2012 & BEYOND: 8 IDEAS TO REINVENT DIESEL

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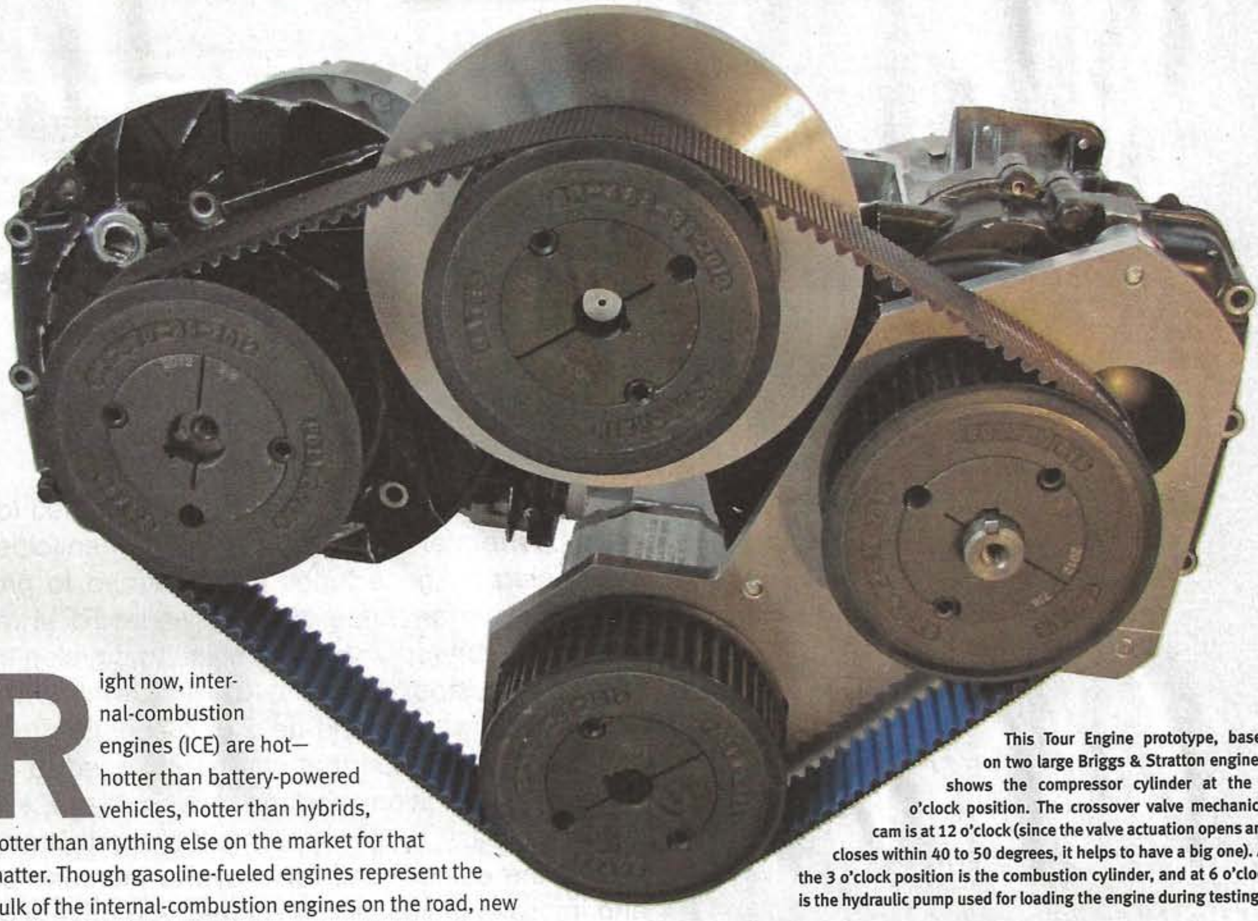
REINVENTING DIESEL

EIGHT COMPANIES DETERMINED TO CHANGE OUR ENGINES FOREVER



This Tour Engine prototype, based on two large Briggs & Stratton engines, shows the compressor cylinder at the 9 o'clock position. The crossover valve mechanical cam is at 12 o'clock (since the valve actuation opens and closes within 40 to 50 degrees, it helps to have a big one). At the 3 o'clock position is the combustion cylinder, and at 6 o'clock is the hydraulic pump used for loading the engine during testing.

Right now, internal-combustion engines (ICE) are hot—hotter than battery-powered vehicles, hotter than hybrids, hotter than anything else on the market for that matter. Though gasoline-fueled engines represent the bulk of the internal-combustion engines on the road, new high-tech diesels are coming on strong.

Traditionally, diesel engines have been simple and robust powerplants. They've changed very little and only in small increments since their creation in 1893. That slow-and-steady trend appears to be changing in today's marketplace. Engineers in Detroit are looking into new compression-ignition concepts, Navistar is investing in innovative up-starts, Cummins is working on new engine architectures, and the Japanese automakers are coming to market with small, lightweight diesels.

It turns out the idealized transition toward fleets of battery-powered electric vehicles isn't as rapid as some media outlets would have you believe. Trust us when we say internal combustion is here to stay for a long time to come.

EIGHT PATHS TO THE FUTURE OF DIESEL

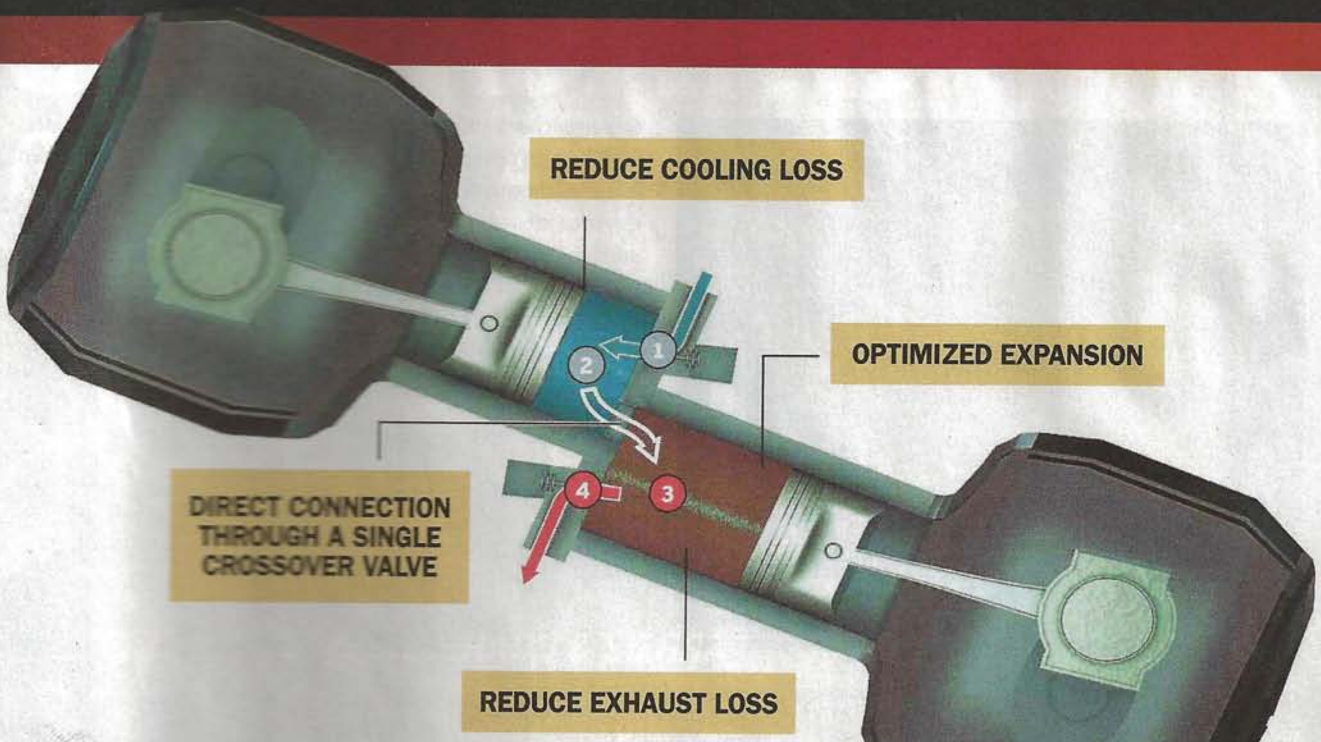
The next generation of diesel engines will follow the principles of thermodynamics much closer. New control strategies and faster computer processors will allow combustion to be more precise than Rudolf Diesel could have ever dreamed. A few years ago, some of the engines we're about to show you were only theories and CAD renderings, but today they're starting to materialize. The following is a look into the future of what diesel engines might look like.

1. TOUR ENGINES

Dr. Oded Tour, CEO of Tour Engines, shared his engine philosophy with us this way: "We could develop a single appliance that acts as a freezer and stove at the same time, but it works much better to keep them separate." This analogy was used to describe the current configuration of the diesel engine. Basically, we have two contradicting things (a cool compressor and a hot combustor) forced to compromise by sharing the same piston and cylinder.

Oded and his father, Lt. Colonel Hugo Tour, founded The Tour Engine company. He was a former researcher at the lab of Roger Tsien,

BY JASON THOMPSON ■ PHOTOS COURTESY OF THE ENGINE MAKERS



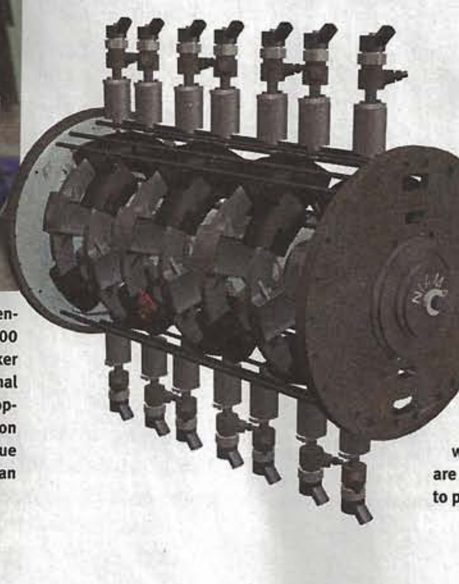
By separating the traditional combustion cycles, the Tour Engine design means the compressor cylinder no longer needs to be cooled to produce dense air. A single and direct crossover valve regulates the air going from the compressor to the combustor. Furthermore, the compressor cylinder's volume is about a third smaller than the combustion cylinder. This means less work to compress the air and more room to expand the combusted gases—this allows for more work on the piston. It also means the combustion cylinder is cooled as a result of the increased expansion—just as Rudolf Diesel intended.

The Niama-Reisser NR-1 concept car holds four passengers, weighs 1,200 pounds, and is reported to get 200 mpg at 70 mph. The car's 1.0L Centrifugal Heinz Boxer (CHB) engine represents a clean break from traditional combustion engines. The CHB engine uses a pair of opposing torus-shaped pistons (they look like a section of a doughnut) that oscillate in a rotary motion. Torque is applied to the crankshaft with a mechanism that can also vary the compression ratio (beyond 25:1).

the 2008 Nobel Prize winner in Chemistry, and his father was previously in charge of all technical aspects at the largest Israeli Air Force Base and has 20 years experience developing novel engines. Their first prototype was built from two small Honda engines sandwiched together with their pistons opposed to each other. You can see this split-cycle engine running for the first time at: http://www.youtube.com/watch?v=ExAO_JA0NgA. The Tour Engine first tried compression ignition by decreasing the phase-lag between the two pistons. This increased the compression ratio. In this setting, the engine kept running without needing a spark plug.

2. NIAMA-REISSER

Even as the push for battery-electric vehicles becomes stronger, Niama-Reisser wants you to resist and hold off on buying that Volt, Leaf, or Prius. Remain unplugged just a little longer, and in one year you'll be able to get behind the wheel of a vehicle capable of obtaining 200 mpg. Based in Coshocton, Ohio, this new car company utilizes ceramic engine materials, ultra-light suspension systems (which we displayed at http://blogs.dieselpowermag.com/6762484/diesel-engines/niama-reisser-200-mpg-diesel-car/index.html), and superb aerodynamics to achieve its amazing fuel economy. Its CHB engine is said to have a

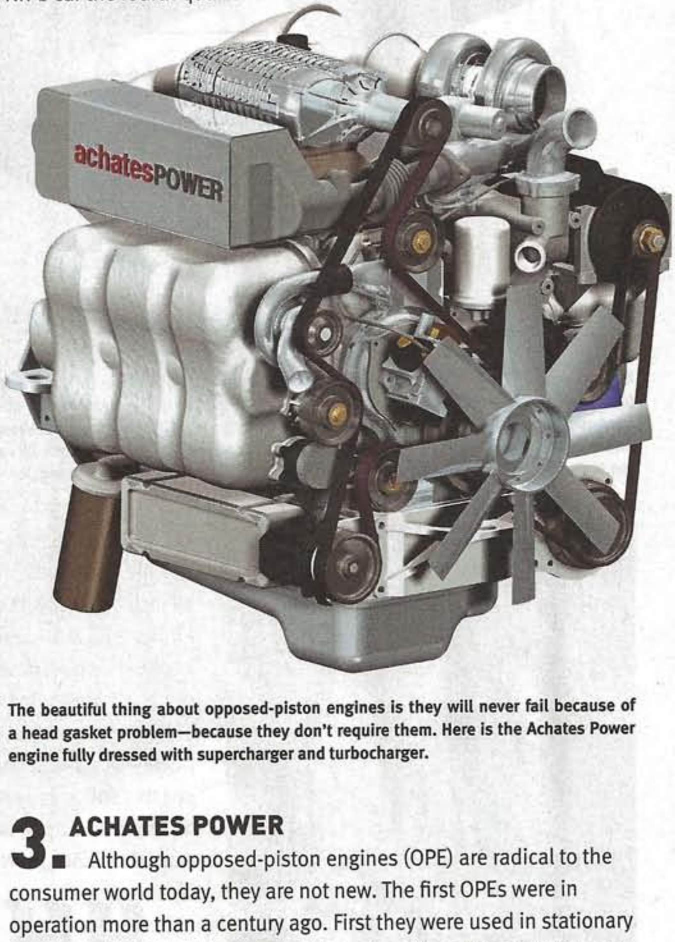


The Niama-Reisser 7.0L CHB-Evo is able to produce 1,120 lb-ft. Seven modules or single CHB engines deliver power to the wheels. Each engine is connected with a clutch and brought online as power is needed. There are 14 fuel injectors and 28 pistons. Each CHB engine is able to produce 221 lb-ft, but the engines are detuned to 160 lb-ft.

The CHB is engineered from ceramic, which means it doesn't need oil lubrication or a liquid cooling system. If that doesn't impress you, then read this: The tolerances are so precise and material so stable, the pistons don't need steel compression rings or cylinder liners when placed in an aluminum cylinder.

Achates Power claims its 3-cylinder will out power 8-cylinder engines we use and love today. This performance increase is due to the opposed-piston architecture that uses two pistons in one cylinder. According to Achates Power, the opposed-piston engine creates a larger cylinder displacement for a given cylinder bore diameter, leading to a reduction of the number of cylinders. Fewer cylinders reduces the surface area available for in-cylinder heat transfer—meaning more work goes into the piston. In addition, a piston replaces the cylinder head, so higher metal temperatures are possible.

60 percent parts count reduction compared to today's diesel engines. It also doesn't need oil for lubrication. Furthermore, it can be turned into a steam engine—the only modification needed is a steam valve, either controlled mechanically or hydraulically. At 1,600 psi steam pressure, the moment reaction at the crankshaft is said to peak at 2,052 lb-ft—not bad for a 1.0L engine. The engine is supposed to be able to handle 2,610 psi. Niama-Reisser just announced it is going to start production on the engine in the second quarter of 2012 and the NR-1 car the fourth quarter of 2012.



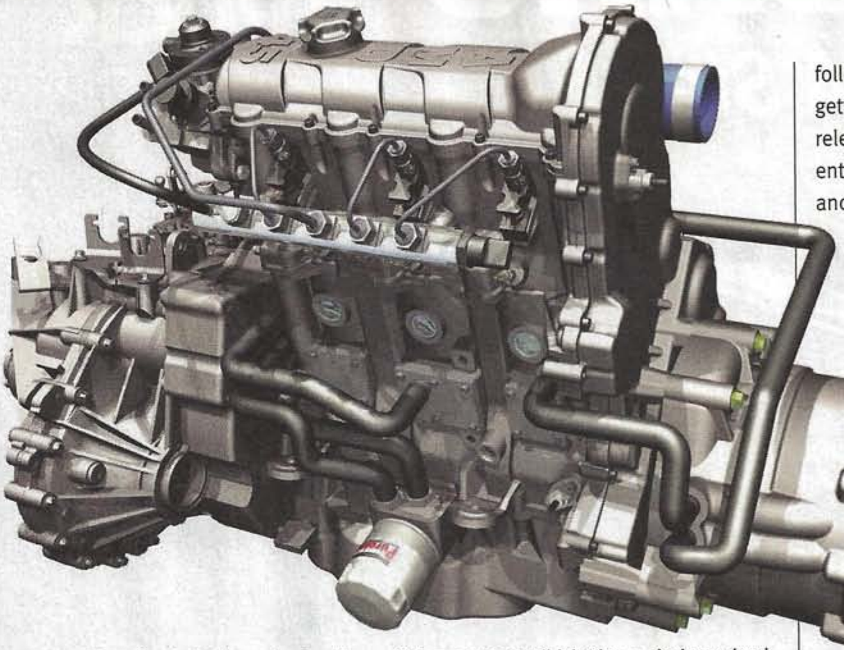
The beautiful thing about opposed-piston engines is they will never fail because of a head gasket problem—because they don't require them. Here is the Achates Power engine fully dressed with supercharger and turbocharger.

3. ACHATES POWER

Although opposed-piston engines (OPE) are radical to the consumer world today, they are not new. The first OPEs were in operation more than a century ago. First they were used in stationary power applications, then marine, then aircraft, and finally truck and tank applications. Opposed-piston engines use two pistons in one cylinder, and the combustion chamber is formed in the middle of the pistons. The two-stroke, diesel-fueled, compression-ignition design of Achates Power uses ports in the cylinder wall instead of a valvetrain to control intake and exhaust flow. Achates Power started back in 2004 when John Walton, son of Sam Walton (founder of Walmart), provided funding for Dr. James U. Lemke.

4. RIVIAN

Ever notice how leaders at most car companies are old and seemingly against new ideas? That's not the case with Rivian. Its CEO, R.J. Scaringe, is in his 20s. We've had a few conversations with R.J., and he is a big supporter of diesel and *Diesel Power*. If you



The Rivian diesel-electric engine has three cylinders, common-rail injection, a single overhead camshaft, and an electric motor integrated into the front of the engine. Transmission choices will be either a manual or an automated manual gearbox.

"The performance, low cost, and fuel flexibility of internal-combustion engines makes it likely they will continue to dominate the vehicle fleet for at least the next several decades."

— U.S. Department of Energy, Report on the First Quadrennial Technology Review 2011

follow our blogs, you already know that we've been getting the scoop first when it comes to Rivian's press releases. We've been told to expect a radically different car from Rivian. It'll have a diesel-electric engine and ultra-light body, which should equal outstanding fuel economy and a car that's actually fun to drive. What's better is it's reported that this will all come at a price most people can afford. The icing on the cake is Rivian is an American company based in Rockledge, Florida.

5. ECOMOTORS

Professor Peter Hofbauer began working on opposed-piston, opposed-cylinder (OPOC) engines that made more than 1 hp per pound in 2003. He has many past accomplishments developing power-dense engines for Volkswagen. The first applications of his new engines were unmanned helicopters, followed by suitcase-sized portable generators for the United States military. Fast-forward eight years, and these power-dense OPOC engines are projected to appear in all kinds of vehicles, including passenger cars and trucks. Right now, Navistar and EcoMotors engineers are busy testing and developing a new version of the opposed-piston, opposed-cylinder engine (OPOC) for its heavy-duty trucks. This engine design is scalable and has been created in several different displacements; multiple engines can be stacked together like Legos to build modular powerplants.

Although there have been other opposed-piston, opposed-cylinder engines in the past, this design has benefited from the financial backing of Bill Gates and Vinod Khosla—not to mention advances in computer power and building materials and processes. The Navistar-EcoMotors OPOC is an early frontrunner in a growing segment, which is unlikely to go away with today's volatile fuel prices and growing environmental concerns.

EcoMotors is located in Allen Park, Michigan. Its EM100 is a two-stroke, opposed-piston, opposed-cylinder turbodiesel. The cylinder bore is 3.937 inches and the engine weighs 296 pounds. The engine measures 22.8x41.3x18.5 inches and is rated for 325 hp at 3,500 rpm while torque is 664 lb-ft at 2,100 rpm.

6. HCPC

Homogenous Charge Progressive Combustion (HCPC) is an innovative way to control homogenous charge compression ignition (HCCI) in diesel-fueled engines. HCCI is the Holy Grail for engine makers and happens when all the factors for combustion are perfect. Practically no emissions result when the engine is in this mode. In current diesel engines, this type of combustion is theoretically possible, but it's like trying to balance an elephant on a stack of pool balls. Rolf Reitz from the University of Madison, and Ettore Musu, Riccardo Rossi, and Roberto Gentili from the Universita di Pisa developed the HCPC engine. It uses the split-cycle principle and one valve that controls the flow from the compression cylinder to the combustion cylinder.

7. SCUDERI ENGINE

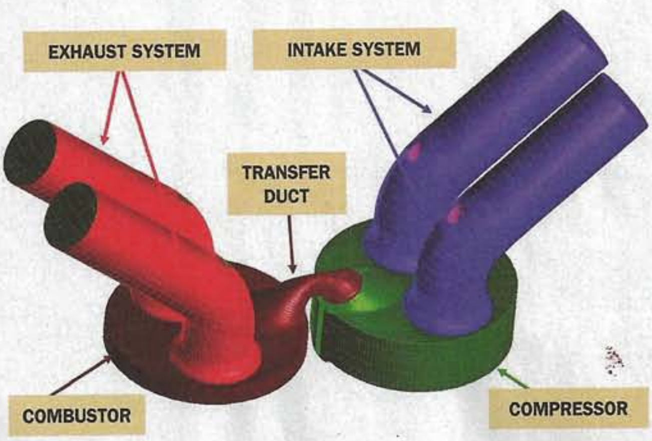
Based in West Springfield, Massachusetts, Scuderi Engine is the brainchild of inventor Carmelo Scuderi. In 1992, he invented an oil-less compressor technology that prevented the release of chlorofluorocarbons. His design captured 70 percent of the refrigerant recovery market in 6 months. Other achievements include work on torpedoes, NASA space suits, and aircraft carrier equipment. His family has carried on the work.

We had a phone interview with Sal Scuderi who explained to us the different aspects of the engine and when we might see it come into production. In about 1½ years, we should see the first Scuderi engine in a marine or stationary power application. In three years, Scuderi expects to see one in an automobile—a prototype might come out sooner. The timeframe is dependent on public demand. A recent computer simulation study by the Southwest Research Institute showed the Scuderi engine could achieve 65 mpg when modeled against the European class high-economy vehicles. To hear this engine running without a muffler, go to: http://www.scuderigroup.com/media-gallery/#Videol.

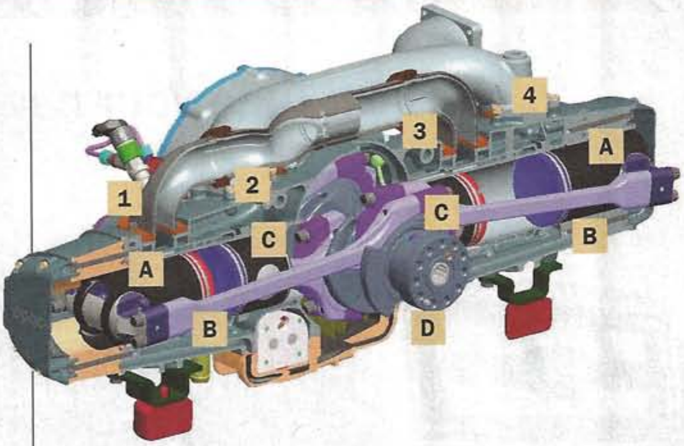
8. STURMAN INDUSTRIES (ADAPT)

Eddie Sturman and his team in Woodland Park, Colorado, never fail to disappoint when it comes to getting out-of-this-world technology into production. We've covered its progress twice in "A Company that Seeks to Digitize the Mechanical World," April '11 and "Digitally Controlling Airflow," Aug. '11.

Sturman Industries' core technology is digital valves. Digital means ones (off) and zeros (on); it also means no energy loss when in those positions thanks to residual magnetism. We've talked about Sturman retrofitting today's engines with variable

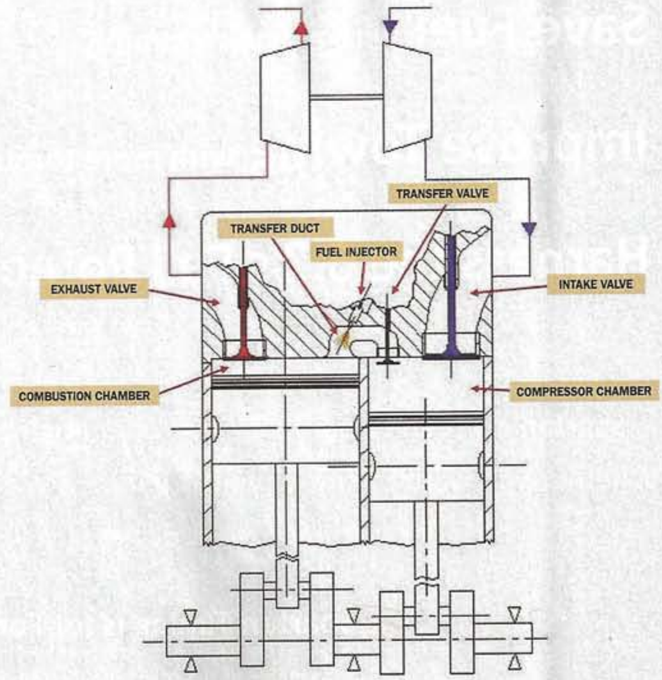


Riccardo Rossi told us, "The difference between HCPC and conventional diesel lies in the mixing process. In both engines, mixing relies on air and fuel momentum inside the combustion chamber, but in the HCPC air momentum is much stronger, leading to better mixing (diesel is 20 meters per second and HCPC is 200 meters per second)."



EcoMotors' opposed-piston, opposed-cylinder, two-stroke diesel has four pistons, two cylinders, and one crankshaft. The outer pistons (A) each have two connecting rods (B) that exert a pulling force on the crankshaft. The inner pistons (C) each have one connecting rod that pushes on the crankshaft (D). There is one combustion chamber for two cylinders. The ports from left to right are: (1) intake, (2) exhaust, (3) intake, and (4) exhaust. This setup is reported to be naturally balanced, and all the forces are directed into the crankshaft instead of into the magnesium block.

"Right now, Navistar and EcoMotors engineers are busy testing and developing a new version of the opposed-piston, opposed-cylinder engine (OPOC) for their heavy-duty trucks."



Rossi went on to say, "The HCPC split-cycle engine realizes the intake and compression cycles in one cylinder (compressor) and the expansion and exhaust phases in a second one (combustor). This process allows for different compression and expansion ratios. Therefore, the engine operation is based on the Miller Cycle, which guarantees higher indicated efficiency. In the HCPC engine, air and fuel are transferred progressively into the combustion chamber during the combustion phase, whereas in a conventional diesel engine, all the trapped air is inside the cylinder when the injection starts."