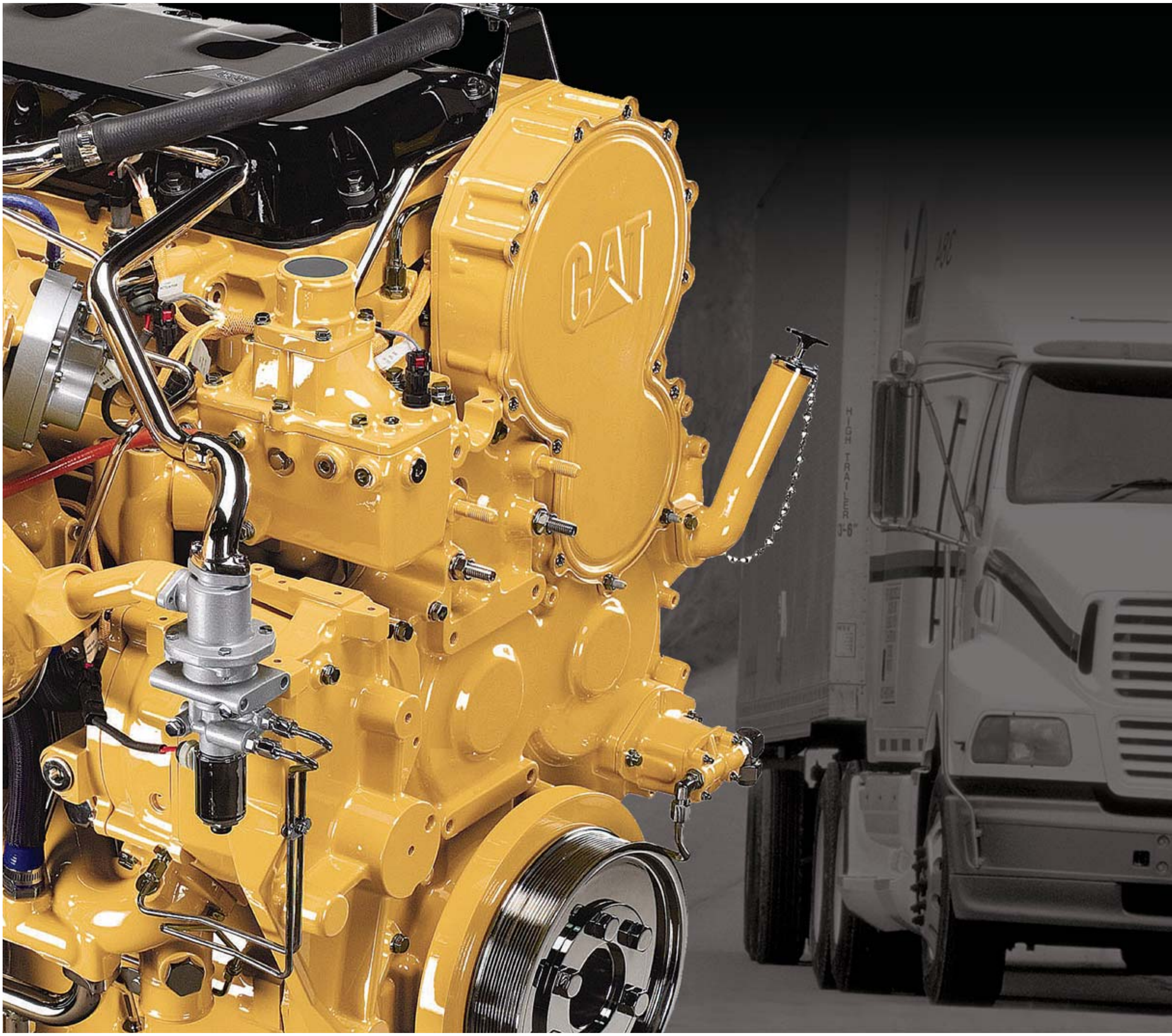
Caterpillar On-Highway Truck Application and Drivetrain Spec'ing



CATERPILLAR®

Truck Spec Training

Why do we think we need another book? Well, there is always movement in our industry with people moving on to other jobs, new people come into the industry, and some just retiring. The bad news in all of this is that when these people move, especially the retirees, the knowledge goes out the door and is sometimes lost forever. We want to take this opportunity to share some of our experiences in this area, to give you information necessary to do your job well, and create more value to our Caterpillar on highway customers. Over many years in the on highway truck engine business, Caterpillar has published many good papers on spec'ing Caterpillar engines for on highway service however, this is the first attempt to compile as much of this information as possible into one area. We want this book to be a building block, and become a base reference library for spec'ing drive trains. This information is a guide to help you, the Caterpillar representative, specify an on highway drive train. The information and equations listed in this book are not intended to replace the engineering knowledge of the OEM, the drive train component manufacturer, or the end user customer. Many times, your own experience with a particular drive train specification in your particular operation will lead you to continue using that spec even though it may not quite meet any or all of the recommendations contained in this guide. There is nothing wrong with using what works, however you need to know that the design of components change and or are updated regularly, so make sure you stay connected to the latest drive train offerings. It is very important that you keep abreast of these changes and updates to ensure that you continue to specify the most cost efficient drive train for your customer. To be successful in this job, you must intimately understand all aspects of the application before you start making recommendations. Wherever possible, go see what the customer is doing with their equipment. Ask questions! Take the time to familiarize yourself with the contents in each section. In putting this guide together, we have been conscious of the fact that there is a need for a simpler, more grass roots approach to this subject. As we step you through the drive train, our goal is to make this process as simple and as straight forward as possible. Take note of the "Rules and Tools" and the "Handy Formulas" as these will help.

Truck Spec Training
- Engine Selection

Truck Spec Training
- Engine Selection

ENGINE GUIDLINES

Before we get into choosing engines for our application, lets review some information on power requirements. There are several factors that affect truck performance, including vehicle configuration, total vehicle weight, vehicle cruising speed, trailer type, trailer gap, tire type, tire tread depth and driver's driving habits among others. Because of these factors and the differing needs of vehicle owners there is no single gearing solution.

ENGINE SELECTION

After identifying the application, determining the power required is necessary in selecting the correct engine. The power required by the application alone can dictate a heavy-duty engine. If it exceeds medium-duty engine ratings, a heavy-duty engine must be used. If the required power falls within the medium-duty range, use a medium-duty engine.

POWER REQUIREMENTS

Verify that the rating being used is neither too large nor small for the application. Selecting an engine with enough power to provide the performance specified by the customer involves looking at the entire power train. For brevity in this section, it is assumed that power train factors, other than those affecting power, have been correctly matched to the engine.

Truck Spec Training
- Engine Selection

MEASURING VEHICLE PERFORMANCE

Regardless of how the power for an application is determined, the determination must be made in terms of the following four measures of vehicle performance.

1. **Load:** The heavier the vehicle, the less speed attainable for the same set of conditions and net engine power.
2. **Road conditions:** These are not as important for on-highway applications. Most vehicles operate on first class highways or Interstates. For those vehicles operating both on-off highway or completely off-highway, road conditions are a very important consideration.
3. **Wind:** A small increase in speed over an already high speed greatly increases the power needed to overcome wind resistance. Vertical side ribs on the body or van have higher wind resistance than do horizontal and smooth sided vans. An open load such as a car carrier can have from 50 to 100% more wind resistance than an enclosed van. Prevailing winds are usually considered insignificant, but their effect is the same as increasing the road speed. More power is needed and travel speeds can be decreased by head winds.
4. **Altitude:** Operating in higher altitudes can reduce performance, because it limits air intake by the engine. Caterpillar turbocharged engines are capable of 3000 m (10,000 ft) before derating. Combinations of altitude, ambient temperature, and load factor can activate an engine protection derate.

MAXIMUM ROAD SPEED (MPH)

This is the maximum attainable road speed for the conditions under which the vehicle will operate. Road speed is often improperly assessed. A top speed may be demanded that is illegal or economically impractical from an application standpoint. If a certain speed cannot be produced from a power train, the engine is usually blamed for lack of power. The following factors must be considered in making this assessment: load, road conditions, wind, and altitude.

CRUISING ROAD SPEED

Cruise speed is a very significant factor affecting fuel economy. The top 5 factors influencing fuel mileage are:

- Driver/Operator
- Vehicle Speed
- Aerodynamics
- Ambient Temperature
- Vehicle Load

The best fleet operators can normally use 25% less fuel than their less skilled counterparts to perform the same task. At 55 mph or higher, every additional mph can represent approximately 0.1 mpg loss in fuel economy. This sensitivity can be influenced by the aerodynamics of the vehicle. In a tractor-trailer combination, the aerodynamics of the tractor alone can influence fuel economy by approximately 0.5 mpg. Fuel economy can be impacted by 0.75 mpg when the ambient temperature changes from 21°C to -4° C (70° F to 25° F) and vice versa due to air density impact on drag. Winter blend API 38 fuel can penalize fuel economy by another 0.15 mpg compared to API 35 fuel (No. 2 diesel). Thus, during winter operation, a total of 0.9 mpg decrease can be attributed to the air temperature and fuel API gravity effects. Cruise speed and maximum road speed power demand must be calculated before selecting an appropriate engine for the customer.

GRADEABILITY (PERCENT)

Gradeability is defined as the maximum grade a vehicle can negotiate without losing ground speed. Typically, gradeability is defined in top gear. For most applications, gradeability at peak torque in top gear should be 1.8% (1.5% minimum). For 40,823- 63,503 kg (90,000-140,000 lb) GCW, 1.5% may be a reasonable expectation with the transmission 1-gear down. For heavier loads, 1.5% may only be achievable 2-gears down. Gradeability at cruise speed in top gear should be 1.0% minimum. Gradeability is easy to measure in a vehicle but difficult to select and apply. Under a given set of conditions one can easily determine just how steep a grade a vehicle can negotiate. It is of more interest, however, to know just how fast a vehicle can climb grades encountered over a specific route. This is important to the owner due to the effect of grades on trip times. Wind, depending upon the speed a grade is negotiated, can be a significant factor when considering gradeability.

Truck Spec Training
- Formulas, Rules, and Tools

As mentioned in the introduction page, we have attempted to list these formulas out in the most logical sequence when specifying a drivetrain. Sometimes you do not need to use all of the formulas, however from an engine suppliers perspective, you will need to have a complete understanding of the loads that the engine will be seeing in your specific application. We cannot over emphasize the importance for you to understand exactly what the end user customer is doing with this equipment BEFORE you make any recommendations. Ask questions and get the facts. Also in this section you will find a new "On Highway Engine Application Review" form that will get you started on the kind of information you need to gather before you start the spec'ing process. Start using this form as this will get you into the habit of asking the right questions all the time.

Caterpillar On-Highway Engine Application Review

Today's Date: ____________

Customer/Fleet: ____________
OEM: ____________
Number of Vehicles: ____________
Projected Build Date:

Dealer Information
Dealer Name: ____________
Dealer Address: ____________

Name of Person
Submitting Request: ____________
Contact Information: ____________
Email: ____________
Telephone: ____________
Fax: ____________

ENGINE INFORMATION:

Model: ____________
HP Rating: ____________
Torque Rating: ____________
Ambient Conditions: ____________ Temperature Range: ________ ° C/° F Max Altitude: ________ m/ft

Vehicle Cruise Speed: ____________ mph/kph
Top Speed Limit Setting: ____________ mph/kph
Emissions Certification Type: ____________

TRANSMISSION INFORMATION:

Manufacturer: ____________
Model: ____________

DRIVELINE INFORMATION:

Rear Axle Manufacturer: ____________
Model: ____________

Axle Ratio: ____________
Number of Driven Axles: ____________

DRIVE TIRES SIZE:

Manufacturer:
Model:

Size: ____________
Revs/Mile (or KM): ____________

☐ Singles ☐ Super Singles ☐ Duals

VEHICLE INFORMATION:

Weight GVWR: ____________ kg/lbs
Weight GCWR (for Vehicles with Trailers): ________ kg/lbs
Weights on Drive Wheels: lbs
Height: ____________ m/ft Width: ________ m/ft

☐ Single Truck ☐ Tractor/Trailer ☐ Double Trailers ☐ Triple Trailers

Other (Describe):
Trailer Size: Height: ________ m/ft Width: ____________ m/ft

VEHICLE PERFORMANCE:

Percent of Time vehicle is loaded: ____________ %
Surface conditions (% of time) - Dry Pavement: ________ % Gravel Roads: ________ %
Off Road: ________ % Wet Conditions: ________ %
Estimate Percent time on grades (Mountains): ________ %
Maximum grade on which vehicle will be required to operate: ________ %

OPERATING ENVIRONMENT:

Describe terrain, soil, climate, ground conditions, ambient working temperature range, and any other factors which may affect component selection:

____
____
____

CALCULATING ENGINE POWER REQUIREMENT

1. Determine desired vehicle road speed (Vehicle Cruise Speed).
2. Determine the application requirements, max loads, max grades, road surface/terrain, tire specifications, and truck details such as make, model, height, width and expected vehicle cruise speed.
3. Based on the information you have collected in question # 2, you can now begin your calculations.
4. Determine engine power required based on cruise speed, max GVW/GCW, frontal area, and maximum grade desired to climb at cruise speed.

Power Rolling Resistance – P_r

$$Pr = \frac{(6.1+(.06 \times MPH)) \times C_p \times GVW \times MPH}{375{,}000}$$

C_p = Tire Pavement Factors

6.1 = Constant

.06 = Constant

375,000 = Constant

NOTE : See table 2 for tire pavement factors.

5. **Power Air Resistance – P_a**

$$P_a = \frac{FA \times C_d \times MPH^3}{156{,}000}$$

C_d = Aerodynamic Drag Coefficient

FA = Frontal Area

156,000 = Constant

NOTE : See table 3 for Aerodynamic Drag Coefficient .

6. **Power Grade Resistance – P_G** – Assume 0.5% for flat ground calculations to meet the minimum cruise gradeability requirement.

$$P_G = \frac{G \times GVW \times MPH}{37{,}500}$$

G= Grade
37,500 = Constant

The total wheel horsepower required will be the sum total of the numbers from items 4,5 and 6. Now we need to determine the HP we need at the engines fly-wheel.

DETERMINE THE ENGINE HP

Drivetrain efficiency – E_{DT} – the combined efficiency of all drivetrain components.

$$E_{DT} = E_T \times E_A \times E?$$

E_T = Efficiency of transmission
E_A = Efficiency of each drive axle

NOTE : See table 1 for drivetrain component efficiency.

These efficiency numbers should be used only for mechanical and or automated mechanical transmissions. Calculating gear efficiencies for full automatic trans-missions is very complex due to the various combinations of power paths and clutches engaged at any one time, so for “Torque Converter” automatic trans-missions, please consult the transmissions manufacturer directly for application guidelines and recommendations.

Accessory Loads – P_{ACC} – power loss due to fan, AC, compressor, etc.

$$P_{ACC} = P_{fan} + P_{AC} + P_{ps} + P?$$

P_{fan} = Power loss due to fan
P_{AC} = Power loss due to Air Conditioner
P_{ps} = Power loss due to power steering

NOTE: If actual accessory load is unknown assume 15HP for total accessory load.

Calculate the engine flywheel HP needed.

$$P_{eng} = \frac{P_{req}}{E_{DT}} + P_{Acc}$$

P_{req} = Horsepower required

E_{DT} = Drivetrain Efficiency

P_{Acc} = Accessory Loads

Now you have the engines flywheel horsepower demand, refer to your engine rating charts to choose an engine that is closest to, but above, the calculated required engine horsepower.

7. Before you go back to the engine section to select the engine that best matches and or exceeds the “Flywheel Horsepower” requirement, careful consideration should be given to the duty cycle when choosing your engine. You may find that your horsepower requirements can be covered by more than one engine family size. If the end user customer can handle the extra size and weight of a larger bore engine family, this may be the way to go. For the same work performed, the larger frame engine will offer a higher life to overhaul.

8. Reserve Power: It should be noted at this time that an 80,000lb GCW truck operating at 65 MPH cruise speed, may only require approximately 250 HP on flat ground, but in order to climb and maintain an acceptable vehicle speed on a grade, the actual HP required is significantly higher. As such, an allowance should be designed into the truck for reserve HP needs. A good rule of thumb is that the truck should be designed to operate up a 0.5% grade indefinitely at the desired cruise MPH. Higher horsepower levels over and above the 0.5% figure should be considered based on customer performance expectations. These higher horsepower levels can offer significant improvement in fuel economy, provided they are used for the purpose of optimizing time in top gear and not for high vehicle speed operation.

Table 1 - Drivetrain Component Efficiency

Component	Efficiency (%)
Transmission - DD	99
Transmission - OD	98
Drive Axle - Tandem	90
Drive Axle - Single	95

Table 2 - Tire Pavement Factor

Surface	Bias	Radial	LP Radial	Wide Base
Concrete	1.00	0.70	0.63	0.50
Cold Blacktop	1.20	0.85	0.70	0.60
Hot Blacktop	1.50	0.90	0.83	0.70
Hard Soil	1.75	1.00	0.98	0.85
Hard Gravel	2.00	1.20	1.13	1.00
Loose Gravel	7.50	1.70	1.63	1.50
Sand	12.00			

Table 3 - Aerodynamic Drag Coefficient - CD

Configuration	Factor
HD Tractor - Full Aero / Van Trailer full aero	0.42
HD Tractor - Full Aero / Van Trailer Typical	0.48
MD VanTruck - Full Aero	0.50
HD Tractor - Full Aero / Van Trailer some aero	0.54
HD Tractor - Full Aero / Tank Trailer Insulated	0.55
HD Tractor - Full Aero/Flat Trailer some aero(Smooth Load)	0.55
HD Tractor - Full Aero / Van Trailer no aero	0.80
HD Tractor - Full Aero/Flat Trailer some aero(Rough Load)	0.80
HD Tractor - Full Aero/Tank Trailer Non Insulated	0.80
HD Tractor - No Aero / Van Trailer no aero	0.80
MD VanTruck - No Aero	0.80
HD Dump	0.90
MD Dump - No Aero	0.90
HD Tractor - Car Hauler	1.00
HD Tractor - No Aero / Flat trailer some aero	1.00

Truck Spec Training
- Formulas, Rules, and Tools

OTHER USEFUL FORMULAS

Miles Per Hour (MPH) = $\frac{60 \times RPM}{Rev \times R_a \times R_t}$

Tire Revolutions per Mile (M) = $\frac{60 \times RPM}{R_a \times R_t \times MPH}$

Ratio, Drive Axle (Ra) = $\frac{60 \times RPM}{Rev \times R_t \times MPH}$

Ratio, Transmission (Rt) = $\frac{60 \times MPH}{Rev \times R_a \times MPH}$

Engine Speed (RPM) = $\frac{MPH \times Rev \times R_a \times R_t}{60}$

Where:

Rev = Tire revolutions per mile

R_a = Rear axle ratio

R_t = Transmission ratio

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Calculations
Table 1
Table 2
Table 3
Other Useful Formulas
Glossory of Terms
Horsepower
Startability
Industry Standard Startability Requirements
Vehicle Cruise Speed
Recommended Engine Cruise Speed
What Is?

C_d	aerodynamic drag coefficient
C_p	tire pavement factor
$E_?$	efficiency of other components placed in the driveline
E_A	efficiency of the drive axle
E_{DT}	efficiency of the drivetrain
E_T	efficiency of the transmission
FA	frontal area of the truck and/or tractor/trailer
G	grade in percent
GVW	gross vehicle or gross combination weight
MPH	truck speed in miles per hour
$P_?$	power required consumed by other engine components
P_a	power required to overcome the air resistance of the vehicle
P_{AC}	power consumed by the air conditioner
P_{Acc}	total power consumed by accessory loads
P_{cruise}	horsepower available at the chosen cruise speed
P_{eng}	engine power required at the flywheel
P_{fan}	power consumed by the engine fan
P_G	power required to overcome the resistance of a grade
P_{ps}	power consumed by the power steering
P_r	power required to overcome the rolling resistance of the vehicle
P_{rated}	rated horsepower of the chosen engine
P_{req}	horsepower required
R_A	axle ratio
Rev	tire revolutions per mile
RPM	engine cruise RPM as recommended by the engine OEM
R_{TranHi}	transmission top gear ratio
R_{TranLo}	transmission lowest gear ratio
S	startability given in percent grade
S_i	Startability index given in percent grade
T_{800}	engine torque at clutch engagement (normally at 800 RPM)
T_{peak}	Max engine torque at rated peak torque engine speed
T_{prod}	producible driveline torque
T_{rated}	rated peak torque of the chosen engine
T_{ws}	driveline torque at wheel slip
W_r	weight on the drive wheels

Truck Spec Training
- Formulas, Rules, and Tools

TORQUE

1.Torque requires:

A force applied to

A lever and produces a twisting effort

2. Torque (T) = Force (F) x Lever (L)
3. Torque, when applied to the performance of a motor vehicle, is the ability to overcome resistance due to grades, loads, road conditions, and wind resistance.
4. Torque **can** be increased or reduced by mechanical means such as levers and gear ratios.

$$\text{Torque} = \frac{\text{HP x 5252(constant)}}{\text{RPM}}$$

HORSEPOWER

1. Horsepower is the rate of doing work.
2. Horsepower is equivalent to 33,000 ft/lbs of work in one minute.
3. Horsepower **cannot** be increased or reduced by mechanical means such as levers or ratios.

$$\text{Horsepower} = \frac{\text{Torque x RPM}}{\text{5252(constant)}}$$

STARTABILITY

Startability is defined as the maximum grade a vehicle can begin to move on without throttle application. For automatic transmissions (Torque Converters), throttle application is required. Typically, startability is defined in the lowest transmission gear ratio. Startability of a vehicle is directly related to its total gear ratio and engine displacement. When gradeability at peak torque meets the minimum 1.5%, startability is usually satisfactory.

Startability is greatly affected by the GVW or GCW, grade, and rolling resistance. Gradeability calculations are based on the maximum torque, while startability is a function of torque available in the low speed range of 600-1,000 rpm. The minimum startability for various applications can be found in the next table. The recommended minimum startability for any vehicle should be 10%.

INDUSTRY STANDARD MINIMUM STARTABILITY REQUIREMENTS.

• Pick up and Delivery	10%
• Linehaul	14%
• On-Off Highway	20%
• Off Highway	25%

Startability

$$S = \frac{T_C \times R \times M}{10.7(constant) \times GCW}$$

Where:

T_c = Engine torque at clutch engagement (800 RPM), lb-ft

R = Overall gear ratio (transmission X auxiliary transmission X each drive axle)

M = Tire revolutions per mile

GCW = Gross Combination Weight (or GVW for straight truck)

How to use this Index –
Simply add up the numbers that coincide with your application, starting at “Max Expected Grade”, Vocation”, “Road Surface” and “Terrain”. Your vehicles startbility should meet this number.

Vocation		Road Surface	
Agriculture	10	Smooth Concrete or Asphalt	0
City Delivery	8		
Construction	8	Rough, Maintained Concrete/Asphalt	1
Fire Service	7		
Heavy Haul	8	Maintained Gravel, Crushed Rock,	
InterCity Bus	10	Hard Packed Dirt or Similar	2
Linehaul	6		
Logging	8	Unimproved and/or Unmaintained	3
Mining	9		
Off-Road	10		
Oil Field	8		
Recreation Vehicle	8		
Refuse	8		
Rescue Vehicle	8		
School Bus	10		
Transit Coach	8		

Maximum Expected Grade

6

If known, use the maximum operating grade numerical value (%). If max grade is unknown, use minimum value. operation on grades in excess of 12 degrees (20%) require application approval.

Terrain - % Off-Highway

0%	=	0
1-10%	=	1
11-25%	=	2
26-40%	=	3
>40%	=	4

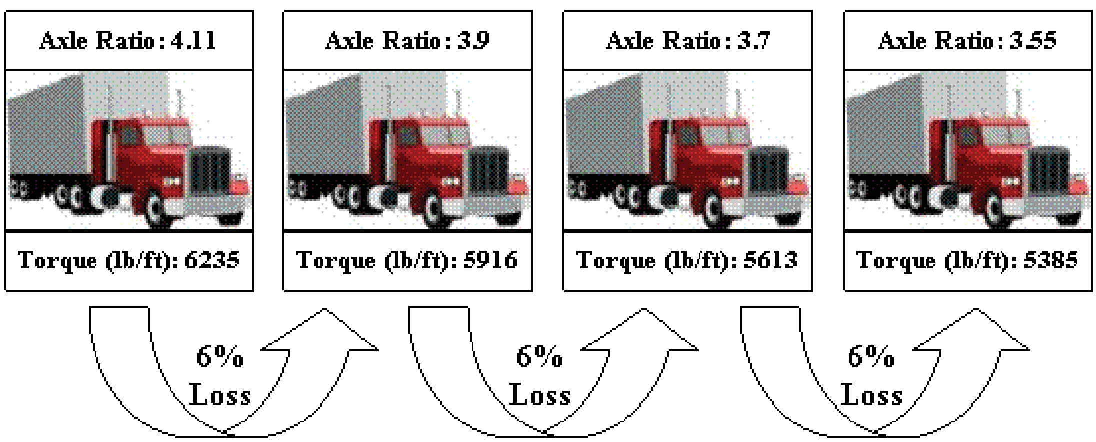
The drive axle ratio you choose will be based on the vehicle speed you have determined you will need for your specific operation, and the recommended engine cruise speed called for in the engine manufacturers recommendations.

WARNING –

THIS IS A COMMON AND VERY COSTLY MISTAKE WE SEE OFTEN!

HOWEVER; YOU NEED TO REMEMBER:

- You cannot take reduction out of a drivetrain and expect the vehicle to perform the same as it did before you made the change.
- As a rule of thumb, you lose up to 6% of torque at the wheel for every ratio change you make numerically lower than what you had when you started i.e., 4.11 – 3.9 – 3.7 – 3.55 and so on. Shown is an example of torque at the wheel on a 2050lb/ft truck with different axle ratios. (We have assumed a transmission top gear ratio of .74)



- If you want the vehicle to perform at the same level as before you made the ratio change, you have to compensate for this loss by increasing engine torque by the same amount, i.e. 6%.

Tip - Never let the max-advertised horsepower tell the whole story because the horsepower generated at the engine operating speed (cruise speed) you have chosen, may tell a different story.

VEHICLE CRUISE SPEED

This is probably the most important number that needs to be understood before anything else in the drive train. Engine power and axle ratios cannot be chosen without first understanding how fast the vehicle cruise speed needs to be. Once this speed is understood, then, and only then, can the correct engine, and engine rating be chosen. Cruise speed and maximum road speed power demand must be calculated before selecting an appropriate engine.

RECOMMENDED ENGINE CRUISE SPEED

There are many factors that affect a trucks performance and it is because of these factors and the differing needs of vehicle owners, that there is no single gearing solution. Cruise speed and maximum road speed power demand must be calculated before selecting an appropriate engine. Caterpillar can provide guidelines and examples to assist you in specifying Caterpillar engines to achieve the best balance between fuel economy and performance.

WHAT IS?

GRADEABILITY

Gradeability is defined as the maximum grade a vehicle can negotiate without losing ground speed. Typically gradeability is defined in top gear at cruise.

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- Formulas, Rules, and Tools

GRADEABILITY AT CRUISE SPEED

Gradeability at vehicle cruise speed in top gear should be 1% minimum. Gradeability is easy to measure in a vehicle but difficult to select and apply. Under a given set of conditions one can easily determine just how steep a grade a vehicle can negotiate. It is of more interest however, to know just how fast a vehicle can climb grades encountered over a specific route. This is important to the owner due to the effect of grades on trip times. Wind, depending upon the speed a grade is negotiated, can be a significant factor when considering gradeability.

$$G = \frac{\left(\left(\left(P_{cruise} - P_{AC} - P_{fan} - P_{ps}\right) \times E_T \times E_A\right) - P_r - P_a\right) \times 37{,}500}{GVW \times MPH}$$

Before you use the Gradeability at peak torque formula below, you need to calculate the vehicle speed (MPH) at the peak torque engine RPM

$$MPH = \frac{RPM \times 60}{Ra \times T_{TranHi} \times \mathrm{Rev}}$$

GRADEABILITY AT PEAK TORQUE

For most applications, gradeability at peak torque in top gear should be 1.5% minimum (up to 80,000lbs). For 90,000 to 140,000lb GCW, 1.5% may be a reasonable expectation with the transmission one gear down. For heavier loads, 1.5% may only be achievable with the transmission 2-gears down.

$$G = \frac{\left(\left(\left(\left(\frac{T_{peak} \times RPM}{5252}\right) - P_{AC} - P_{fan} - P_{ps}\right) \times E_T \times E_A\right) - P_r^{*} - P_a^{*}\right) \times 37{,}500}{GVW \times MPH}$$

* = Remember to recalculate with MPH at peak torque engine RPM

Engine	Peak Torque Engine RPM
C7	1440
C9	1400
C13	1200
C15	1200

OTHER COMPONENTS TO BE CONSIDERED

Accessory loads – alternators, fans, PTO's – drivetrain efficiency:

Accessory load power demands have increased dramatically over the last few years. For example, new emission requirements have resulted in larger cooling fans. Additionally, as more electrical components have made their way into on highway trucks so has the electrical demand increased, resulting in larger capacity alternators that take more power to drive. While some of these components do not work at full capacity all the time, nonetheless their max power demand should be considered when calculating the engine power needed under worst-case conditions.

GROSS HORSEPOWER

Gross or rated power is used for determining the total power needed, including accessory loads and net flywheel power at maximum road speed under normal conditions.

NET HORSEPOWER

Net horsepower is used for determining cruise speed power demand.

Net Power = Gross Power – Accessory Loads x Drivetrain efficiency
If drivetrain efficiency is not known, use .97 for each compenent.

NEVER LET THE MAX ADVERTISED HORSEPOWER TELL THE WHOLE STORY, BECAUSE HP AT YOUR CHOSEN OPERATING SPEED MAY BE A TOTALLY DIFFERENT NUMBER. STUDY THE CURVE, ESPECIALLY THE CURVE OF THE ENGINE YOU ARE REPLACING. OVERLAY THE TWO CURVES TO MAKE CERTAIN THERE IS NOT A REDUCTION IN POWER AT ONE OR MORE OF YOUR EXPECTED OPERATING POINTS.

START TORQUE

While gradeability at Vehicle Cruise speed and Peak torque are calculations based on the maximum torque, startability is a function of torque available in the low engine speed range of 600 to 1000 rpm. This is referred to as Start Torque.

TRANSMISSION SPEED RANGES

The transmission must have sufficient speed ranges, so that the engine rpm does not fall below peak torque rpm when shifting to the next higher gear, at speeds above 30 mph. At road speeds below 30 mph the power demand is usually so low that engine operation below peak torque is acceptable.

RETARDERS

Engine and driveline retarders are necessary in certain vocations or applications. The amount of power and torque developed by these multiple retarders must be calculated when specifying a drivetrain. Excessive power and torque losses due to operation of multiple retarders could lead to performance issues with the vehicle. The total amount of power and torque generated by all vehicle retarders should be calculated and compared against maximum power and torque ratings/limits of all other drivetrain components (i.e. engine, transmission, etc.). Changes to the type and level of retarding force may be required in order to function properly with the rest of the drivetrain.

Truck Spec Training
- Drivetrain Spec'ing

We have listed the most popular transmission and axle components OEM's currently offer in the industry. We make no recommendations on any of this equipment, because this is a preference only the customer and the component supplier should be making. We highly recommend that you get to know your counterparts from these suppliers, as these contacts can help guide you through the jungle of offerings that are out there today.

Eaton - www.roadranger.com
Allison - www.alissiontransmission.com
Meritor - www.arvinmeritor.com

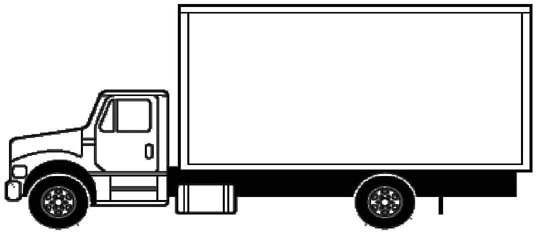
Truck Spec Training
- Vocation Engine Guidlines

- Cat Delivery
- Line Haul
- Construction
- Heavy Haul
- Logging
- Mining
- Oil Field (OWS)
- Motor Home
- Refuse
- School Bus
- Fire Service
- Rescue

The following is a list of the more common vocations you could expect to see. There are literally thousands of different and unique applications; therefore, it would simply be impossible to cover them all. If you come across some of these unique applications in your area, make note of the specs, this type of information may help you with a problem later down the road. Take notes, you will be glad you did.

Truck Spec Training
- Vocation Engine Guidlines

City Delivery



Vocational Description

–Pickup and delivery service within cities and / or suburban areas.
–100% of operation on road surfaces of concrete, asphalt, and maintained gravel.
–Three (3) miles between starts / stops (typical).
–100% load going / up to 40% load return (typical).

Typical Vehicle Types

–Auto Transport Truck
–Moving Van
–Refrigerated Truck
–Tanker Truck
–Beverage Truck
–Municipal Truck
–Pickup and Delivery
–Roll Back Auto Transporter
–Wrecker
–Flatbed Truck
–Newspaper Delivery
–Stake Truck
–Livestock Hauler

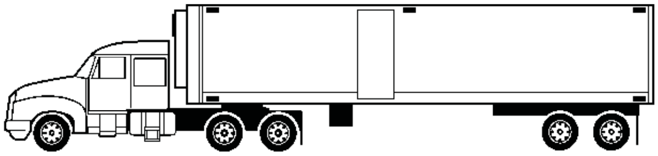
Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
30000	5 Speed	520-860	210
33000	5 Speed	520-860	230
30000	6 Speed	520-860	275
33000	6 Speed	520-860	275
<60000	6 to 10 speed	1050	350
<80000	6 to 10 speed	1650	435

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Truck Spec Training
- Vocation Engine Guidlines

Line Haul



Vocational Description

–Long distance transport of various types of freight in high mileage operation (minimum of 60,000 miles / year).

–Exclusive operation on road surfaces of good to excellent concrete or asphalt.

–Vehicle routes are typically on limited access highways and exceed 30 miles between starts and stops.

–Maximum infrequent grades of up to 8%.

–Majority of vehicles are 4 x 2, 6 x 2 (fixed tag or pusher), and 6 x 4 tractor / trailer combinations, and some straight trucks.

Typical Vehicle Types

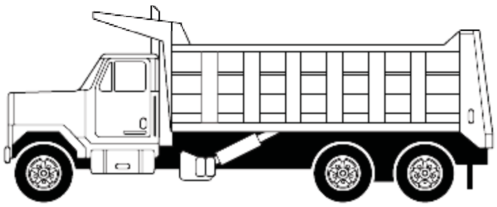
–Auto Hauler
–Flatbed Trailer
–Refrigerated
–Freight
–Pipe Hauler
–Bulk Hauler
–Van Trailer
–Livestock Hauler
–Tanker Double
–Grain Hauler
–Moving Van
–Triple

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
60000	10 Speed	1050	370
80000	10 Speed	1250	370
80000	10 Speed	1450	450
80000	10 Speed	1550	450
80000	10 Speed	1650	500
110000	13 Speed	1650	550
120000	18 Speed	1650	550
130000	18 Speed	1850	550
140000	18 Speed	1850	550
150000	18 Speed	2050	600
160000	18 Speed	2250	600

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Construction



Vocational Description

–Movement of material to, from, or around a job site.
–90% of loaded operation on prepared road surfaces of concrete, asphalt, gravel, crushed rock or hard packed dirt up to 10% of loaded operation into sandy or muddy work areas.
–Liftable tag and pusher axles are often used to increase legal load capacity on-highway.
–Vehicles typically operate a high percentage of time off-highway making a high number of stops and starts.
–Straight trucks as well as trucks with equipment trailers are considered construction vehicles. Tractor / semi-trailers and straight trucks pulling material trailers or dump body pumps will be considered mining applications and should be reviewed based on guidelines established for that vocation.

Typical Vehicle Types

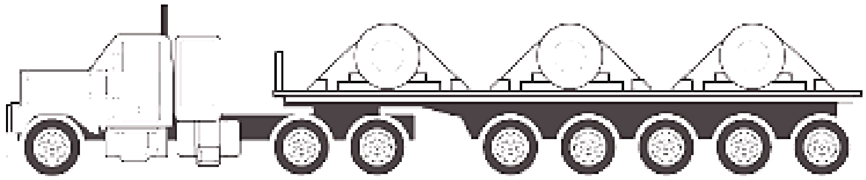
–Asphalt Truck
–End Dump
–Mixer
–Utility Truck
–Block Truck
–Flatbed Truck
–Concrete Pumper
–Landscape Truck
–Snowplow / Snowblower

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
60000	6A/10M	1050	370
80000	6A/10M	1250	370
80000	6A/10M	1450	450
110000	11/13/2018	1550	500
120000	11/13/2018	1650	500
130-140000	11/13/2018	1850	600
150-160000	11/13/2018	2050-2250	600

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Heavy Haul



Vocational Description

–Movement of heavy equipment or materials at legal maximums or special permit loadings.
–Loads > 110,000 lbs. Gross Combination Weight (GCW).
–Exclusive operation on prepared road surfaces of concrete, asphalt, and maintained gravel.
–High horsepower engines and auxiliary transmissions are typically used.
–100% Loaded going and empty return.

Typical Vehicle Types

–Equipment Hauler
–Flatbed
–Lowboy
–Steel Hauling

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
80-85000	13/18	1650	500
85-90000	13/18	1850	550
100000	13/18	2050	600
110000	13/18	2050	600
110-140000	13/18	2050	600
140-200000	13/18	2050	600
200-240000	13/18	2050	600

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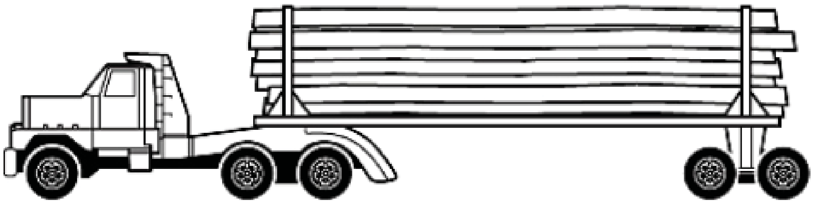
Truck Spec Training
- Vocation Engine Guidlines

Logging



Vocational Description

–Movement of logs, chips, and pulp between logging sites, mills, or processing plants.
–High horsepower engines and vehicle retarders are typically used in this vocation.
–Vehicle routes are typically 3 to 30 miles between starts and stops.
–100% Fully loaded going and empty return.
–Majority of vehicles are 6 x 4 tractors or trucks with full trailers unique to this vocation.

Typical Vehicle Types

–Chip Hauler
–Straight Truck with Trailer
–Log Hauler
–Tractor with Pole Trailer

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
120000	13/18	1650	500
140000	13/18	1850	550
150000	13/18	2050	600
160000	13/18	2250	600

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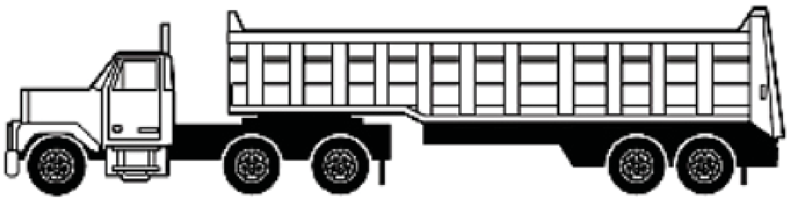
Truck Spec Training
- Vocation Engine Guidlines

Mining



Vocational Description

–Movement of rock, ore, gravel, and minerals around mine sites and between mines and processing plants.
–High horsepower engines are typically used in this vocation.
–Vehicle routes are typically 3 to 30 miles between starts and stops.
–90% of operation on-road with up to 10% into sandy or muddy job sites.
–100% loaded going and empty return.
–Tractor / semi-trailer and straight truck / material trailer combinations are considered mining vehicles. Straight trucks without trailers or trucks with equipment trailers are considered construction applications and should be reviewed based on the guidelines established for that vocation.

Typical Vehicle Types

–Bottom Dump Trailer
–Transfer Dump

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
120000	13/18	1650	500
140000	13/18	1850	550
150000	13/18	2050	600
160000	13/18	2250	600

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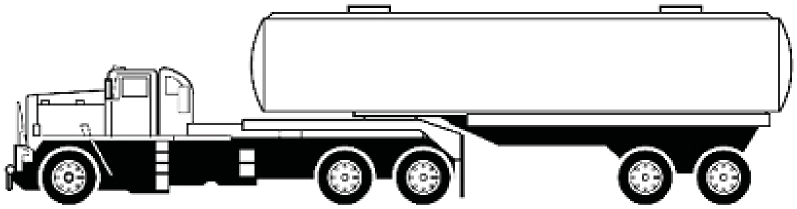
Truck Spec Training
- Vocation Engine Guidlines

Oil Field (OWS)



Vocational Description

–Movement of production related products, supplies, and tools between job sites.
–Movement of processing equipment and laboratories on job sites.
–Low mileage operation on road surfaces made of concrete, asphalt, maintained gravel, crushed rock, or hard-packed dirt.
–High horsepower engines common.
–Vehicles are typically 6 x 4 or 6 x 6 straight trucks or tractors with permanently mounted equipment for well servicing or exploration.

Typical Vehicle Types

–Cementing Vehicle
–Geophysical Exploration
–Demolition
–Rigging Truck

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
80000	6A	1450	450
120000	11/13/2018	1650	500
140000	11/13/2018	1850	550
150000	11/13/2018	2050	600
160000	11/13/2018	2250	600

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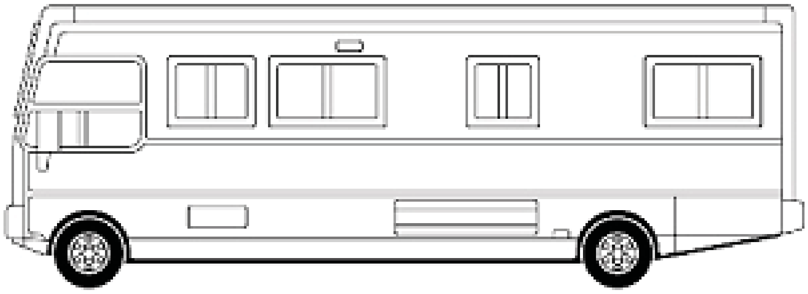
Truck Spec Training
- Vocation Engine Guidlines

Motor Home



Vocational Description

–Vehicles generally used for non-commercial transportation and as traveling domiciles for families.
–Loaded full-time.
–May pull small passenger car, boat, or pick-up truck.
–Typically vehicle routes exceed 30 miles between starts and stops.
–Annual mileage generally less than 30,000 miles.
–Typical operation is on paved roads and short distances within campgrounds and parks.
–Equipped with automatic transmissions.

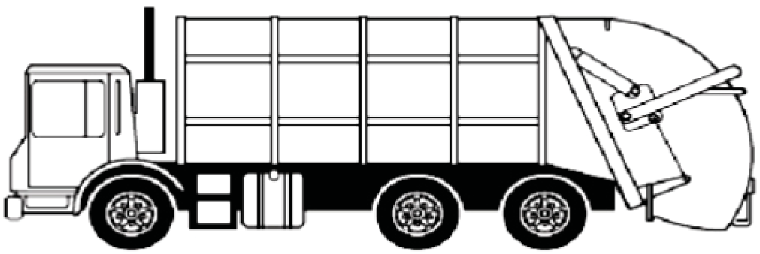
Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
60000	6A/12AM	1950	625
80000	6A/12AM	1950	625

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Truck Spec Training
- Vocation Engine Guidlines

Refuse



Vocational Description

–4 x 2 and 6 x 4 straight trucks, generally with automatic transmissions, used for residential refuse / recycle pickup.
–Typically a high number of stops and starts per mile.
–6 x 4 straight trucks operating in commercial / industrial pickup with approximately 1 to 3 miles between stops.
–6 x 4 tractor / semi-trailers or 6 x 4 straight trucks with roll-off bins used for transfer / relocation of material. Stops are typically more than 10 miles apart.
–90% of loaded operation on road surfaces of concrete, asphalt, or maintained gravel and up to 10% of loaded operation into landfill, transfer or recycling sites.

Typical Vehicle Types

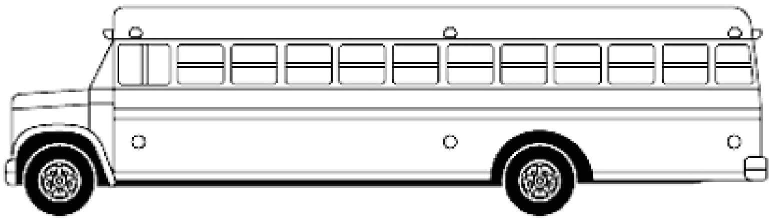
–Front / Rear / Side Loader
–Sewer / Septic / Vacuum
–Residential / Commercial Pickup
–Scrap Truck
–Transfer Vehicle
–Liquid Waste Hauler
–Street Sweeper
–Roll-Off

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
60000	6A	1450	370
80000	6A	1450	400
120000	10	1650	450
140-60000	13	1850	475

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

School Bus



Vocational Description

–Transporting students to and from school and / or school sponsored events.
–Operation on prepared road surfaces of concrete, asphalt, maintained gravel, crushed rock, or hard-packed dirt.
–2 stops per mile is considered typical.
–Automatic transmissions are typical.
–100% load going / empty return (typical).

Typical Vehicle Types

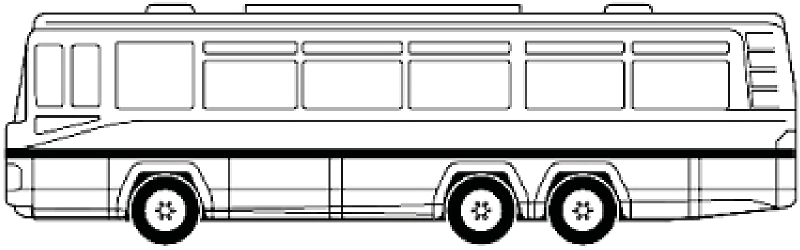
–Front Engine Commercial Chassis
–Front Engine Integral Coach
–Rear Engine Integral Coach

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
16000	5A	520	210

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Intercity Coach



Vocational Description

–Transportation of people and, on occasion, light freight between cities or sub-urban areas.
–Exclusive operation on well maintained paved surfaces.
–High mileage operation.
–Typical vehicle routes exceed 30 miles between start and stop.
–No towed load allowed.

Typical Vehicle Types

–Tour Coach
–Cross Country Coach

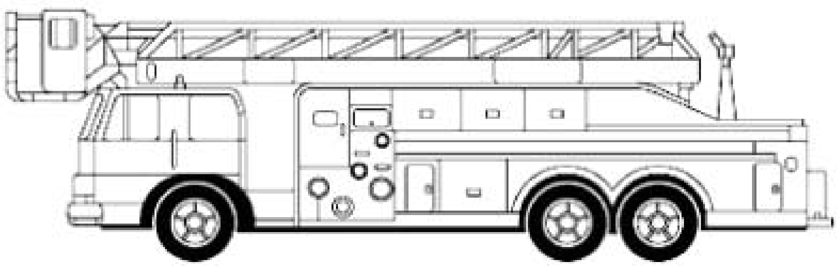
Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
16000	6A12AM	1650	450

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Truck Spec Training
- Vocation Engine Guidlines

Fire Service



Vocational Description

–Vehicles used to transport people and equipment for the purpose of extinguishing fires or ambulance service.
–90% of operation on prepared road surfaces of concrete, asphalt, gravel, crushed rock, or hard packed dirt and up to 10% of loaded operation into sandy or muddy areas.
–Mileage is typically under 15,000 miles per year.
–Typical vehicle routes are three (3) miles between start and stop.
–Vehicle retarders (engine, exhaust, transmission, or electromagnetic) are common.
–High engine horsepower typical.
–Loaded 100% of the time,
–High idle time is typical (85%).

Typical Vehicle Types

–Aerial Ladder
–Pumper
–Tanker

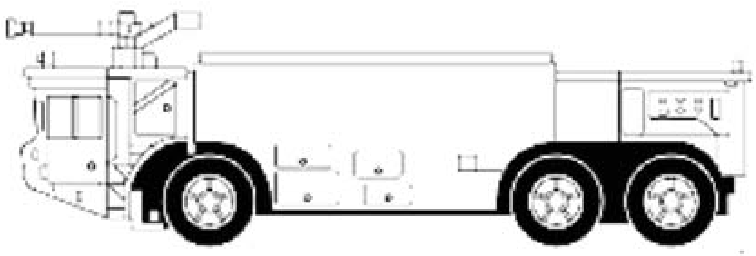
Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
80000	6A	1850	525

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

Truck Spec Training
- Vocation Engine Guidlines

Rescue



Vocational Description

–Specialized all wheel drive vehicles designed for rapid acceleration to airport crash sites.
–Operation on road surfaces made of concrete, asphalt, maintained gravel, crushed rock, hard-packed dirt, or other
–Similar surfaces for 90% of the total miles and sandy or muddy crash sites for the remaining 10%.
–Extremely low mileage operation.
–High horsepower engines and automatic transmissions are typical.
–Vehicle retarders are common (engine, exhaust, transmission, electro-magnetic).

Typical Vehicle Types

–Airport Rescue Fire (ARF)
–Crash Fire Rescue (CFR)
–Rapid Intervention Vehicle (RV)
–Emergency Service

Typical Specs

GVM/GCM (lbs)	Transmission	Max Torque	Max HP
80000	6A	1850	525

Note: These are not recommendations of Caterpillar just an example of common specs per vocation

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