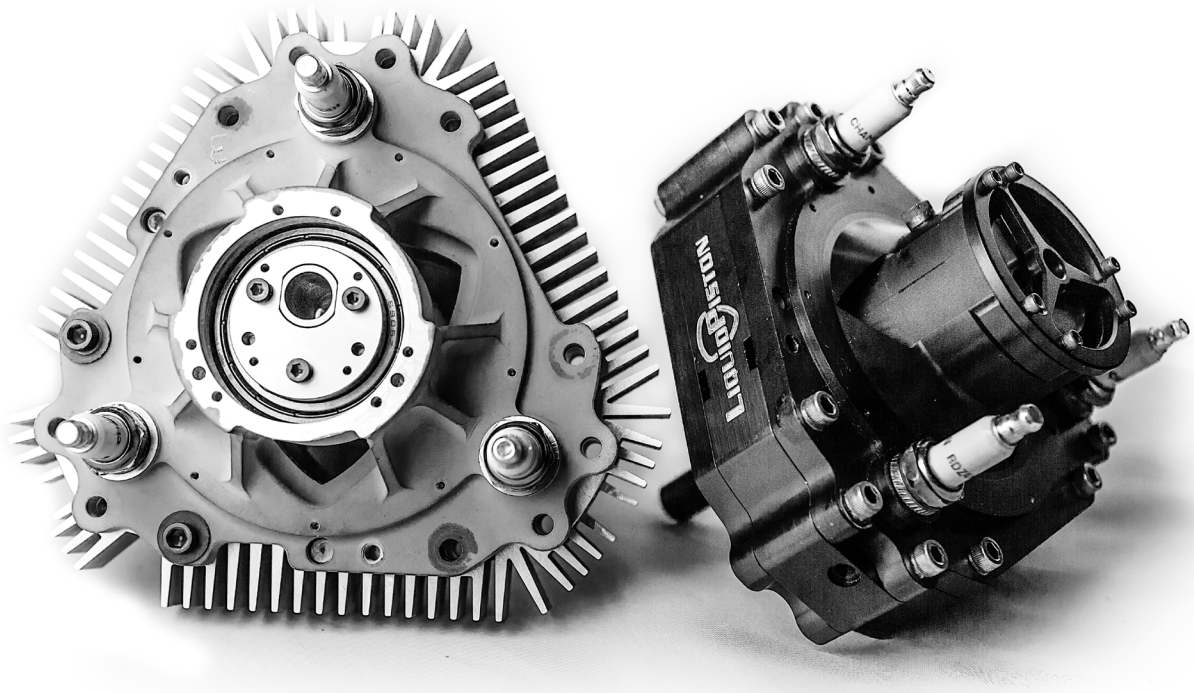
LiquidPiston's X Engines

Compact, Quiet, Low-Vibration, High-Efficiency



X Mini 70cc 4-stroke gasoline engine

LiquidPiston develops advanced rotary engines based on the company's patented HEHC thermodynamic cycle and engine architecture. LiquidPiston engines are designed to be:

Lightweight and Compact

- High power density - up to 2 HP/Lb (3.3 kW/kg)
- 30% smaller and lighter for spark-ignition (SI) gasoline engines
- Up to 75% smaller and lighter for compression-ignition (CI) diesel engines

Quiet

- No poppet valves
- Exhaust turbulence minimized by over-expansion; no muffler required

Low-Vibration

- Only two primary moving parts, optimally balanced, resulting in near-zero vibration

High-Efficiency

- 20% decrease in fuel consumption possible for SI gasoline engines
- 50% decrease in fuel consumption possible for CI diesel engines

Multi-Fuel Capable

- Diesel, gasoline, natural gas, JP-8

Scalable

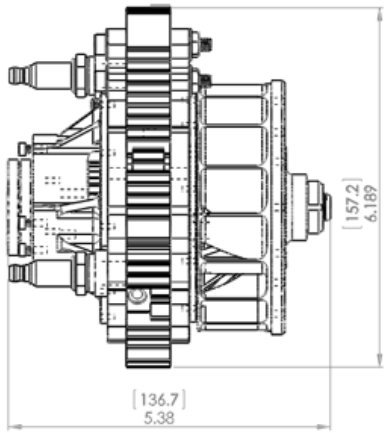
- From 1 HP to over 1000 HP

Specifications

Model	X Mini Alpha Prototype November 2014	X Mini Beta Prototype	Mature Commercial Design
Type	SI-HEHC cycle air-cooled rotary engine	SI-HEHC cycle air-cooled rotary engine	SI-HEHC cycle air-cooled rotary engine with SkipFire Control
Fuel	Gasoline (PFI or Carb.)	Gasoline (PFI or Carb.)	Multi-Fuel (Direct Injection)
Compression Ratio	9.2	9.2	10.5
Num. of Rotors / Injectors	1 / 1	1 / 1	1 / 3
Power Output @10K RPM	3.5 hp / 2.5 kW (Indicated)	3.5 hp / 2.5 kW (Brake)	>5 hp / 3.7 kW (Brake)
Maximum Speed (RPM)	13,000	15,000	15,000
Intake Stroke Volume	19cc/chamber	19cc/chamber	19cc/chamber
Displacement	23 cc/chamber 70cc total	23 cc/chamber 70cc total	23 cc/chamber 70cc total
Dimensions	6.6"x6.2"x5.4"= 221 in^3	6.6"x6.2"x5.4"= 221 in^3	6"x6"x5"= 180 in^3
Dry Weight++	4 lbs.	3.5 lbs.	3 lbs.
Specific Power	0.9 hp/lbs. (indicated)	1 hp/lbs. (brake)	1.7 hp /lbs.
Peak Efficiency	15% 545 g/kw-hr (ISFC)	15% 545 g/kw-hr (BSFC)	30% 280 g/kw-hr (BSFC)
Time between overhaul	3 hours	100 hours	1000 hours

++Engine core, excluding fuel system

X Mini Engine



Alpha Prototype
November 2014

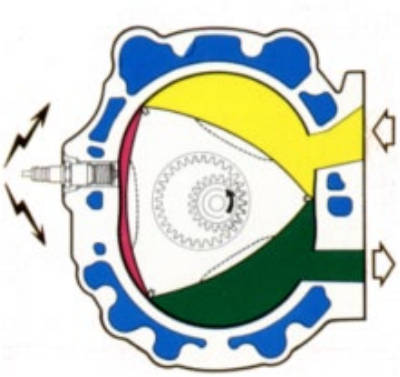
Technology

LiquidPiston's X Engine architecture is a non-Wankel rotary embodiment of the company's innovative High Efficiency Hybrid Cycle (HEHC). The X Engine has few parts and three combustion events per rotor revolution, resulting in tremendous power density. The X Engine's few moving parts consist of a rotor (the primary work-producing component) and an eccentric shaft. Except for ancillary parts such as injectors, fuel pumps, and oil pumps, there are no other moving parts, making the X Engine extremely simple and elegant. LiquidPiston's X Engine architecture geometry allows for standard materials and 2-D manufacturing to be used, greatly decreasing the design, build and testing cycle.

To see an animation of how the engine works, go to: www.liquidpiston.com

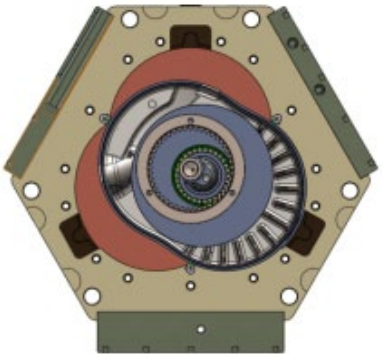
Not a Wankel

Wankel Engine



- Low compression ratio
- No constant-volume combustion
- No over-expansion

LPI X1 Engine



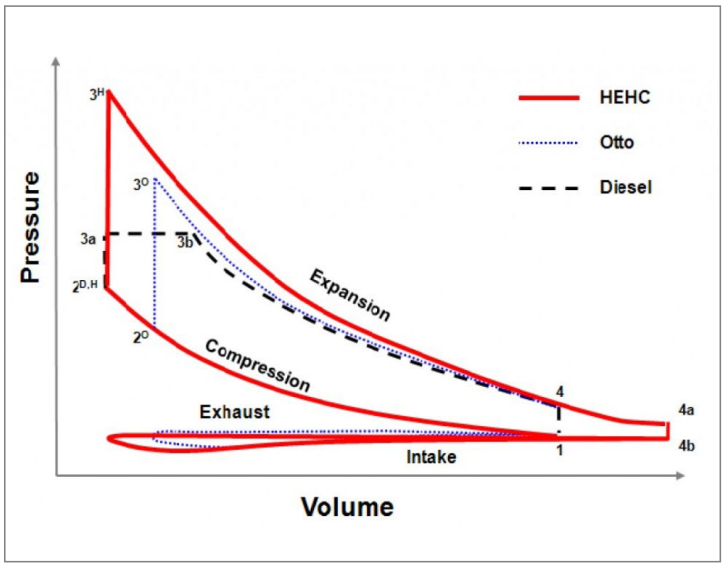
- High compression ratio
- Constant-volume combustion
- Over-expansion

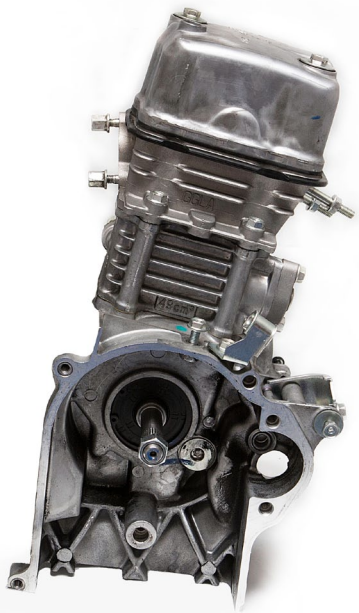
While it is a rotary engine, LiquidPiston's X Engine is NOT a Wankel engine. It has a fundamentally different thermodynamic cycle, architecture and operation.

High Efficiency Hybrid Cycle (HEHC)

LiquidPiston's HEHC is a patented thermodynamic cycle that combines the advantages of Diesel, Otto and Atkinson thermodynamic cycles. The cycle elements include:

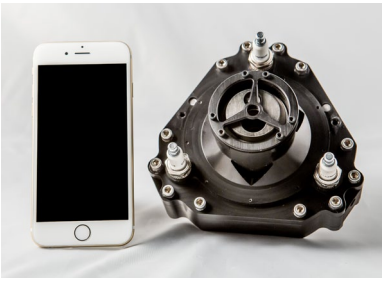
1. Compression: For maximum efficiency, air is compressed to a high compression ratio, fuel is injected and compression ignited (CI-HEHC). The X Mini utilizes a spark-ignition (SI-HEHC) version of the cycle with a lower compression ratio standard for gasoline engines.
2. A dwell near top-dead-center forces combustion to occur at nearly constant-volume conditions.
3. Combustion products are over-expanded using a larger expansion volume than compression volume, as in the Atkinson Cycle.
4. Cycle-skipping power modulation allows high efficiencies at low power settings while simultaneously cooling the engine's walls internally and providing partial heat recovery.
5. Water may be injected to internally cool the engine. Some of this cooling energy is recuperated, as the water turns to steam, increasing the chamber pressure.





LiquidPiston's 3-5 HP X Mini 70cc engine prototype (right) next to a 49cc Honda Metropolitan moped engine

LiquidPiston Overview

Disruptive combustion engine technology	LiquidPiston develops advanced rotary engine technology based on the company's patented thermodynamic cycle and engine architecture. The X Mini engine demonstrator is a spark-ignited (gasoline) 70 cc, 4 stroke, air-cooled, rotary engine prototype that is designed to be power-dense, virtually vibration-free, quiet, and low-cost. The company has also developed 40-70hp high-efficiency CI-HEHC engines.
Initial capability of engine proven	LiquidPiston's X Mini 70cc gasoline 4-stroke engine prototype is designed for high-power density, low-vibration, and quiet operation. The X Mini prototype, undergoing development, has so far demonstrated 3.5 HP (net indicated at 10,000 RPM), and the ability to run steady-state with air cooling for 40 minutes at a time and multiple hours cumulatively. With further development, the engine is expected to produce 5HP, weighing only 3 lbs, and be >30% smaller and lighter than comparable 4-stroke gasoline engines. Previously, LiquidPiston has demonstrated proof-of-principle 70 and 40 HP engine prototypes (X1 and X2) that are capable of running for a short time at light load, and demonstrate compression ignition of diesel or JP-8 fuel, and net indicated efficiency of 33% (at light-load).
Markets	LiquidPiston's engines are scalable from 1 to over 1000 HP and can address most combustion engine markets. Initial markets for the engines include: • Handheld outdoor power equipment • Lawn and garden equipment • Generators and auxiliary power units • Mopeds • Unmanned Aerial Vehicles (UAVs) • Range extenders • Robotics  LiquidPiston's 70cc X Mini prototype next to an iPhone 6
IP portfolio	LiquidPiston has comprehensive patent coverage that includes the company's novel High Efficiency Hybrid Cycle (HEHC) thermodynamic cycle, engines that embody the cycle, and enabling technologies.
Licensing opportunities	LiquidPiston is soliciting strategic partners to co-develop engines targeted for specific end markets and license the technology for manufacture and use.
Experienced engine team	With decades of combined experience, LiquidPiston's technical team provides expertise in engine design and program management, with technical backgrounds in physics, mechanical design, modeling, and optimization.
Financing	Venture capital backed. Key investors include: Northwater Capital and Adams Capital Management.

LiquidPiston, Inc
1292a Blue Hills Ave, Bloomfield, CT 06002, USA
(860) 838-2677 | info@liquidpiston.com
www.liquidpiston.com