THE WALL STREET JOURNAL.
Europe Edition ▾ | June 20, 2019 | Print Edition | Video

THE FUTURE OF EVERYTHING

THE CAR ENGINE OF TOMORROW: CLEANER, LIGHTER, WITH ONE MOVING PART

Aquarius Engines is developing a super-efficient, 22-pound gasoline engine, as startups, auto makers and researchers reimagine the more than century-old technology

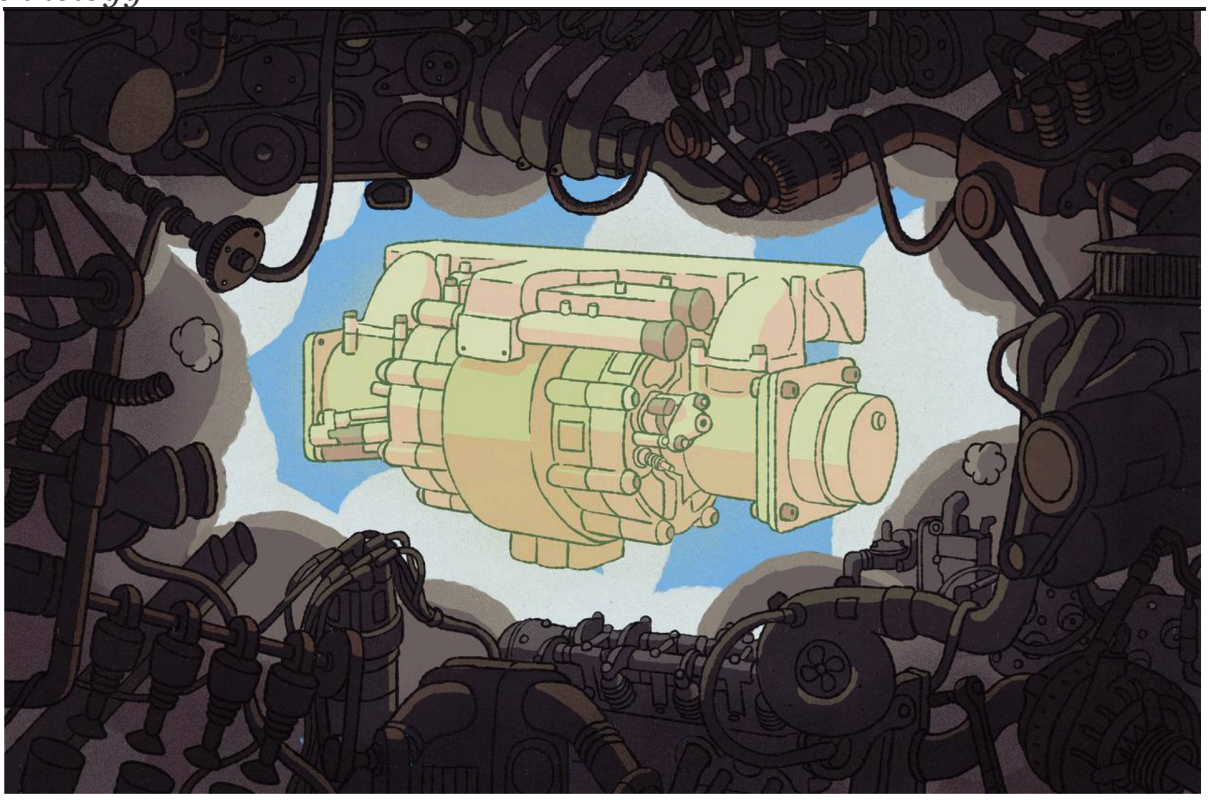


ILLUSTRATION: TIM PEACOCK

AUTHOR SARA TOTH STUB
UPDATED JUNE 20, 2019 9:57 AM ET

ROSH HAAYIN, Israel—Back in 2014, Shaul Yaakoby was spending his days assessing damaged vehicles for insurance companies. He spent his nights in a Tel Aviv-area machine shop cutting and assembling pieces of aluminum. The self-described inventor, a high-school dropout who grew up on an Israeli communal citrus farm and spent the last 25 years as an insurance assessor, has several patents for products ranging from a water purification system to a theft-proof car key. Now, he is seeking to make a light, cheap and efficient car engine—one that runs on significantly less fuel and produces fewer polluting emissions than what's available today.

"When you feel you have the idea for something big, you just have to do it," Mr. Yaakoby said. "So I bought a block of aluminum and cut it by hand to build my engine."

After several months of work, he took his product to his business partners, Gal Fridman, a technology-marketing veteran, and Ariel Gorfung, an industrial engineer. They founded Aquarius Engines Ltd. in 2014 to bring Mr. Yaakoby's super-efficient gasoline-powered engine to the increasingly environmentally conscious automotive market. Now on its fifth-generation machine, the company has successfully tested its engine in the lab, though not in cars.

Aquarius, named for the perfect future imagined in the hit song, "The Age of Aquarius," has raised more than $25 million, including from executives at Mobileye, the Israeli autonomous-vehicle technology startup acquired byIntel Corp. in 2017, and employs 42 people in Israel, Germany and Poland. The company expects its product to hit the market in the next two years, with applications from cars to electricity generators to drones.

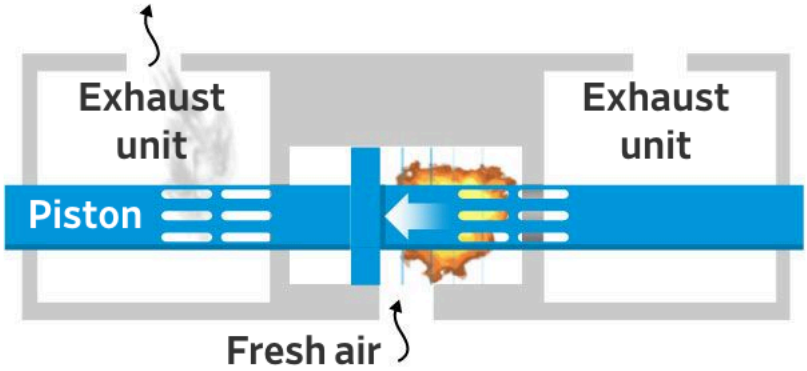
Aquarius Engines expects its product to hit the market in the next two years. From left to right: Gal Fridman, chairman and chief marketing officer; Maya Gonik, head of business development; and Ariel Gorfung, chief executive, at the company's headquarters outside Tel Aviv. PHOTO: DAVID KATZ

Aquarius is not alone in betting on a revamped internal combustion engine. Automakers are under pressure from governments and consumers to build cars that give off lower carbon emissions. At the same time, battery-powered electric vehicles have limitations, including production cost, range limitations and the need for infrastructure, like the production of electricity to charge them. Sales of electric vehicles have been growing about 60% a year globally, but they make up less than 5% of new car sales in most markets, and auto makers lose money on them, according to a March report from McKinsey & Co. "When the electric vehicle came around, everyone was hoping that will solve the problem, but it's not that simple," said John B. Heywood, a professor emeritus of mechanical engineering at Massachusetts Institute of Technology who studies cleaner energy and transportation.

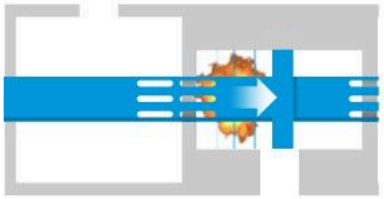
The Aquarius engine

One sliding piston replaces multiple rotating pistons. The movement generates electricity that powers the wheels.

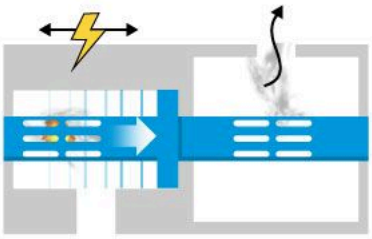
1. Fresh air and fuel enters the combustion chamber from below



2. The mixture ignites, pushing the piston left, as exhaust is captured in the piston's vent holes



3. The fuel/air mixture ignites, pushing the piston back to the right



4. Movement back to the right pushes out the exhaust from the previous explosion

Sources: the company (new engine); University of Calgary (typical four-stroke engine)

After years of considering the internal combustion engine out of date, some startups, car makers and academic researchers are working to improve the century-old technology. Internal combustion engines will make up 40% of the global car market by 2030, while 23% of cars sold will have engines that use both electricity and burn other fuel, like gasoline, according to a JPMorgan Chase & Co. report. "Now it seems that the internal combustion engine has a bright future, with vast potential of efficiency

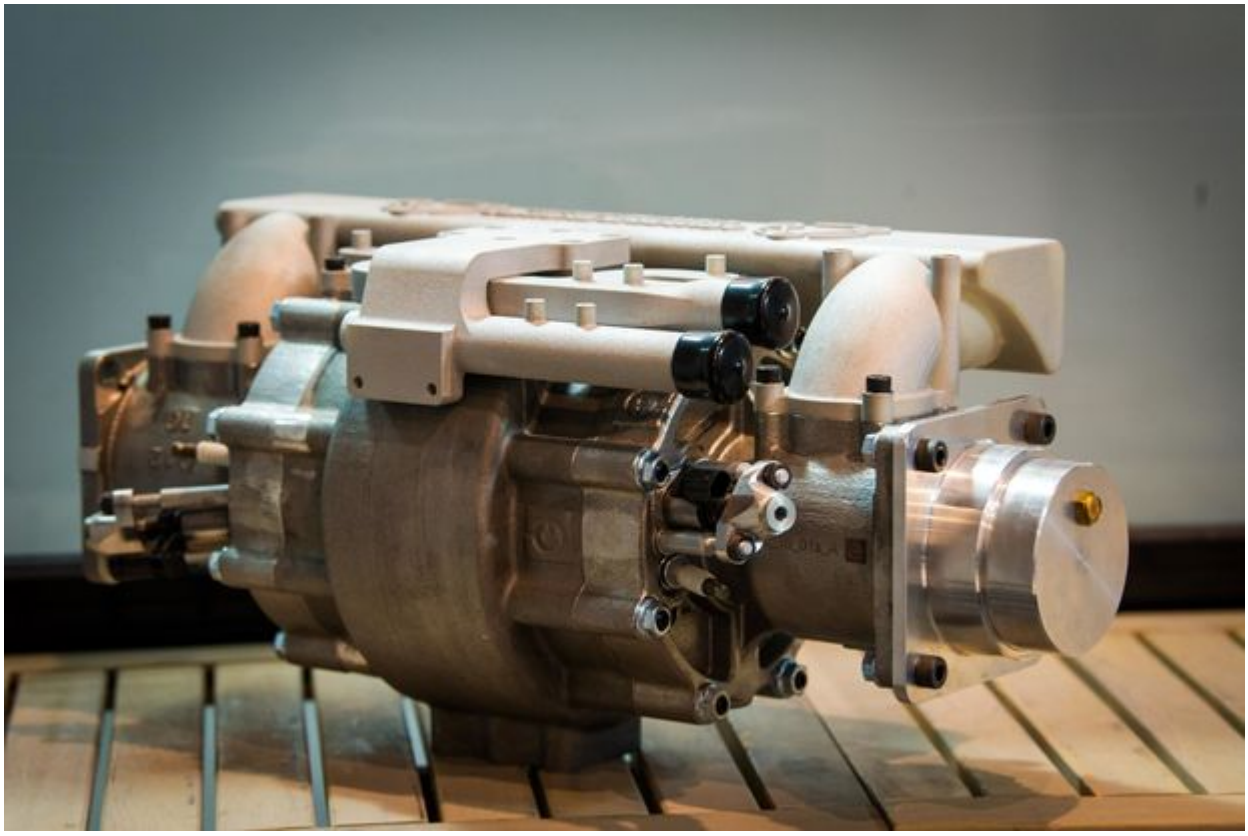
improvement and emission reductions," said Leonid Tartakovsky, head of the internal combustion engines laboratory at the Technion Israel Institute of Technology.

Mazda Motor Corp. said that in the fall it will ship its first cars with Skyactiv-X, an ignition system that the company says can improve efficiency by 20% to 30% in some driving situations, and is developing additional models.Nissan Motor Co. Ltd. said in 2018 that it had started producing cars with variable compression ratio-engines, which the company says cut fuel consumption by about 30%. More auto makers are using turbochargers, which reuse wasted heat, and engines that shut off while cars are idling. Toyota Motor Co.'s research-and-development subsidiary is developing a free-piston engine. (A company spokeswoman declined to give details.)

San Diego-based Achates Power Inc. is collaborating with the engine company Cummins Inc. to develop a lightweight opposed-piston engine for U.S. military combat vehicles. Achates also said it is working with another company to integrate an opposed-piston engine, developed with the help of a $9 million grant from the U.S. Department of Energy, into a pickup truck. Pinnacle Engines, based in San Carlos, Calif., designs engines for scooter, motorcycle, automotive and industrial use, and is focused on the Asian market, according to its website.

The latest version of the Aquarius engine weighs 22 pounds; a typical engine weighs 250 pounds. It has just one moving part—a piston that slides back and forth—compared to at least 20 found under the hood of your average car, though it generates only 43 horsepower. It requires 20% less fuel than the average internal combustion car engine, said Mr. Yaakoby, who is chief technology officer at Aquarius. Further adjustments to the fuel-injection system could increase that difference to 30%, he said. Because there is no friction between the piston and the engine parts, it does not require lubrication, eliminating the need for oil and reducing maintenance costs.

The engine is a free-piston linear engine, which means that it produces electricity when it burns fuel, rather than producing rotational energy like a typical car engine. The electricity can be used as the primary energy source to power a motor in a traditional car, or it can be used as a range extender or backup charger for a battery-powered electric car, the company said. "Whether it's as the engine of the car itself or as a battery charger, there will be a place for it," said Mr. Fridman, the company's chief marketing officer.



The latest version of the Aquarius engine weighs 22 pounds and has just one moving part—a piston that slides back and forth. PHOTO: DAVID KATZ

Free-piston engines date to the early 20th century, and were used to power generators on ships. By the 1950s, diesel engines had replaced most of them in the marine sector, said Tony Roskilly of Newcastle University, who researches free-piston engines. “Now there’s been a spike of interest in them again,” he said.

The main challenge for linear-piston engines is the lack of fine control of the fuel-injection and exhaust escape processes, which often results in higher levels of unburned hydrocarbons in the exhaust—something regulators are also trying to reduce, said Gregory W. Davis, director of the Advanced Engine Research Lab at Kettering University in Flint, Mich.

“But if they can use computer technology to overcome this, and control the gas and air flow, then we could see cars moving over to these types of engines,” Mr. Davis said. “The potential for increased efficiency is really good.” Additional cylinders, each with a piston sliding back and forth, would increase horsepower, he said.

Still, an improved internal combustion engine is not a panacea. “The internal combustion engine, even with major improvements on it, cannot get to the levels that

regulators want," said Russell Hensley, head of McKinsey's Center for Future Mobility. "That's why we see the investment in electric vehicles." At least nine countries have announced future bans on sales of diesel and gasoline engines, and many more, including the U.S., have offered incentives, such as free parking and tax breaks, for owners of battery-powered vehicles. Many auto executives say they believe gasoline engines have reached their maximum efficiency and are now shifting more resources into electric cars to meet tougher emissions rules.

Another major hurdle to switching car-engine designs or shapes is that auto makers would have to redesign their assembly lines and cars to accommodate them as the main energy source, said Mr. Roskilly. The difficulty—and the need to justify that the benefits are worth it—are two key reasons cars have changed relatively little over the decades. "When you have anything that's disruptive, it's difficult," Mr. Roskilly said. "It needs a lot of investment to make it to the point of manufacturing it in cars." But increased pressure to reduce emissions—and the resulting growth in research-and-development budgets—has started to change industry attitudes, experts say.

Aquarius acknowledges the challenge. In the meantime, it's going after other applications, said Mr. Fridman. Starting in 2020, Aquarius plans to roll out its engines in electricity generators at remote locations, including communication towers in Canada, Europe and the Asia Pacific region.

To cut down on carbon emissions from cars, many solutions are needed, including better combustion engines, battery-powered vehicles and cleaner fuels, said Mr. Heywood. "Going for the passenger car is very ambitious," he said. "One is trying to challenge something that has been very successful, and all the alternatives still have their Achilles heel."