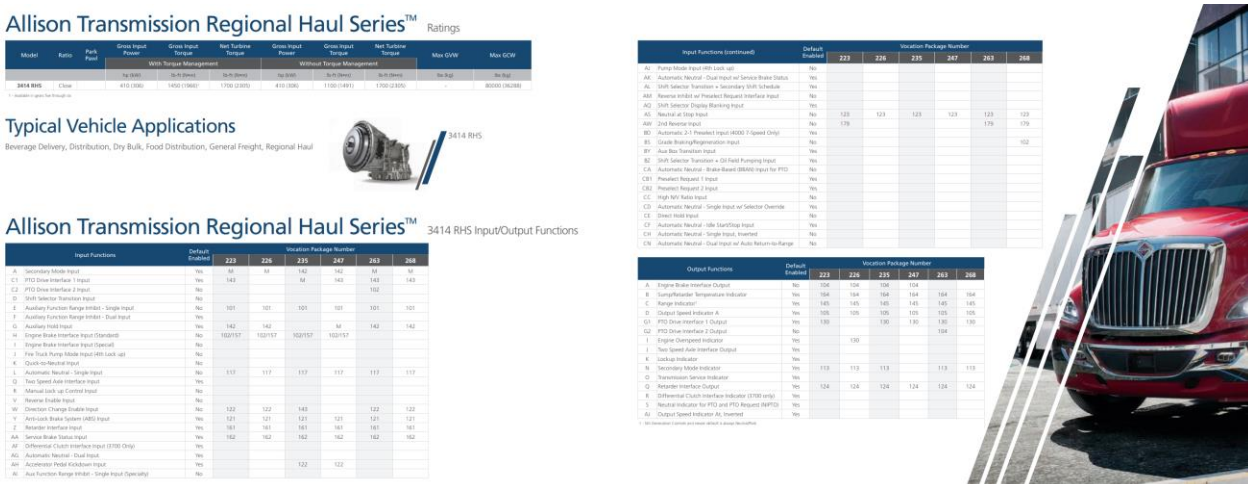
Big rigs are among the biggest gas guzzlers on the road. With gas prices and environmental concerns rising, federal agencies are being tasked with finding new ways to improve fuel efficiency for our nation's largest vehicles. Of course, drivers and trucking companies have a real stake in reducing fuel costs as well. Fuel makes up the largest expense for drivers and eats away at profits.

To curb fuel consumption, drivers are often advised to slow down and find the "sweet spot." The sweet spot refers to the ideal RPM at which an engine should be running for maximum fuel efficiency. Most owner's manuals list the ideal range or sweet spot for a particular engine, which could be anywhere from 1,200 to 1,500 RPMs.

J1

https://allisontransmission.com/docs/default-source/marketing-materials/brochures-us/vocationalmodelguide.pdf?sfvrsn=6628f41d_5

(Page 29 typical out of 59 pages in selections brochure PDF)



Allison Transmission Regional Haul Series™ Ratings

Model	Ratio	Park Pawl	Gross Input Power	Gross Input Torque	Net Turbine Torque	Gross Input Power	Gross Input Torque	Net Turbine Torque	Max GVW	Max GCW
			With Torque Management			Without Torque Management				
			hp (kW)	lb-ft (N·m)	lb-ft (N·m)	hp (kW)	lb-ft (N·m)	lb-ft (N·m)	lbs (kg)	lbs (kg)
3414 RHS	Close		410 (306)	1450 (1966)[1]	1700 (2305)	410 (306)	1100 (1491)	1700 (2305)	-	80000 (36288)

Typical Vehicle Applications

Beverage Delivery, Distribution, Dry Bulk, Food Distribution, General Freight, Regional Haul

3414 RHS

Allison Transmission Regional Haul Series™ 3414 RHS Input/Output Functions

	Input Functions	Default Enabled	223	226	235	247	263	268
A	Secondary Mode Input	Yes	M	M	142	142	M	M
C1	PTO Drive Interface 1 Input	Yes	143		M	143	143	143
C2	PTO Drive Interface 2 Input	No					102	
D	Shift Selector Transition Input	No						
E	Auxiliary Function Range Inhibit - Single Input	No	101	101	101	101	101	101
F	Auxiliary Function Range Inhibit - Dual Input	Yes						
G	Auxiliary Hold Input	Yes	142	142		M	142	142
H	Engine Brake Interface Input (Standard)	No	102/157	102/157	102/157	102/157		
I	Engine Brake Interface Input (Special)	No						
J	Fire Truck Pump Mode Input (4th Lock up)	No						
K	Quick-to-Neutral Input	No						
L	Automatic Neutral - Single Input	No	117	117	117	117	117	117
Q	Two Speed Axle Interface Input	Yes						
R	Manual Lock up Control Input	No						
V	Reverse Enable Input	No						
W	Direction Change Enable Input	No	122	122	143		122	122
Y	Anti-Lock Brake System (ABS) Input	Yes	121	121	121	121	121	121
Z	Retarder Interface Input	Yes	161	161	161	161	161	161
AA	Service Brake Status Input	Yes	162	162	162	162	162	162
AF	Differential Clutch Interface Input (3700 Only)	Yes						
AG	Automatic Neutral - Dual Input	Yes						
AH	Accelerator Pedal Kickdown Input	Yes			122	122		
AI	Aux Function Range Inhibit - Single Input (Specialty)	No						

	Input Functions (continued)	Default Enabled	223	226	235	247	263	268
AJ	Pump Mode Input (4th Lock up)	No						
AK	Automatic Neutral - Dual Input w/ Service Brake Status	Yes						
AL	Shift Selector Transition + Secondary Shift Schedule	Yes						
AM	Reverse Inhibit w/ Preselect Request Interface Input	No						
AQ	Shift Selector Display Blanking Input	Yes						
AS	Neutral at Stop Input	No	123	123	123	123	123	123
AW	2nd Reverse Input	No	179				179	179
BD	Automatic 2-1 Preselect Input (4000 7-Speed Only)	Yes						
BS	Grade Braking/Regeneration Input	No						102
BY	Aux Box Transition Input	Yes						
BZ	Shift Selector Transition + Oil Field Pumping Input	Yes						
CA	Automatic Neutral - Brake-Based (BBAN) Input for PTO	No						
CB1	Preselect Request 1 Input	Yes						
CB2	Preselect Request 2 Input	Yes						
CC	High N/V Ratio Input	No						
CD	Automatic Neutral - Single Input w/ Selector Override	Yes						
CE	Direct Hold Input	No						
CF	Automatic Neutral - Idle Start/Stop Input	Yes						
CH	Automatic Neutral - Single Input, Inverted	No						
CN	Automatic Neutral - Dual Input w/ Auto Return-to-Range	No						

	Output Functions	Default Enabled	223	226	235	247	263	268
A	Engine Brake Interface Output	No	104	104	104	104		
B	Sump/Retarder Temperature Indicator	Yes	164	164	164	164	164	164
C	Range Indicator[1]	Yes	145	145	145	145	145	145
D	Output Speed Indicator A	Yes	105	105	105	105	105	105
G1	PTO Drive Interface 1 Output	Yes	130		130	130	130	130
G2	PTO Drive Interface 2 Output	No					104	
I	Engine Overspeed Indicator	Yes		130				
J	Two Speed Axle Interface Output	Yes						
K	Lockup Indicator	Yes						
N	Secondary Mode Indicator	Yes	113	113	113		113	113
O	Transmission Service Indicator	Yes						
Q	Retarder Interface Output	Yes	124	124	124	124	124	124
R	Differential Clutch Interface Indicator (3700 only)	Yes						
S	Neutral Indicator for PTO and PTO Request (NIPTO)	Yes						
AJ	Output Speed Indicator At, Inverted	Yes						