

## Just the Basics

### Diesel Engine

**Today's direct-injection diesel engines are more rugged, powerful, durable, and reliable than gasoline engines, and use fuel much more efficiently, as well.**

#### Diesel Engines Yesterday, Today, and Tomorrow

Diesels are workhorse engines. That's why you find them powering heavy-duty trucks, buses, tractors, and trains, not to mention large ships, bulldozers, cranes, and other construction equipment. In the past, diesels fit the stereotype of muscle-bound behemoths. They were dirty and sluggish, smelly and loud. That image doesn't apply to today's diesel engines, however, and tomorrow's diesels will show even greater improvements. They will be even more fuel efficient, more flexible in the fuels they can use, and also much cleaner in emissions.

#### How Diesel Engines Work

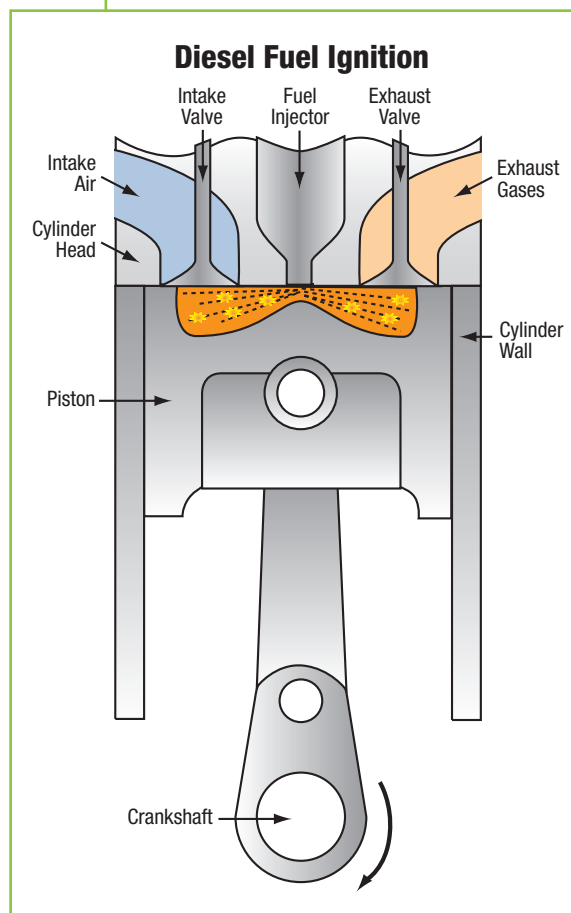
Like a gasoline engine, a diesel is an internal combustion engine that converts chemical energy in fuel to mechanical energy that moves pistons up and down inside enclosed spaces called cylinders. The pistons are connected to the engine's crankshaft, which changes their linear motion into the rotary motion needed to propel the vehicle's wheels. With both gasoline and diesel engines, energy is released in a series of small explosions (combustion) as fuel reacts chemically with oxygen from the air. Diesels differ from gasoline engines primarily in the way the explosions occur. Gasoline

engines start the explosions with sparks from spark plugs, whereas in diesel engines, fuel ignites on its own.

Air heats up when it's compressed. This fact led German engineer Rudolf Diesel to theorize that fuel could be made to ignite spontaneously if the air inside an engine's cylinders became hot enough through compression. Achieving high temperatures meant producing much greater air compression than occurs in gasoline engines, but Diesel saw that as a plus. According to his calculations, high compression should lead to high engine efficiency. Part of the reason is that compressing air concentrates fuel-burning oxygen. A fuel that has high energy content per gallon, like diesel fuel, should be able to react with most of the concentrated oxygen to deliver more punch per explosion, if it was injected into an engine's cylinders at exactly the right time.

Diesel's calculations were correct. As a result, although diesel engines have seen vast improvements, the basic concept of the four-stroke diesel engine has remained virtually unchanged for over 100 years. The first stroke involves drawing air into a cylinder as the piston creates space for it by moving away from the intake valve. The piston's subsequent upward swing then compresses the air, heating it at the same time. Next, fuel is injected under high pressure as the

*Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle*



*In the modern direct-injection diesel engine, fuel combustion is confined to a specially shaped region within the head of each piston. There, diesel fuel ignites spontaneously, yet in a carefully controlled manner. Old-style indirect-injection diesels were not capable of this precision. As a result, fuel efficiency suffered and emissions soared.*

piston approaches the top of its compression stroke, igniting spontaneously as it contacts the heated air. The hot combustion gases expand, driving the piston downward in what's called the power stroke. During its return swing, the piston pushes spent gases from the cylinder, and the cycle begins again with an intake of fresh air.

## How Diesel Engines Have Improved

Older diesel engines mixed fuel and air in a precombustion chamber before injecting it into a cylinder. The mixing and injection steps were controlled mechanically, which made it very difficult to tailor the fuel-air mixture to changing engine conditions. This led to incomplete fuel combustion, particularly at low speeds. As a result, fuel was wasted and tailpipe emissions were relatively high.

Today's diesels inject fuel directly into an engine's cylinders using tiny computers to deliver precisely the right amount of fuel the instant it is needed. All functions in a modern diesel engine are controlled by an electronic control module that communicates with an elaborate array of sensors placed at strategic locations throughout the engine to monitor everything from engine speed to coolant and oil temperatures and even piston position. Tight electronic control means that fuel burns more thoroughly, delivering more power, greater fuel economy, and fewer emissions than yesterday's diesel engines could achieve.

Modern direct-injection diesel engines produce low amounts of carbon dioxide, carbon monoxide, and unburned hydrocarbons. Emissions of reactive nitrogen compounds (commonly spoken

of as NO<sub>x</sub>) and particulate matter (PM) have been reduced by over 90 percent since 1980, as well. Nevertheless, NO<sub>x</sub> and PM emissions remain at relatively high levels. NO<sub>x</sub> contributes to acid rain and smog, while adverse health effects have been associated with exposures to high PM amounts.

## What Improvements Need to Be Made?

Diesel engines are already more efficient than gasoline engines (45 percent versus 30 percent), and further advances are possible (to 55-63 percent). Widespread use of diesel engines, particularly in trucks, vans, and sport utility vehicles, therefore promises to substantially reduce United States dependence on foreign petroleum products. The stumbling block to reaching this goal, however, remains NO<sub>x</sub> and PM emissions. Unfortunately, increasing diesel efficiency does not necessarily make these emissions go away.

Three basic strategies are being pursued to meet the U.S. Environmental Protection Agency's increasingly stringent emissions standards. The first concerns research into the diesel combustion process to better understand how soot particles and NO<sub>x</sub> gases form. The second involves development of NO<sub>x</sub> and PM removal technologies to eliminate residual emissions in much the same way that catalytic converters eradicate emissions from gasoline engines. The third research area relates to improving diesel fuels. The U.S. Department of Energy is working with engine manufacturers and fuel suppliers to develop diesel fuels that are optimized for today's and tomorrow's advanced diesel engines. The new fuel formulations will enable both high fuel economy and very low emissions.

## A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.



**U.S. Department of Energy**  
**Energy Efficiency**  
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