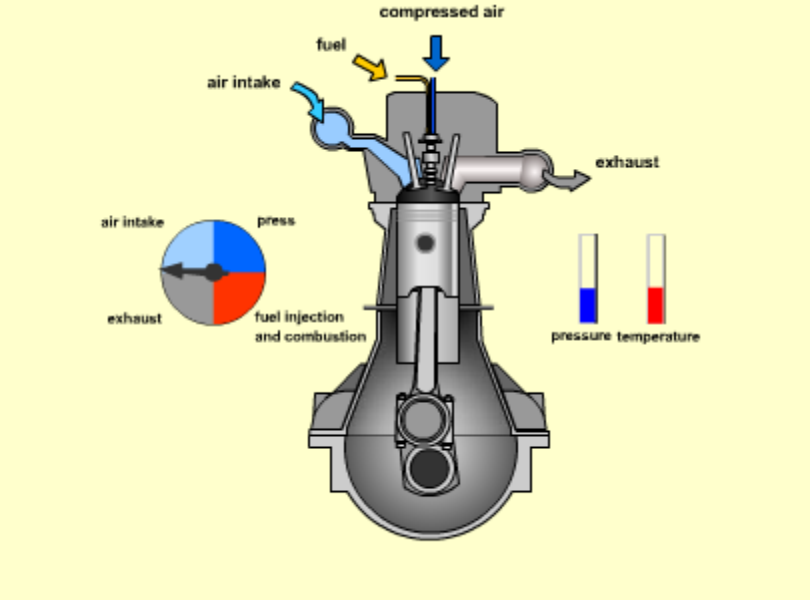
How Diesel Engines Work

Diesel Engines vs. Gasoline Engines

In theory, diesel engines and gasoline engines are quite similar. They are both **internal combustion engines** designed to convert the chemical energy available in fuel into mechanical energy. This mechanical energy moves pistons up and down inside cylinders. The pistons are connected to a crankshaft, and the up-and-down motion of the pistons, known as linear motion, creates the rotary motion needed to turn the wheels of a car forward.

Both diesel engines and gasoline engines covert fuel into energy through a series of small explosions or combustions. The major difference between diesel and gasoline is the way these explosions happen. In a gasoline engine, fuel is mixed with air, compressed by pistons and ignited by sparks from spark plugs. In a diesel engine, however, the air is compressed first, and then the fuel is injected. Because air heats up when it's compressed, the fuel ignites.

Diesel Engine



Gasoline Engine

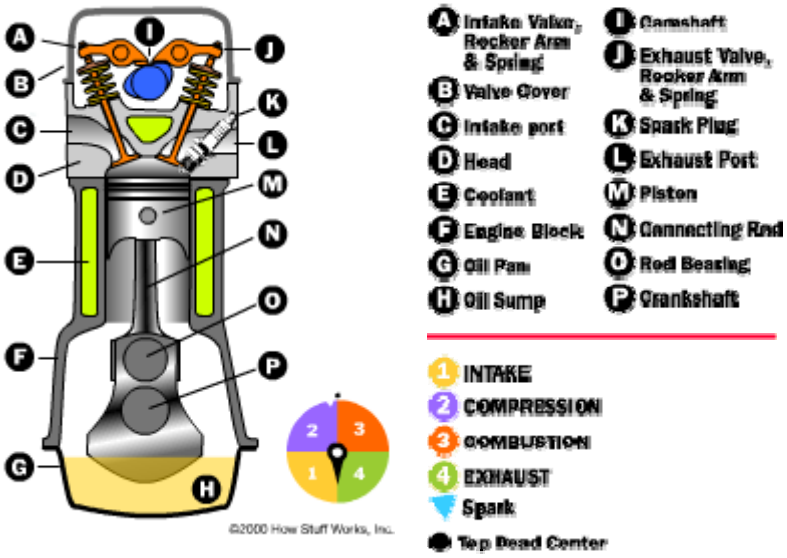


Image courtesy Baris Mengutay

The diesel engine uses a four-stroke combustion cycle just like a gasoline engine. The four strokes are:

Intake stroke -- The intake valve opens up, letting in air and moving the piston down.
Compression stroke -- The piston moves back up and compresses the air.
Combustion stroke -- As the piston reaches the top, fuel is injected at just the right moment and ignited, forcing the piston back down.
Exhaust stroke -- The piston moves back to the top, pushing out the exhaust created from the combustion out of the exhaust valve.

Remember that the diesel engine has no spark plug, that it intakes air and compresses it, and that it then injects the fuel directly into the combustion chamber (direct injection). It is the heat of the compressed air that lights the fuel in a diesel engine. In the next section, we'll examine the diesel injection process.

Compression

When working on his calculations, Rudolf Diesel theorized that higher compression leads to higher efficiency and more power. This happens because when the piston squeezes air with the cylinder, the air becomes concentrated. Diesel fuel has a high energy content, so the likelihood of diesel reacting with the concentrated air is greater. Another way to think of it is when air molecules are packed so close together, fuel has a better chance of reacting with as many oxygen molecules as possible. Rudolf turned out to be right -- a gasoline engine compresses at a ratio of 8:1 to 12:1, while a diesel engine compresses at a ratio of 14:1 to as high as 25:1.

Diesel Fuel Injection

One big difference between a diesel engine and a gas engine is in the injection process. Most car engines use port injection or a carburetor. A port injection system injects fuel just prior to the intake stroke (outside the cylinder). A carburetor mixes air and fuel long before the air enters the cylinder. In a car engine, therefore, all of the fuel is loaded into the cylinder during the intake stroke and then compressed. The

compression of the fuel/air mixture limits the compression ratio of the engine -- if it compresses the air too much, the fuel/air mixture spontaneously ignites and causes **knocking**. Because it causes excessive heat, knocking can damage the engine.

Diesel engines use direct fuel injection -- the diesel fuel is injected directly into the cylinder.

The injector on a diesel engine is its most complex component and has been the subject of a great deal of experimentation -- in any particular engine, it may be located in a variety of places. The injector has to be able to withstand the temperature and pressure inside the cylinder and still deliver the fuel in a fine mist. Getting the mist circulated in the cylinder so that it is evenly distributed is also a problem, so some diesel engines employ special induction valves, pre-combustion chambers or other devices to swirl the air in the combustion chamber or otherwise improve the ignition and combustion process.

Photo courtesy DaimlerChrysler

Atego six-cylinder diesel engine

Some diesel engines contain a **glow plug**. When a diesel engine is cold, the compression process may not raise the air to a high enough temperature to ignite the fuel. The glow plug is an electrically heated wire (think of the hot wires you see in a toaster) that heats the combustion chambers and raises the air temperature when the engine is cold so that the engine can start. According to Cley Brotherton, a Journeyman heavy equipment technician:

All functions in a modern engine are controlled by the ECM communicating with an elaborate set of sensors measuring everything from R.P.M. to engine coolant and oil temperatures and even engine position (i.e. T.D.C.). Glow plugs are rarely used today on larger engines. The ECM senses ambient air temperature and retards the timing of the engine in cold weather so the injector sprays the fuel at a later time. The air in the cylinder is compressed more, creating more heat, which aids in starting.
Smaller engines and engines that do not have such advanced computer control use glow plugs to solve the cold-starting problem.

Of course, mechanics aren't the only difference between diesel engines and gasoline engines. There's also the issue of the fuel itself.

Diesel Fuel

Petroleum fuel, or crude oil, is naturally found in the Earth. When crude oil is refined at refineries, it can be separated into several different kinds of fuels, including gasoline, jet fuel, kerosene and, of course, diesel.

If you have ever compared diesel fuel and gasoline, you know that they are different. They certainly smell different. Diesel fuel is heavier and oilier. Diesel fuel evaporates much more slowly than gasoline -- its boiling point is actually higher than the boiling point of water. You will often hear diesel fuel referred to as "diesel oil" because it is so oily.

Staff/Getty Images

A sample of diesel fuel

Diesel fuel evaporates more slowly because it is heavier. It contains more carbon atoms in longer chains than gasoline does (gasoline is typically C_9H_{20}, while diesel fuel is typically $C_{14}H_{30}$). It takes less refining to create diesel fuel, which is why it used to be cheaper than gasoline. Since 2004, however, demand for diesel has risen for several reasons, including increased industrialization and construction in China and the U.S. [source: Energy Information Administration].

Diesel fuel has a **higher energy density** than gasoline. On average, 1 gallon (3.8 L) of diesel fuel contains approximately $155x10^6$ joules (147,000 BTU), while 1 gallon of gasoline contains $132x10^6$ joules (125,000 BTU). This, combined with the improved efficiency of diesel engines, explains why diesel engines get better mileage than equivalent gasoline engines.

Diesel fuel is used to power a wide variety of vehicles and operations. It of course fuels the diesel trucks you see lumbering down the highway, but it also helps move boats, school buses, city buses, trains, cranes, farming equipment and various emergency response vehicles and power generators. Think about how important diesel is to the economy -- without its high efficiency, both the construction industry and farming businesses would suffer immensely from investments in fuels with low power and efficiency. About 94 percent of freight -- whether it's shipped in trucks, trains or boats -- relys on diesel.

In terms of the environment, diesel has some pros and cons. The pros -- diesel emits very small amounts of carbon monoxide, hydrocarbons and carbon dioxide, emissions that lead to global warming. The cons -- high amounts of nitrogen compounds and particulate matter (soot) are released from burning diesel fuel, which lead to acid rain, smog and poor health conditions. On the next page we'll look at some recent improvements made in these areas.

Diesel Improvements and Biodiesel

During the big oil crisis in the 1970s, European car companies started advertising diesel engines for commercial use as an alternative to gasoline. Those who tried it out were a bit disappointed -- the engines were very loud, and they would arrive home to find their cars covered from front to back in black soot -- the same soot responsible for smog in big cities.

Over the past 30 to 40 years, however, vast improvements have been made on engine performance and fuel cleanliness. Direct injection devices are now controlled by advanced computers that monitor fuel combustion, increasing efficiency and reducing emissions. Better-refined diesel fuels such as ultra low sulfur diesel (ULSD) will lower the amount of harmful emissions and upgrading engines to make them compatible with cleaner fuel is becoming a simpler process. Other technologies such as CRT particulate filters and catalytic converters burn soot and reduce particulate matter, carbon monoxide and hydrocarbons by as much as 90 percent. [source: Diesel Technology Forum]. Continually improving standards for cleaner fuel from the European Union will also push the auto industries to work harder at lowering emissions -- by September 2009, the EU hopes to have particulate matter emissions down from 25mg/kilometer to 5mg/kilometer [source: EUROPA].

Photo courtesy Mario Tama/Getty Images

Cleaner fuel and stricter emissions levels should reduce the number of early deaths due to diesel engine pollution.

You may have also heard of something called biodiesel. Is it the same as diesel? Biodiesel is an alternative or additive to diesel fuel that can be used in diesel engines with little to no modifications to the engines themselves. It's not made from petroleum -- instead it comes from plant oils or animal fats that have been chemically altered. (Interesting fact: Rudolf Diesel had originally considered vegetable seed oil as fuel for his invention.) Biodiesel can either be combined with regular diesel or used completely by itself. You can read more about biodiesel in How Biodiesel Works.

For more information on diesel engines and related topics, check out the links on the next page.