Truck Systems
Engines

PARTS EXPERT℠

PARTS PROFESSIONAL CERTIFICATION PROGRAM

Freightliner LLC

The material within the *Truck Systems Engines* module is for Freightliner LLC instructional purposes only.

Reference to an “authorized” dealer signifies a dealer under contract with Freightliner LLC via signed dealer agreement.

Getting Started

This Module describes the main parts found in a typical diesel engine and briefly explains how a large diesel engine functions. The program won't make you a service technician but covers the basics so that a parts person can know more about engine parts and how they work together. This will help you recommend and sell parts more competently and add value when you talk to customers and service people.

Key Words

Once you have read and studied this Module you should be familiar with these terms:

Aftercooler
Air Cleaner
Cam
Camshaft
Catalytic Converter
Connecting Rod
Crankcase
Crankshaft
Cylinder
Cylinder Block
Cylinder Head
Distribution Pump
Electronic Control Module (ECM)
Engine Block
Engine Brake
Fan
Fan Clutch
Fan Shroud
Fuel Filter
Fuel Heater
Fuel Injector
Glow Plug
Governor
Horsepower (HP)
Injector
Lifters
Manifold
Muffler
Oil Filter
Oil Pan
Oil Pump
Overflow Tank
Piston
Piston Rings
Pushrods
Radiator
Rocker Arms
Relief Valve
Stroke
Thermostat
Timing Gears
Turbocharger
Valves
Valve Head
Valve Train
Water Filter/ Separator
Water Pump

About Our Industry

The last few pages of this module give a brief, informative overview of the trucking industry. You won't be tested on the information and it's well worth reading.

Learning Objectives

Upon successful completion of this module you will:

1) Know the names of key engine parts.

2) Understand basic engine operation and how key engine parts function.

3) Have the knowledge and ability to recommend related engine parts.

Theory of Operation

Internal combustion engines power the world. The name "internal combustion" comes from the fact that fuel burns (combusts) *inside* the engine. Truck engines, car engines — even jet engines and rocket engines — are all internal combustion engines.

The internal combustion engine works by mixing air and fuel in an enclosed space where one end (called a piston) moves under pressure. The fuel explosively burns, quickly heating and expanding the air inside the space. This creates great pressure that forces the piston down. Several pistons are connected to a tube or shaft that goes through many different mechanical connections to send power to the wheels. Precisely timed "explosions" put the pistons in a rhythmic up and down motion that turns the shaft. In this way, back and forth motion is converted into rotational (spinning) force that mechanically turns the wheels.

The diesel engine is named after European engineer Rudolf Diesel who invented it in the early 1890s. Diesel engines draw in huge amounts of air and compress it, which super heats it *before* the spray of fuel is added. This makes diesel engines different from gasoline engines. Gasoline engines use a spark plug to produce a spark that ignites a fuel and air mixture already in the chamber. Diesel engines depend upon the superheated compressed air to spontaneously ignite fuel when it is injected.

Horsepower and Torque

Engineers use the terms "**horsepower**" and "**torque**" to measure the ability of a machine to do work. Horsepower is measured in foot-pounds and torque is measured in pounds per square foot. Horsepower measures the ability to do work over a period of time. Torque measures twisting force without any element of time.

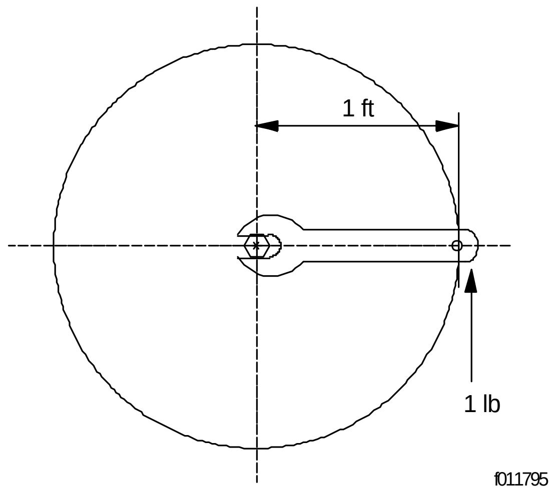
A diesel engine's horsepower can be determined several different ways:

- Indicated horsepower (IHP) is the total power developed in all cylinders by combustion. It is the total HP an engine can produce.
- Friction horsepower (FHP) is the amount of power it takes just to overcome the internal friction in the engine, just to "turn it over."
- Brake horsepower (BHP) is the amount of work power available and is calculated by subtracting FHP from IHP. An engine rated at 400 HP is commonly stating its BHP.

Torque (or torsion) measures twisting force — the power going down the drive train. If an engine's BHP is its work power, then torque is its work capacity. Engine torque directly relates to an engine's compression ratio: the higher the compression ratio, the greater the torque output.

Torque is measured by the pound-foot (not to be confused with horsepower measured by the foot-pound). One pound-foot of torque is defined as the amount of force created when you apply one pound of effort 12 inches from the center.

Figure 1: *The pound-foot measure calculates "twisting" or "torque" force.*



As RPM (the number of revolutions per minute) increases, torque decreases. For this reason high torque at low engine speed is needed for good acceleration and allows an engine to pull heavy loads without stalling. High-torque engines are usually required for vehicles carrying heavy loads such as cement trucks, large dump trucks and liquid transporters. A beefier, high-torque engine might also be specified for trucks that regularly drive steep grades, carry high weight payloads at highway speeds or work off-road and need the extra power.

v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v

Mini Fact: Human Horsepower

A foot-pound represents the energy it takes to move a one-pound weight 12 inches or one foot. One horsepower is defined as the ability to do 33,000 foot-pounds of work in one minute. How many horsepower does a person create by bench pressing 100 pounds twenty times in one minute? Assuming that the person is pushing the weights 18 inches above his or her chest with each press, that's 1.5 feet x 100 pounds x 20 repetitions which = 3,000 foot-pounds — not even 1/10 of a horsepower for all that heavy lifting!

Freightliner does not make its own engines. Freightliner LLC partners with quality engine manufacturers who design and build the engines we install. The hundreds of models and options allow us to virtually custom-fit the exact power plant to each truck's purpose and its driver's desires.

Figure 2: *Some popular engines Freightliner offers (ratings subject to change).*

	Model	HP Range	Torque (lb-ft) (rated @ highest HP)	RPM	Note
Caterpillar	C-10	305 – 370	1350 @	1200	Fuel economy; low weight
	C-12	335 – 430	1650 @	1200	Lowest cost of ownership
	C-15	355 – 550	1850 @	1200	Tough, heavy haulers
	C-16	575 – 600	2050 @	1200	Power; performance
	3406E	355 – 600	Varies (Depends on HP)	1200	C-15 & C-16 predecessor
	3126B	175 – 330	860 @	1440	Work-horse mid-range engine
Cummins	ISB	185 – 275	660 @	1600	Best power to weight ratio
	ISC	215 – 350	1050 @	1400	Rugged durability
	ISL	310 – 363	1200 @	1300	Heavy duty design
	ISM	280 – 370	1450 @	1800	Economy, low maintenance
	ISX	400 – 600	1850 @	1200	Upgradable performance
	N-14	330 – 525	1850 @	1200	Power with durability
	Signature 600	565 – 600	2050 @	1200	Muscle with speed
Detroit Diesel	Series 60	330 – 500	1650 @	1200	Best selling heavy duty engine in North America
Mercedes-Benz	MBE 900	150 – 300	860 @	1400	On the road driveability
	MBE 4000	350 – 450	1550 @	1100	Outstanding fuel economy

The trucking industry continues to demand more and more horsepower. Since 1990, the industry average horsepower for heavy-duty trucks has risen from 340 HP to 380 HP, nearly a 12% increase in a decade. HP ratings will probably continue to rise.

Parts and service for Mercedes-Benz engines throughout North America will be provided exclusively by Freightliner and Sterling dealers.

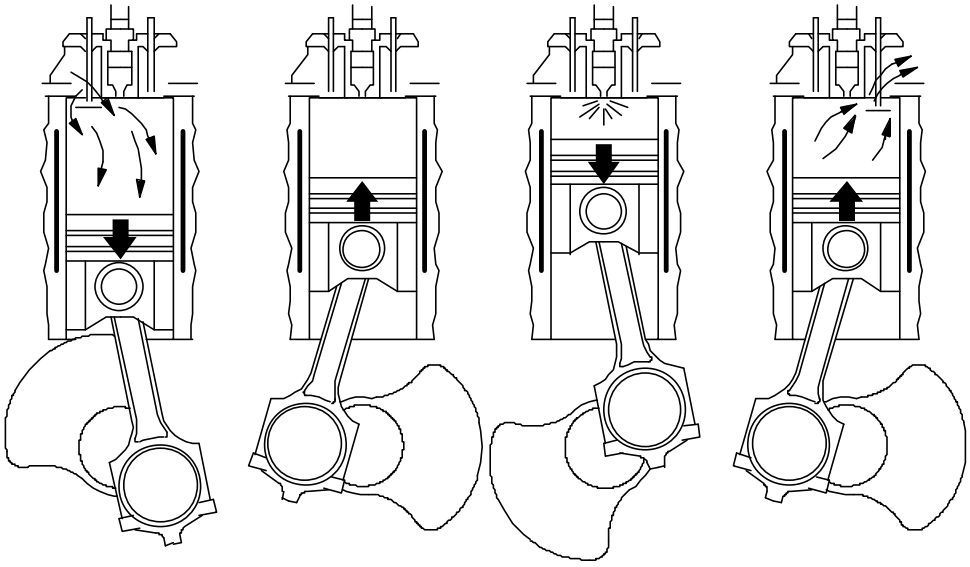
Freightliner LLC also distributes remanufactured engines. A future module, *Remanufactured Parts*, will cover these engines in detail. Meanwhile, if you have questions about remanufactured engines, please contact your RPM.

Four-Stroke Operation

A stroke is one movement of the piston either up or down.

- Top dead center (TDC) marks the piston's position at its upper limit of travel. The piston comes to a dead stop at TDC.
- Bottom dead center (BDC) marks the piston's position at its lower limit of travel. The piston comes to a dead stop also at BDC.
- Stroke indicates the distance the piston moves from TDC to BDC.

Figure 3: *The four-stroke cycle means the piston moves four times (twice in each direction) to complete one cycle. Each stroke has a name: induction (intake), compression, power and exhaust.*



Induction Stroke

On the induction (or intake) stroke, the piston moves down and the intake (or inlet) valve opens. (Spark plug engines draw both fuel and air into the cylinder, while diesel engines take in air only during this stroke.) Diesel engines use a turbocharger that acts like a pump to force pressurized air into each cylinder's combustion chamber.

Compression Stroke

The intake valve closes as the piston rounds BDC (bottom dead center) and moves up. The air is compressed to high pressure (500-600 pounds per square inch or about the weight of one wheel of your car parked on your toe!).

When air is compressed to high pressure it heats up. (In typical diesel engines, the temperature normally reaches 1000 degrees F.) At the end of the compression stroke when the piston nears TDC, a high-pressure pump (called a fuel injector) sprays a fine mist of fuel that rapidly distributes inside the combustion chamber. Almost instantly, ignition occurs because the air temperature in the combustion chamber is so high.

The diesel engine is a compression ignition (CI) engine. In other words, it depends upon the heat of compression to cause ignition. A diesel engine does not require a spark plug because the diesel fuel self-ignites when exposed to hot air. In diesel engines, the injections of fuel are precisely timed to determine when combustion occurs.

The gasoline engine is different. It uses timed spark ignition (SI) from spark plugs that create a single point of combustion. In the diesel engine, each individual drop of fuel spray ignites on its own.

v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v

Mini Fact: Squeezed Heat

Compression ratio *defines how much the air in the combustion chamber is "squeezed." The ratio compares the incoming volume of outside air to the volume when the piston compresses it in the chamber during the compression stroke. Diesel engines compress the air to make it 15 to 21 times smaller. That's like squeezing a basketball down to the size of a tennis ball. This creates such heat that fuel spontaneously ignites when injected.*

Power Stroke

The hot, burning gases expand, pushing the piston back down inside the cylinder and driving the crankshaft to deliver the engine's power. As the piston nears BDC, the exhaust valve opens.

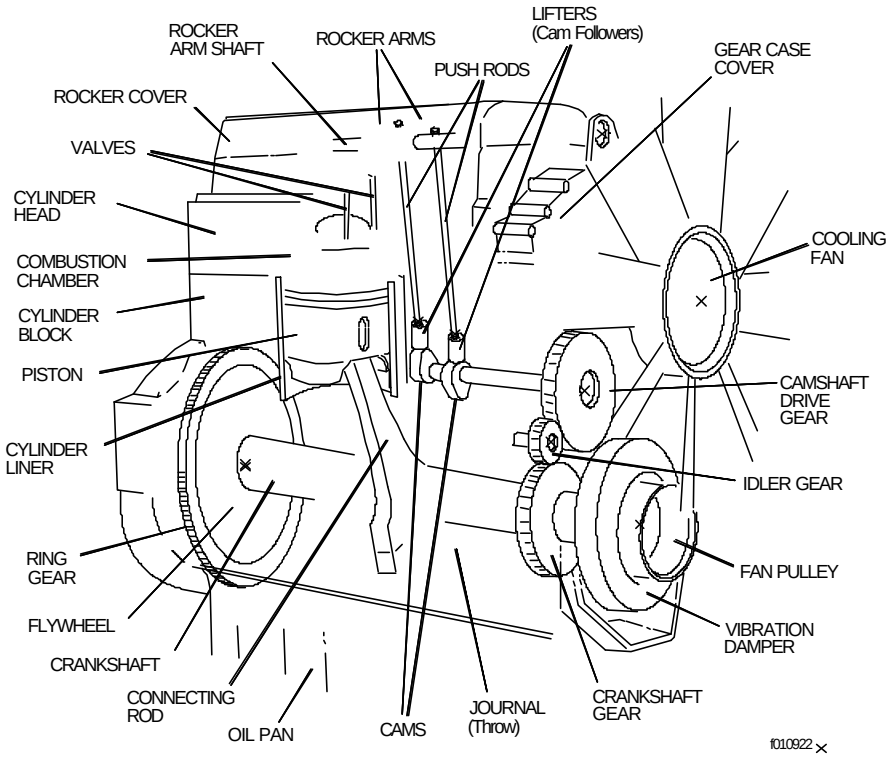
Exhaust Stroke

As the exhaust (or outlet) valve opens the rising piston pushes the burned gases out of the cylinder. When the piston again reaches TDC, the four-stroke cycle is complete, the crankshaft has turned twice and the cycle begins again.

Basic Engine Parts

Although different diesel engine manufacturers make different engines, they all follow the same general design using similar key parts. These parts are described in the paragraphs that follow.

Figure 4: *Typical diesel engines for trucks weigh 2,000 to 3,000 pounds — as much as a subcompact car.*



Cylinder Block

The **cylinder block** (or **engine block**) is the basic frame for the engine. It is usually forged in cast iron to withstand the stresses coming from the crankshaft and pistons. Oil passages for lubrication and cooling are built into it. Water passages are also cast in the block so that coolant can be pumped throughout. The cylinder block contains several tube-like **cylinders**.

Cylinder Head

The cylinder (or block) head seals off one end of the cylinders. The head has channels and mounting points for intake valves, exhaust valves and valve rocker assemblies. The camshaft is also usually located in the cylinder head. The area enclosed by the cylinder head and piston is called the **combustion chamber**.

There are two types of combustion chambers:

1) Direct injection (DI) chambers take fuel and air directly into the combustion area.

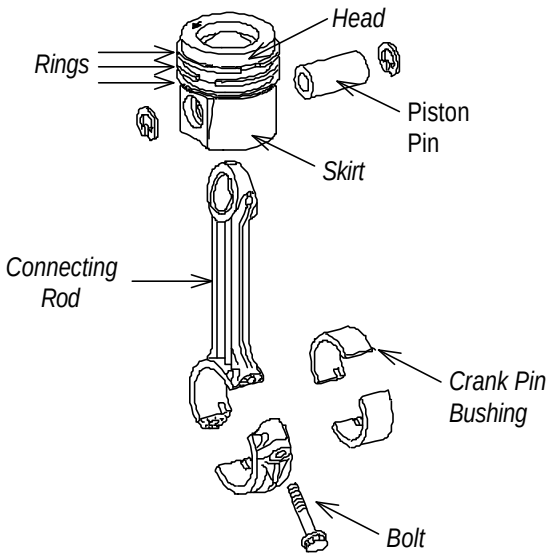
2) Indirect injection (IOI) chambers are divided and have a separate pre-mixing area.

There are many **precombustion chamber** designs. Precombustion chambers help mix and distribute the fuel before it enters the main combustion chamber. This allows fuel to burn more efficiently and cleanly.

Pistons

Pistons take the force of combustion. Their movement rotates the crankshaft. They must withstand high pressures and temperatures and precisely fit within cylinders yet freely move up and down in a straight line inside the cylinder. (This up and down motion of the piston is called reciprocating motion.)

Figure 5: *Typical piston components.*



Most diesel engines use articulated (two-piece) pistons consisting of a **skirt** and a **head**. This two-piece construction keeps heat from conducting through the metal and keeps it away from the combustion chamber's surfaces. The two-piece design also saves weight (with an aluminum skirt) and helps the piston withstand high pressure and heat (with a forged steal piston head). A piston pin (or wrist pin) holds the two pieces of the piston together.

Piston rings are critical to engine performance. They keep combustion gases contained within the cylinder and keep engine lubrication oil from getting in and burning. There are many different designs but in general there are three types of piston rings:

1) The top or "fire" ring is exposed to the fire of combustion.

2) The middle "compression ring" helps maintain a tight seal to maintain pressure inside the cylinder by keeping gases from escaping.

3) The bottom "oil control ring" scrapes oil from the cylinder wall and returns it to the crankcase.

Connecting Rods

A **connecting rod** links the piston to the crankshaft. A bushing (a friction-reducing part) at the upper end of the rod allows the rod to swing on the piston pin. The lower end of the rod is attached to the crankshaft and contains a friction reducing bearing so it can rotate freely.

Crankshaft

The **crankshaft** converts the up and down motion of the piston into rotary or spinning motion. Crankshafts are usually steel forged for the mechanical strength to withstand the stresses that pistons and connecting rods put on the crank. The shaft must absorb the thrust of the power strokes and must be carefully balanced to avoid vibration.

Crankcase

This is the cradle or pan for the crankshaft, cylinder block and sometimes the camshaft. Like the cylinder block, the **crankcase** contains ready-made passages for lubricating and cooling oil, and for circulated cooling water.

Valves and Valve Gears

The **valves** open and close to let clean air into and exhaust gases out of the cylinders. The **valve head** is machined and fits (or seats) into a matching surface (called the "valve seat") in the cylinder head. This precise fit holds gases within the cylinder when the valves are closed.

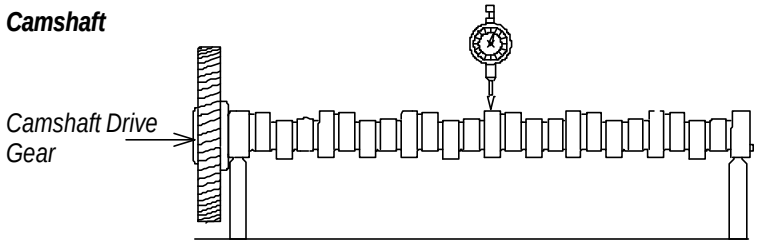
A diesel engine usually has four valves per cylinder: two intake valves and two exhaust valves. They open and close at precise times to move air through the cylinder in the internal combustion cycle. This exact pattern of opening and closing valves is accomplished by the **valve train** which consists of a camshaft, timing gears, rocker assemblies and (when the cam is not mounted on the cylinder head itself), a series of pushrods and lifters.

Camshaft

Like the crankshaft, the **camshaft** is forged and hardened. It has one or more lobes that change the shaft's rotary motion into the up and down motion of the valves.

Each cylinder's pair of intake valves and exhaust valves has a cam. There is also usually a third cam for each cylinder that operates a fuel injector. Cam lobes are positioned on the camshaft to open the valves in correct order with each piston stroke.

Figure 6: *The simplest **cam** is a fixed wheel with one or more high spots or lobes. A rod pressed against this lopsided wheel moves up and down over these rotating projections. In this way, the cam changes spinning rotation into linear movement.*



Rocker Assemblies

Springs supply pressure to open intake or exhaust valves. **Rocker assemblies** turn the upward motion of the pushrods or cam lobe into downward force to overcome that spring. A shaft acts as a fulcrum that allows the **rocker arms** to seesaw up and down. As the cam lobe rotates, one side of the rocker is forced up and the other goes down, opening its valves. As the camshaft lobe rotates further, the valve spring pushes the rocker arm in the opposite direction and the valves close.

Pushrods and Lifters

Valve **lifters** ride on the cam lobes, lifting the **pushrods** on one side of a rocker arm. An "overhead camshaft" is so named because it is mounted in such a way that the cam lobes themselves push directly on the rocker arms without using lifters or pushrods.

Timing Gears

The crankshaft uses **timing gears** to drive the camshaft. These gears position the cam lobes with respect to the crankshaft crankpins so that the valves open and close correctly in the cycle. With a gear ratio of 1:2, the camshaft rotates at one-half the engine's speed. This produces one valve opening and closing for every two turns (four strokes) of the crankshaft. The timing gears also drive the air compressor, water pump, power steering pump, fuel pump and oil pump.

Glow Plugs

A **glow plug** may be necessary to start a cold diesel engine when sustained outside temperatures are well below freezing. Glow plugs are generally installed as a starting aid for indirect injection (IOI) engines. Glow plugs raise the temperature in the combustion chamber so that fuel can spontaneously combust. Once the engine warms up, the glow plug is not used.

Electronic Control Module (ECM)

The modern diesel engine is a mechanical and electronic hybrid. Computers are now as significant as pistons and camshafts. Modern trucks use computers — called **electronic control modules (ECM)** — to maximize performance, regulate use and inform the driver on all aspects of the vehicle's operation. Relative to the engine, an ECM monitors engine speed, oil pressure, air pressure entering the cylinders, fuel efficiency and throttle position. ECMs are used throughout the truck to manage many of its systems including fuel, brakes, air supply, climate control, geographic positioning and more.

Engine Support Systems

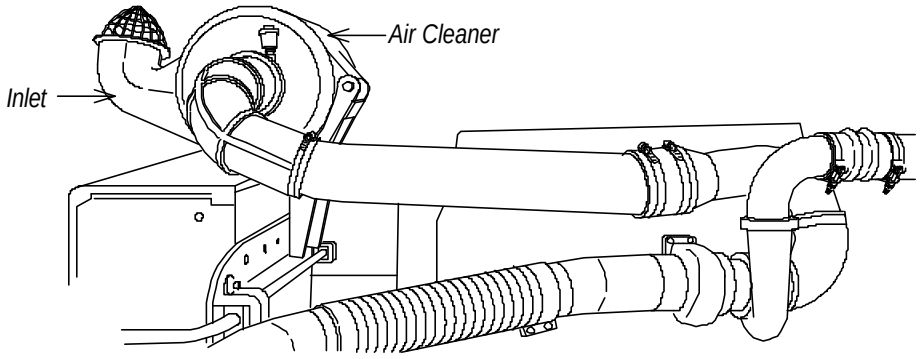
Lubrication System

Without lubricating oil, an engine would fail within minutes. Oil is constantly supplied to coat metal-to-metal moving parts. This helps keep parts cool, reduces wear and prevents corrosion. Diesel engines commonly cycle oil in a pressurized system. It pumps oil from a pool in the oil pan (or crankcase). The oil pump is connected to the timing gears to supply more oil the faster the engine turns. A relief valve in the oil pump prevents oil pressure from becoming too high when the engine is cold and the oil's viscosity (thickness) is high. An oil filter is installed to take out contaminants such as tiny slivers of metal, grains of sand, gasoline, water and other foreign material.

Air Intake System

Air is necessary for combustion. Clean air is vital for engine life. A diesel engine requires a tremendous amount of air (typically about 200 cubic feet per pound of fuel for four strokes). If the air isn't clean, the engine will wear too fast and not be efficient. Diesel engines run with open manifolds, restricted only by the pressure drop across the air filter. Air intake systems are made up of the contaminate-removing parts and the plumbing or ducting.

Figure 7: *Typical air intake system.*



Air cleaners need to filter out 99.9% of contaminates. A precleaner may also be used if the operating environment is dusty, smoky or in some other way subject to airborne contaminates. Some of these also remove moisture and large solid contaminates.

Most air filters have a primary filter that removes and holds large amounts and a secondary or safety filter that prevents contaminate from reaching the clean side of the ducting during service or if the primary filter is badly installed.

There are also one- and two-stage air cleaners. One-stage air cleaners are usually installed where there is less contaminate, such as on-highway applications. Two-stage air cleaners are recommended for agricultural, construction and mining environments.

The life of a filter is determined two ways depending upon how servicing is done:

1) When the intake system has reached the maximum allowable restriction in the filter and any more would reduce airflow below the limit.

2) When the filter is changed out regularly based on the number of hours or miles the filter was in use.

Selling Related Parts Air filters are vital to engine life and should be regularly inspected and changed.	
Key System: Air Intake	
Related Part	**Reason (Benefit)**
Air filters	▪ Clean incoming air extends engine life, maximizes performance and permits the greatest fuel economy. ▪ It's especially critical to have clean, properly installed air cleaners in high-contaminate environments. ▪ Generally, the larger the filter, the longer its life, but never substitute an air filter based only on the dimensions.
Two-stage filter	▪ A truck with a one-stage air cleaner might consider installing a two-stage cleaner to take advantage of a precleaner to achieve 99.9% clean incoming air.

Turbochargers

A **turbocharger** is an exhaust-powered supercharger that (unlike conventional superchargers) has no mechanical connection to the engine. Rapidly moving exhaust gases spin the turbine wheel and shaft that sucks in filtered outside air. The air is compressed by the compressor impeller and directed to the engine's air intake. Turbocharging is the easiest, least expensive way to boost diesel engine performance.

Aftercoolers

When air is compressed it heats up. Hot air is less dense than cooler air. In theory, this defeats the purpose of supercharging if the compressed air got too hot. An **aftercooler**, intercooler or heat exchanger cools incoming air so the engine gets a denser charge of air for a cleaner, more efficient burn. Aftercoolers also lower exhaust temperature so that exhaust valves last longer.

Aftercoolers look like radiators. Air-to-water systems cool air by running it through a radiator filled with engine coolant. Air-to-air systems use outside air for cooling and are generally more reliable and easier to maintain.

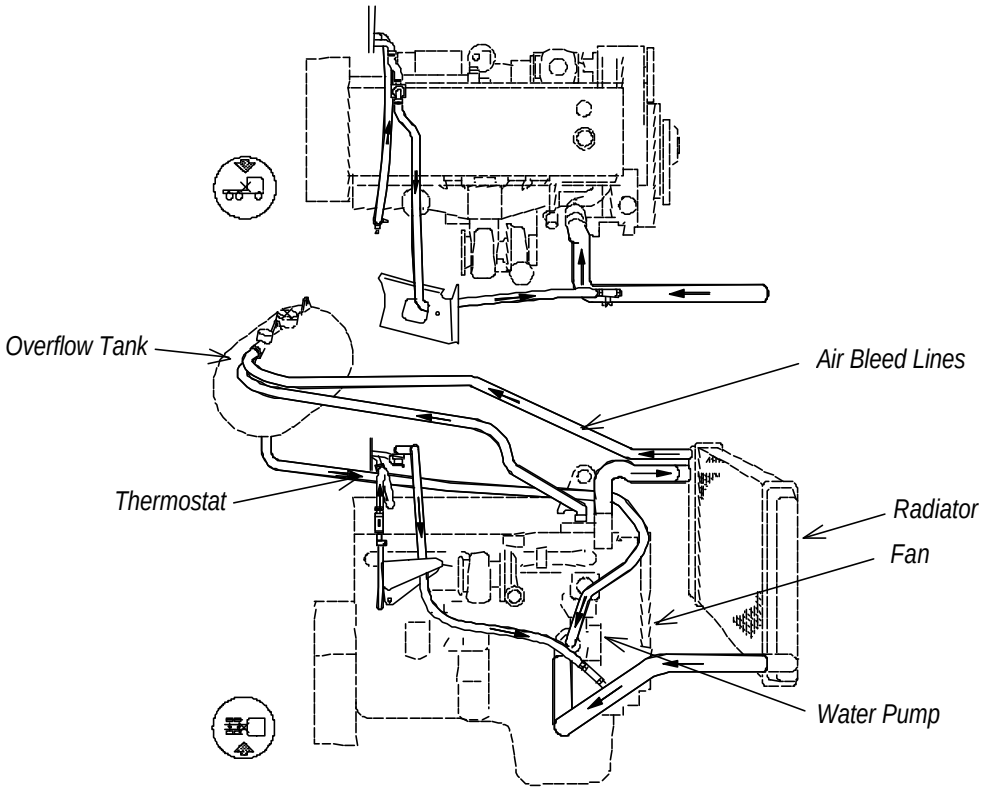
Cooling System

One of our engine manufacturers states that over 40% of engine failures result from cooling system problems. A cooling system is really a temperature control system that keeps engine temperature operating above a minimum and below a maximum. Diesel engines for heavy-duty trucks use water-cooled rather than air-cooled systems. Water is 3500 times more efficient than air at removing heat. That's why diesel engines are liquid cooled and not air cooled, even though it requires a heavier, more complicated system.

There are several components:

- The **water pump** circulates engine coolant throughout the system and can be either gear- or belt-driven.
- The **radiator** is a heat exchanger that transfers heat from the engine coolant to the outside air. A **fan** sucks outside air through the radiator core. A **fan shroud** keeps hot air in the engine compartment from recirculating around the radiator.
- The **thermostat** closes to raise engine temperature by circulating coolant through the block yet bypassing the radiator. It opens once the engine reaches operating temperature and diverts coolant through the radiator and back to the engine. The **fan clutch** keeps the engine from over-cooling. The thermostat controls this clutch so that it runs only when the engine needs cooling.
- The **water filter** or corrosion resistor neutralizes any acid or alkaline build-up. This prevents internal corrosion, a critical factor in diesel engines.
- **Overflow tanks** and **dearation** (air-bleed) **lines** keep air out of the coolant and the cooling system.

Figure 8: *A typical cooling system and its component parts.*



Selling Related Parts The cooling system is your critical defense — keeping the engine protected and clean.	
Key System: Cooling	
Related Part	**Reason (Benefit)**
Hoses (top and bottom radiator, inlet and return heater, to and from degassing tank)	▪ Wear and fatigue is often invisible. Hoses can soften and fail even from a spot of oil contamination. ▪ A hose could rupture on the road when a driver is most vulnerable. It's in the driver's best interest to check and replace all hoses regularly.
Belts	▪ The top of the belt can look fine but underneath it may be pitted, scarred and cracked. It can slip, reducing performance. Worse, it can break, leaving the driver sitting by the side of the road.
Thermostat	▪ Some drivers change out winter and summer thermostats to make sure the engine is running optimally. The thermostat should maintain a recommended range of 190 to 210 degrees F (88 to 99 degrees C) not just for the engine, but to maintain the integrity of the coolant.
Coolant	▪ Coolant consists of water, glycol (antifreeze) and coolant conditioner (inhibitor). Each must be in correct proportion. Check regularly to make sure the coolant is within spec and change it regularly.
Water pump, radiator, fan, filler cap	▪ Check these parts regularly for proper operation. Recommend that your dealership's service technician inspect for damage or wear that could affect performance, or worse, produce failure on the road. This will enable you to sell these related parts.

Diagnosing Overheated Engines

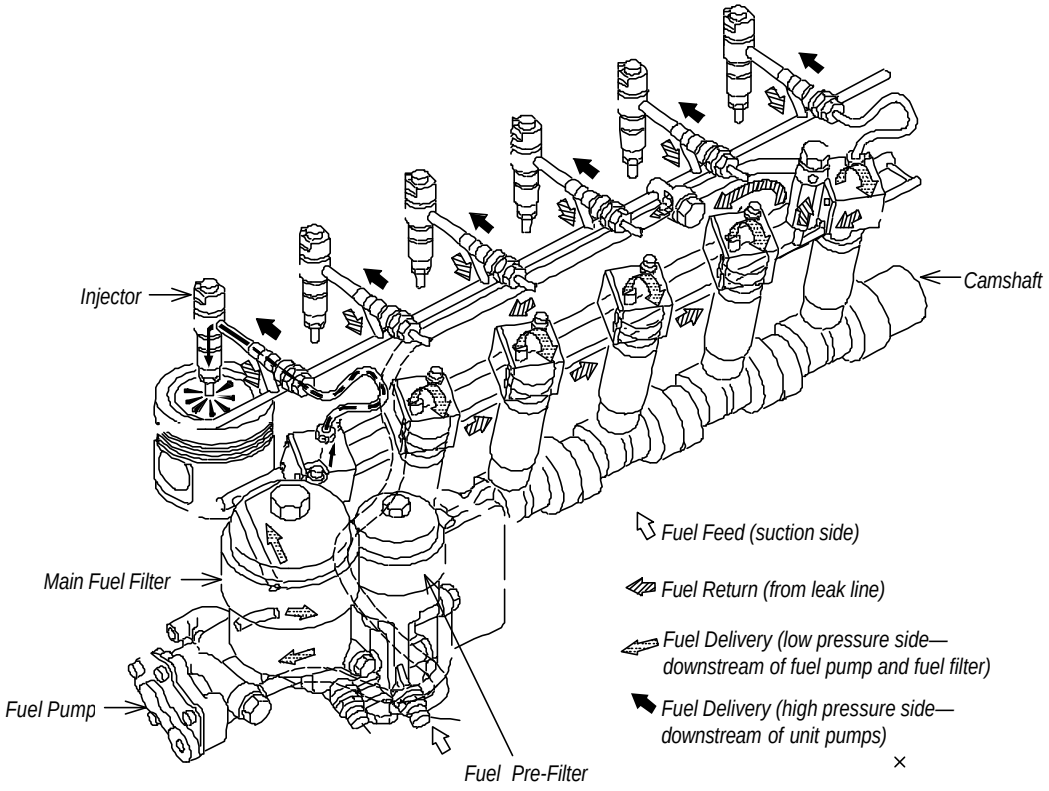
Engine life depends on keeping engine temperatures within a specific range. Here are ten things to look for and the possible parts to recommend if you uncover a problem.

1. Are coolant passages free of rust, liners not pitted?	Coolant (If rust present and liners are pitted, may need engine rebuild kit.)
2. Is the coolant chemistry appropriate?	Coolant (and perhaps new thermostat if overheating changed coolant chemistry)
3. Are the belts in good condition and properly adjusted?	Belts
4. Are hoses free of cracks, hard spots and oil-softened spots?	Hoses
5. Does the thermostat open and close at specified temperature; is there any physical damage?	Thermostat
6. Are there restrictions, corrosion or cross-leaks in the oil cooler?	Oil filter
7. Does the radiator have any leaks, rust or suspect dents?	Radiator; radiator flush and fresh coolant
8. Does the pressure cap hold; do the gasket and vent vale operate properly?	Radiator pressure cap
9. Does the shutter radiator control open and close at the proper temperature?	Coolant sensor
10. Does the thermostatic fan start and stop properly?	Thermostat fan, motor

Fuel System

The fuel system typically consists of a storage tank, low-pressure transfer pump, filters, **injectors** or an injection pump and its high-pressure fuel lines and nozzles, and a governor. Today's practice is to deliver fuel to injector nozzles in small, high-pressure lots. Most diesel engines today use electronically controlled fuel injection systems to meet EPA (Environmental Protection Agency) standards.

Figure 9: *Typical fuel system.*



Fuel Injectors

Injection pumps are classified by where they are located.

- When each injector is fitted with its own cam-operated pump, this is known as a **unit injector**. Unit injectors provide low-pressure fuel to the high-pressure injector pump assemblies. Electronic unit injectors are commonly found in heavy-duty diesels after 1993 to meet lower particulate emission standards.

- When a central pump is mounted somewhere on the engine and connected to the injectors by piping, the pump is either **in-line** (with a plunger for each injector) or **distributor-type** (with a single plunger or plunger set and fuel apportioned by a rotary valve).

High-pressure injection systems use an in-line, multiple-plunger, high-pressure fuel pump and injectors at each cylinder. Low-pressure injection systems deliver low-pressure fuel to unit injectors that then mechanically increase fuel pressure.

Cummins	▪ Electronic fuel pump with constant high-pressure fuel injection
Caterpillar	▪ Mechanically-actuated, electronically controlled unit injectors
Detroit Diesel	▪ ECM-controlled direct actuation fuel injectors
Mercedes-Benz	▪ Centered 8-hole and pencil injectors, individually pumped

Fuel Heaters

In cold conditions, diesel fuel can produce wax crystals that solidify and settle out. This is called the fuel "cloud point." Fuel waxing restricts fuel flow and can actually block it. **Fuel heaters** are required with diesel engines that operate in cold weather. Usually installed in the fuel tank, the heater moves warm coolant through tubes installed in the tank to warm the fuel above the cloud point.

Fuel Filters

The extremely close tolerances among moving parts in injectors make them vulnerable to damage from rust, dirt or other foreign material that can be found in fuel. The **fuel filter** removes these foreign particles as well as water. Too much water in the fuel filter can make it useless. For this reason **fuel filter/water separators** are also often used for the same purpose.

Exhaust System

Exhaust gases from combustion must be efficiently ported out of the engine without creating any “back-pressure” or build-up of gases that could surge back in. Exhaust must also stay within noise and emission standards. The exhaust system consists of a **manifold** or turbo outlet on top of the engine, flex connections to withstand vibration between the engine and the muffler, clamps and shields, and piping. Systems are designed to accommodate any body style and may be mounted under the frame, off the cab or in some custom arrangement based on truck bed or trailer design.

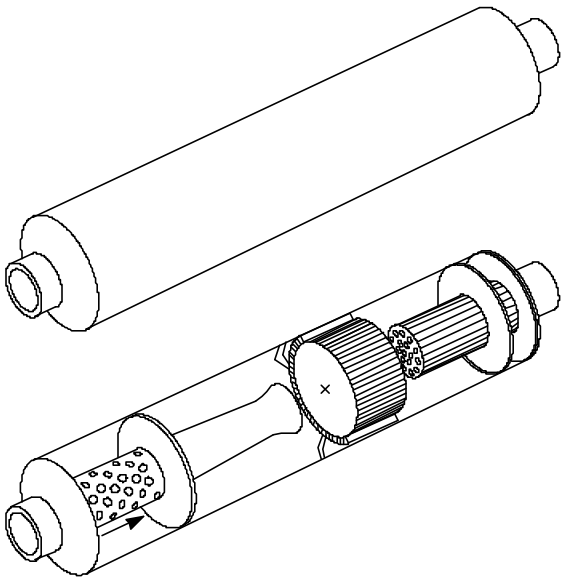
Catalytic Converter

Catalytic converters scrub away many exhaust pollutants by chemically changing them. The converter surfaces are coated with catalyst metals. A “catalyst” is something that speeds up or slows down a chemical reaction without being changed itself. The catalyst metals in these converters (platinum, palladium and rhodium) combine with exhaust gases (carbon monoxide, nitrogen oxide and hydrocarbon fuel) to turn the exhaust into safer carbon dioxide, nitrogen and water vapor.

Muffler

Mufflers break up sound waves to reduce engine exhaust noise. They come in many styles that may look alike on the outside yet have quite different inside configurations.

Figure 10: *The **muffler** (or silencer) uses a series of plates with holes in them to reduce the pressure of the exhaust gases.*



f490058

Engine Brakes and Governors

Engine brakes (frequently known as Jake Brakes™) are systems on a diesel engine that let the driver energize the engine in a way that reduces vehicle speed without employing the service brakes. This saves on vehicle brake wear.

There are two general types of engine brakes, based on their function: exhaust and compression.

Exhaust-type engine brakes are the most common. In this system, a butterfly valve in the exhaust system closes, restricting flow to increase backpressure during the engine exhaust stroke. The engine slows down because of this higher than normal pressure, causing the vehicle to slow down.

Compression-type engine brakes change compression pressures in the cylinder. This is also an effective way to use the engine to slow the vehicle down.

v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v v

Mini Fact: Diesel Fuel is Red, White or Blue

Diesel fuel is slightly heavier than kerosene or jet fuel. Commonly known as No. 2-D, it now comes in red, blue and clear varieties as part of the federal Clean Air Act. Red diesel is stained this color to indicate that it is a low-sulfur fuel for government vehicles and the American Red Cross (but not other charitable organizations) that operate on public highways and do not pay taxes. Blue diesel indicates a high-sulfur variant that is permitted for agricultural and construction equipment, railroads, commercial vessels and diesel-fired heating systems. Clear (or "white") diesel is the low-sulfur type used on the road today.

Engine Efficiency

High-compression ratios give CI engines better thermal efficiency than SI engines. A well-designed CI engine converts about 40% of the heat generated from combusting fuel to turn the crankshaft. SI engines can only achieve about 30% efficiency. The remainder goes out the exhaust and into the cooling system and lubricating oil.

By this measure — which becomes quite critical if global warming is true — diesel engines are the most efficient engines known. (Gas turbines are more efficient but only at a constant speed.) Compression ignition was once considered a mature technology. Recent government regulation and global competition has changed all that.

End of Module

KKK Certification Questions KKK

1. What makes diesel engines different from gasoline engines?
   a) Diesel engines draw less outside air
   b) Diesel engines do not use spark ignition
   c) Diesel engines have a compression stroke
   d) All of the above

2. Which of the following is occurring in a diesel engine when hot, burning gases expand, pushing the piston down?
   a) Muffler is ready to fail
   b) Compression stroke
   c) Spark ignition
   d) Power stroke

3. What is the purpose of the oil pump relief valve?
   a) Increase oil pressure when the engine is idling
   b) Prevent high oil pressure in a cold engine
   c) Release excess oil into the crankcase
   d) None of the above

4. Which of the following IS NOT contained in the cylinder head?
   a) Valve mounting points
   b) Combustion chamber
   c) Pushrod-driven camshaft
   d) All of the above

5. What engine part is normally associated with a “skirt” and a “head?”
   a) Piston
   b) Injector
   c) Thermistor
   d) Intake or exhaust valve

6. What is an “ECM?”
   a) Engine control monitor
   b) Exhaust converter module
   c) Electronic control module
   d) Emission control monitor

7. A “fire ring” refers to what?
   a) Spontaneous ignition during power stroke
   b) Bottom piston ring
   c) Sequence of cylinder strokes
   d) None of the above

8. Which of the following are true of a crankshaft?
   a) Must withstand high stresses
   b) Uses timing gears
   c) Is located within the cylinder head
   d) a and b above

9. Which of the following is true of the camshaft?
   a) Rotates at exactly twice the engine's speed
   b) Changes rotary motion into up and down motion
   c) Is turned by the connecting rods
   d) a and b above

10. Which of the following are true of air cleaners?
    a) Usually contain a primary filter and a secondary filter
    b) Are key protections against premature engine wear
    c) Filter out 99.9% of contaminates
    d) All of the above

11. Which of these is the BEST reason for recommending new hoses?
    a) Wear and fatigue can be invisible; it makes good sense
    b) Hoses are inexpensive
    c) Ruptured hoses are difficult to replace
    d) New compounds make hoses more stable; replace often

12. Which of these is used to cool air before it goes into the engine?
    a) Aftercooler
    b) Intercooler
    c) Heat exchanger
    d) All of the above

13. Pushrods are normally not found on engines with:
    a) In line injectors
    b) Camshafts mounted in the cylinder head
    c) Horsepower ratings higher than 550 HP
    d) Lifters

14. Which of these IS NOT an engine cooling system component?
    a) Dearation lines
    b) Water filter
    c) Turbocharger
    d) Fan

15. Which of these is NOT TRUE of the exhaust stroke?
    a) The outlet valve opens
    b) Hot gases expand
    c) The piston pushes out gases
    d) a and c above

16. Which part DOES NOT normally have a lobe?
    a) Camshaft
    b) Crankshaft
    c) Injector
    d) a and b above

17. Which of these should also be considered when a new thermostat is installed?
    a) New filler cap
    b) New coolant
    c) New inlet and return heater hoses
    d) All of the above

18. Which of these is the BEST reason for recommending new coolant?
    a) High temperature may have changed chemistry
    b) Belts were slipping and squealing
    c) Need new coolant every 3000 miles
    d) Change of season

19. What is the space enclosed by the cylinder head and piston called?
    a) Manifold
    b) Engine block
    c) Combustion chamber
    d) None of the above

20. Which of these IS NOT considered a fuel system component?
    a) Injector
    b) Transfer pump
    c) Inlet valve
    d) Governor

21. What does “CI” mean relative to diesel engines?
    a) Consumption Index (fuel)
    b) Compression Ignition
    c) Cold Injection
    d) None of the above

22. Which of these IS NOT a reason for having an exhaust system?
    a) To meet noise and air quality standards
    b) To eliminate the need for a catalytic converter
    c) To meet federal emission requirements
    d) To avoid back-pressure for exhaust gases

23. Which of these is NEVER characteristic of an engine brake?
    a) It is a friction-producing part attached to the wheels
    b) It can be an expected increase in exhaust backpressure
    c) It can be an expected change in cylinder pressure
    d) It slows a vehicle down

24. What is a BHP rating?
    a) Base hydrostatic pressure
    b) Engine friction measurement
    c) Brake horsepower
    d) Pound-foot conversion standard

25. Which of these is the BEST reason for recommending new belts?
    a) Belts can overtighten with age
    b) New belts have better elastic tension
    c) Belts can split and crack on the underside where you may not see the wear
    d) Belts are like rubberbands and need to be replaced frequently

About Our Industry...

Trucking Today

Brief History

Trucking was born over 100 years ago in a generation where "horsepower" referred to the 25 million horses in the United States that did all the heavy pulling work. For decades early trucks were all small, with carrying capacities like pick-ups today.

World War I (1914-1918) changed all that. Trucks proved their value as dependable beasts of burden. By the end of 1918 there were 600,000 trucks in the U.S. (Now, over 200,000 new tractors alone are sold each year in North America.)

Mechanical power also came to the family farm during the 1920s and 1930s as tractors replaced horses. By 1925 there were three million trucks on the road. And within a generation, horsepower had left the horse behind.

Before the interstate highway system began developing in the 1950s, nearly all trucking was local. But as permanent, all-season roads began crisscrossing the land, long-haul truckers were cruising over them, bringing goods from anywhere to everywhere.

Many say that America's truckers are the Knights of the Road, the most mobile part of our very mobile nation. True or not, there is still the romance associated with the open road. Like the early pioneers who crossed the distances with a taste for adventure and a better life, the big rig trucker is a spiritual descendent, sitting six feet above everything else on the road, gazing far, far ahead along a journey of many destinations.

The Trucking Industry

Commercial trucking is our nation's largest private industry. It employs over seven million people of which 2.5 million are drivers.

The commercial freight market is divided into two general segments: private fleets and for-hire carriers.

- Private carriers are shippers who haul their own raw materials and finished goods (mainly food distribution; manufacturing and processing, wholesaling and retailing; and petroleum). The private fleet is an extension of the parent company and a source of pride, representing the company beyond its doors. Private Truck Council estimates there are more than three million trucks operated by private fleets transporting 3.5 billion tons each year.
- For-hire carriers are most visible in the independent trucker who owns a tractor and hires out for hauling. Since the trucking industry was deregulated in 1980, the number of for-hire truckers has tripled. Even so, there is a critical shortage of drivers, especially the long-haul trucker.

For-hire carriers are further divided into two general types: the truckload (TL) group and the less-than-truckload (LTL) group.

1) TL carriers move large shipments between major points. Three of every four TL shipments are less than 500 miles. Truckload carriers got the name when shipments of 10,000 pounds were considered a full load. Today, with shipments of 40,000 and even as much as 129,000,000 pounds, a TL carrier may haul several shipments of 7,000 to 10,000 pounds each.

2) The LTL carriers move smaller shipments, usually through a network. Less-than-truckload carriers have benefited from just-in-time (JIT) inventory practices where inventories are held to minimums and new stock is continually delivered. Also, with e-commerce, experts predict that Internet orders will bring much more business to the LTL haulers delivering packages direct to consumers.

Figure 11: *American Trucking Industry Overview*

People employed in trucking industry	7,000,000
Truck drivers	2,500,000
Total truck traffic (annually)	3 billion tons
Fuel used (annually)	53 billion gallons
Trailer types	▪ 18-wheeler (single trailer) ▪ Double trailer ▪ Triple (“pup”) trailer ▪ Special (vocational) such as cement trucks, dump trucks, liquid transport, logging, mining, construction, etc.

Source: U.S. Industry and Trade Outlook, 1996

Truck Classifications

Trucks themselves are classified in two major ways: by gross vehicle weight and by number of axles and drive wheels.

Gross Vehicle Weight

Gross Vehicle Weight (GVW) is the weight of the vehicle and the load it can carry. Heavy-duty trucks carry 33,001 pounds GVW and over.

Figure 12: *Classification by Gross Vehicle Weight*

Classification	**Class**	**Gross Vehicle Weight (pounds)**
Light Duty	1, 2, 3	Less than 14,000
Medium Duty	4, 5, 6	14,001 – 26,000
Light Heavy Duty	7	26,001 – 33,000
Heavy Duty	8	33,001 and more

Axle and Wheel Count

When the number of axles and drive wheels classifies a rig, it's referred to with two numbers with an "x" in between. The x stands for "by" as in 4 x 4 (four by four). The first number is the total number of wheels (or sets of wheels when there are dual wheels) counting both ends of the axle. The second number tells you how many of the wheels are driven by the powertrain. For example, a tractor with a tandem rear axle (a close-coupled pair of axles) where only the front rear axle is driven would be a 6 x 2; it has six outside wheels but only two drive the vehicle.

Figure 13: *Classification by Truck Wheel and Axle Number*

Classification	Total Wheels (or dual sets)	Driven Wheels	Drive Axles	Total Axles
4 x 4	4	4	2	2
6 x 2	6	2	1	3
6 x 4	6	4	2	3
6 x 6	6	6	3	3
8 x 4	8	4	2	4
8 x 8	8	8	4	4

Trucking's Impact on Commercial Freight

Today, the trucking industry handles over three-fourths of U.S. commercial freight — about $350 billion in annual revenue and about three billion tons hauled. Trucks tend to be used to move manufactured goods; other modes move bulk commodities. The table below gives you an idea how much freight each group carries.

Figure 14: *Commercial Freight Revenues (1998)*

	Revenue (in Billions – $,000,000,000)	**Percent of Total**
Trucking (total)	**344**	**79.8**
▪ Private, interstate	115	26.4
▪ Private, local	85	19.5
▪ Truckload (TL)	65	14.9
▪ Local for-hire	40	9.2
▪ LTL, national	9	2.0
▪ LTL, regional	11	2.5
▪ Package/express (ground)	19	4.4
Railroad	*36*	*8.3*
Pipeline (oil/gas)	*26*	*6.0*
Air freight (domestic package)	*17*	*3.9*
Air freight (heavy, domestic	*6*	*1.4*
Water (Great Lakes, rivers)	*7*	*1.6*
Industry Total	**436**	**100.0**

Source: Forrester Research, U.S. Statistical Analysis, 1998

Look forward to ***About Our Industry*** in the Truck Systems: Drivetrain module where you'll learn all about Freightliner LLC's history.

Acknowledgements

Special thanks to these companies for their support and information:

- Caterpillar Inc.
- Cummins Engine Company Inc.
- Detroit Diesel Corp.
- Donaldson Company, Inc.