

Innovative Lightweight Power



Automotive



Aerospace



Marine

SPARCS of Innovation in the Wankel rotary engine

Nathan Bailey – Engine Expo 2016



**Advanced
Innovative
Engineering**

AIE

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AIE Overview



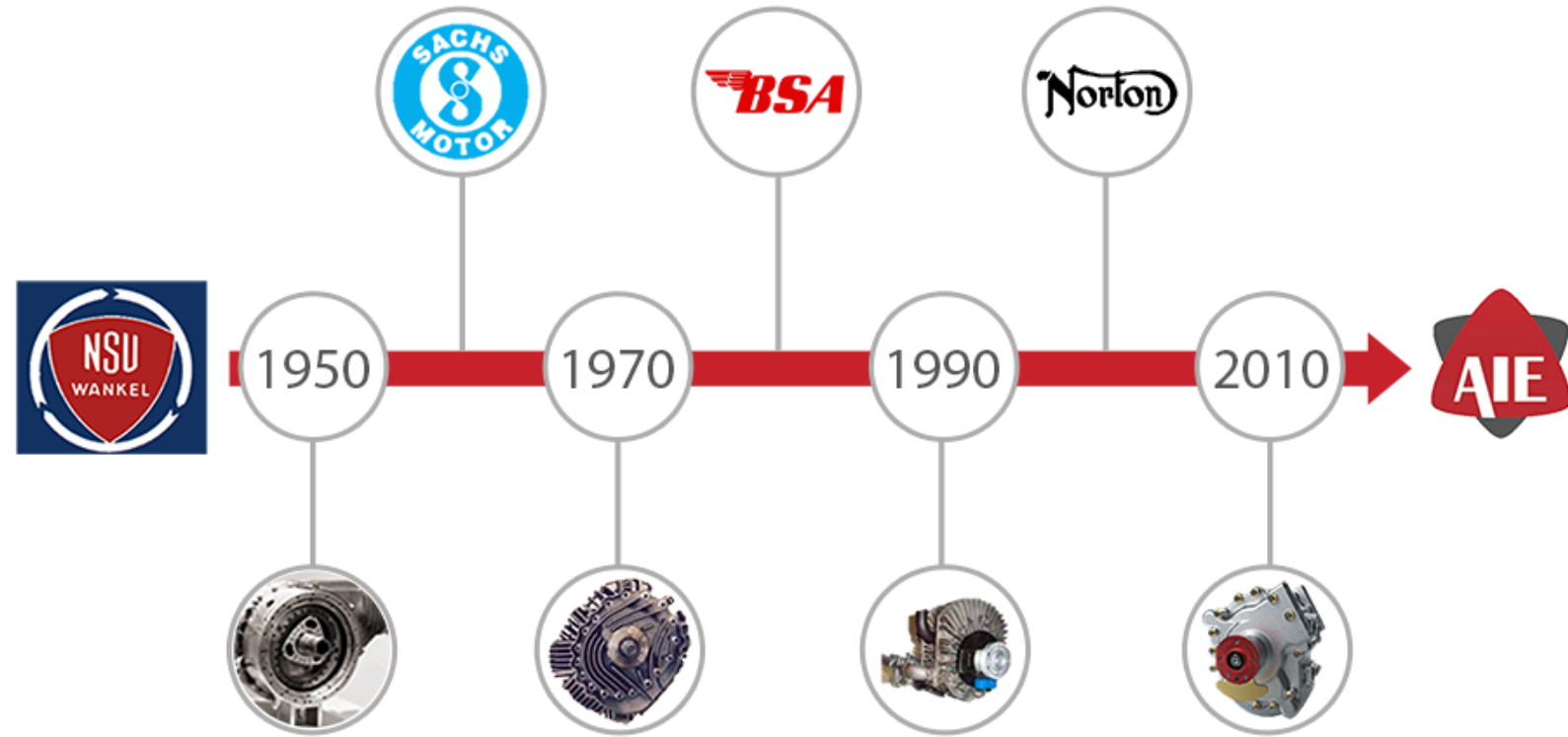
Advanced Innovative Engineering

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- AIE is a UK-based engineering company specialising in the development of innovative Wankel rotary engines.
- AIE's team has a combined experience of over 80 years in rotary engine Design, R&D, and Manufacturing.
- AIE is located on the outskirts of Birmingham in the United Kingdom, an area recognised as the heart of British advanced Aerospace Engineering and Manufacturing.
- We deliver products and services that have exceptional reliability, versatility and low total cost of ownership (TCO) for the global Aerospace, Automotive and Marine markets.



Advanced Innovative Engineering's Heritage Timeline 1950 to Present



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AIE Full-Spectrum Capability



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Innovative ideas come to life through the free flow of communications and dynamic processes set in a creative engineering environment.

Concept



Technical library containing publications on engine technology, market reports, and print media complement the continuous improvement cycle through innovation.

Research



Latest CAD design, CFD, and finite element analysis software create fully-specified manufacturing drawings and allow virtual design assessment.

Design



In-house 3D-printing turns concepts into reality, producing visual aids to development to save overheads and lead times.

Prototype



Rotor balancing and CMM machines measure part precision. Testing and dyno cells capture real-time data for analysis of engine performance and mapping.

Development



State-of-the-art, Mazak 5-axis CNC milling and dedicated build rooms enable rapid metal- machining and engine assembly.

Production



Key Benefits

- Clean
- Multi-fuel
- Compactness
- Low vibration
- Long endurance
- Few moving parts
- High power-to-weight
- Low total cost of ownership
- Revolutionary cooling system



Cooling System



Time Between
Overhaul



Fuel Type



Engine Core
Weight



Engine Power
Output



Fuel Consumption



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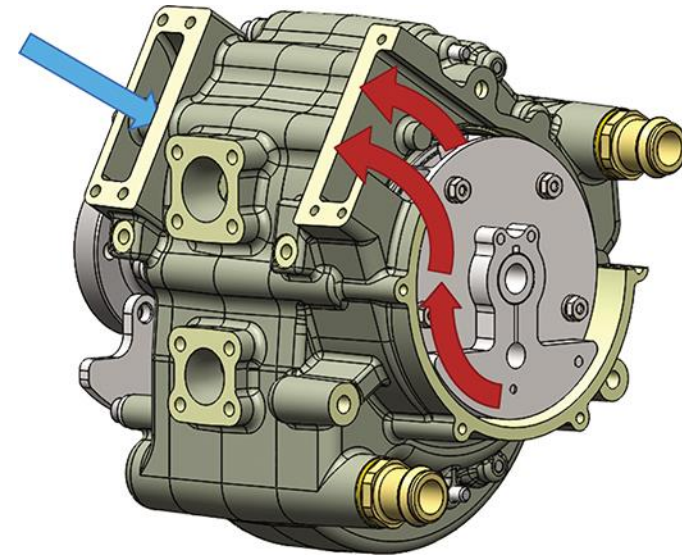


Technology: Patented, Liquid-Cooled SPARCS*

Existing Wankel rotary engines available on the market typically use either closed-loop, oil-cooled or forced-air-cooled systems. AIE's innovative SPARCS* cooling system combines simplicity of design with the inherent high power-to-weight advantage of rotary engines, while practically eliminating the drawbacks these systems had in the past.

The SPARCS* cooling system for Wankel Rotary Engines utilises the self-pressurising blow by gases from the combustion process (which have escaped into the interior of the engine's core via the rotor's side seals) as a cooling medium. This pressurised air-gas mixture is recirculated in a completely closed loop circuit by an internal fan which is driven by the main shaft. As it recirculates, the air-gas mixture passes through the engine's rotor where it picks up heat before then being ducted through an external heat exchanger to reject the heat. The key to the system is that the high density of the pressurised air-gas mixture enables higher levels of heat removal from the engine's rotor than through standard air cooling methods.

As the SPARCS* system is completely sealed, the oil loss to atmosphere typical of air cooled rotary engines is completely eliminated. Oil supplied to the engine core is continually recirculated in the cooling gas mixture lubricating all moving surfaces, until eventually migrating past the seal pack (providing lubrication) before being burnt in the combustion process. As the lubrication oil in the engine core is recirculated many times, overall oil consumption is significantly reduced.



**Self-Pressurising-Air Rotor Cooling System*



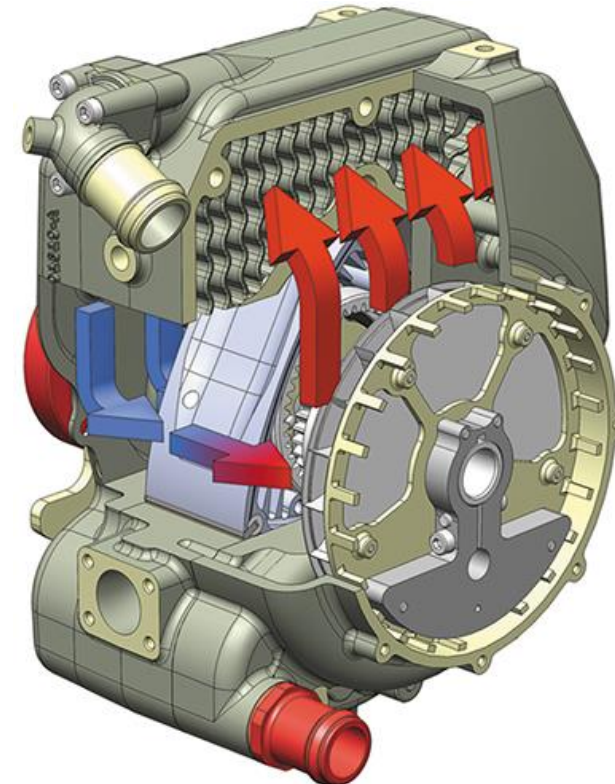


Technology: Patented, Liquid-Cooled Compact SPARCS*

Compact SPARCS* is integrating an intercooler, or heat exchanger within the rotor housing. As with SPARCS*, the re-circulating oil-gas mixture passes through the engine's rotor, absorbing heat before being ducted through the integrated heat exchanger, which rejects heat into the engine's rotor housing and ultimately to the engine's main liquid cooling system.

The Compact SPARCS* system utilises the same self-pressurising blow-by gases from the SPARCS* patent detailed overleaf. As in the standard SPARCS* system, the pressurised oil-gas mixture is again recirculated in a completely closed loop circuit through the rotor and then through a heat exchanger by an internal fan which is mounted to the engine drive shaft. In Compact SPARCS* however, the heat exchanger is integrated within the engine's rotor housing meaning that the heat can be transferred to and ultimately be rejected through the engine's main liquid cooling system. Compact SPARCS* builds on the benefits of SPARCS* by delivering an even more compact cooling system with even fewer components.

Integrating the heat exchanger within the rotor housing also has the positive effect of heating the previously cold areas of the engine (i.e. induction port area), improving overall thermal balance and allowing a more even axial thermal expansion of the engine to take place. This thermal balance improves gas sealing at the axial ends of the apex seals which results in increased engine operational efficiency and reduced work load for the rotor's seal pack.



**Self-Pressurising-Air Rotor Cooling System*





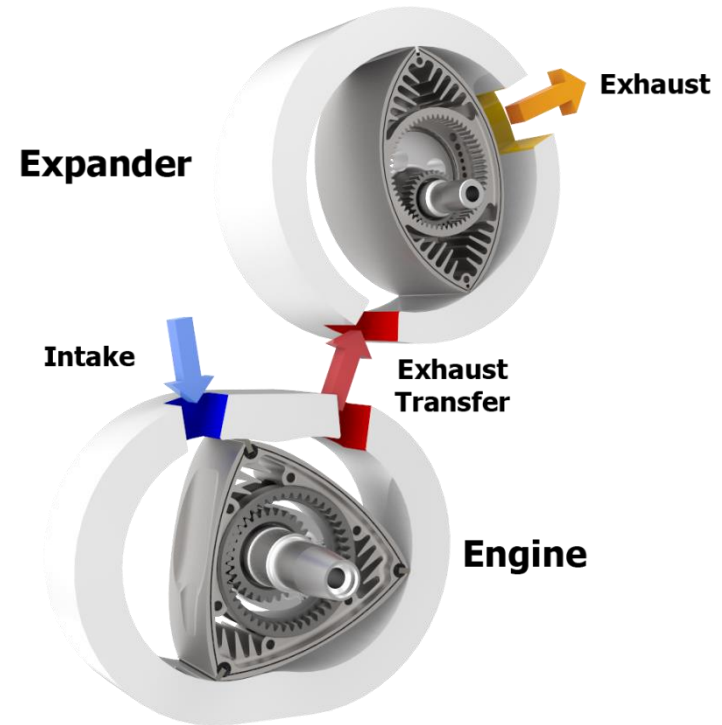
Technology: Patented Exhaust Expander System CREEV*

Wankel Rotary engines have many advantages over reciprocating engines and these advantages can be further enhanced with the use of AIE's patented exhaust expander technology (CREEV*), reducing overall exhaust emissions and increasing thermal efficiency by up to 20%

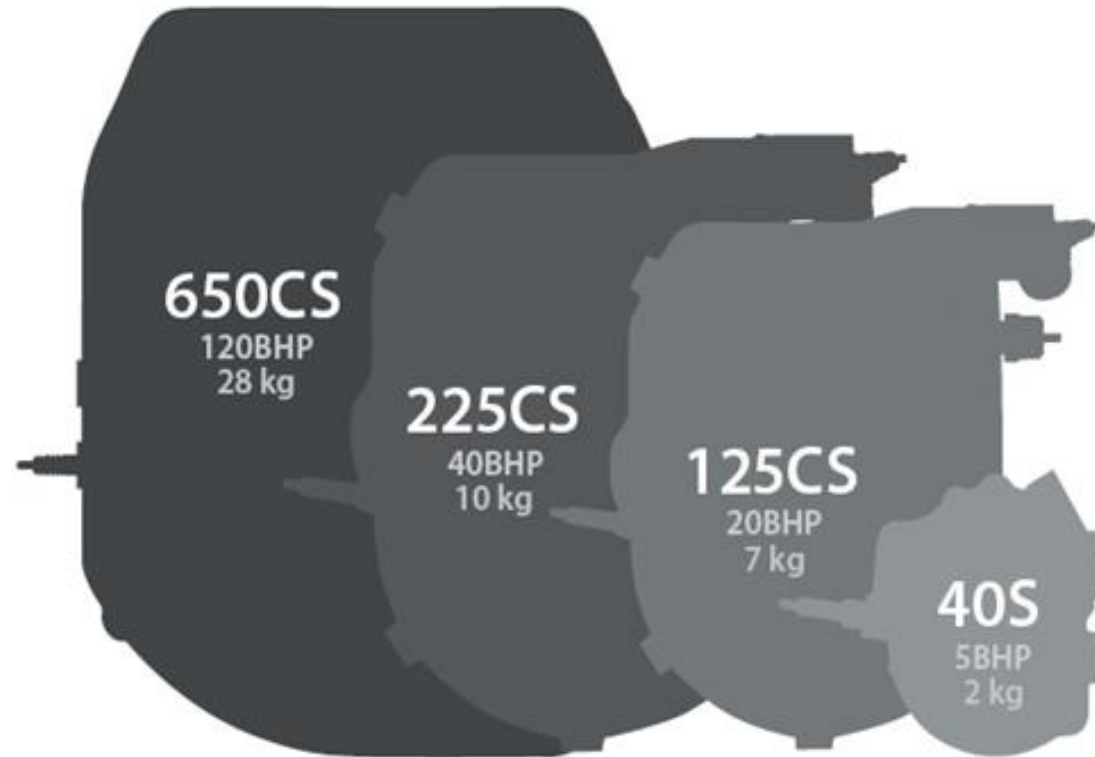
Rotary engines have many advantages for range extender, series hybrid (S-HEV) and power generation applications. The advantages include small form factors, low weight, low vibration and higher power density. Historically their use in these applications has been limited due to the engine's high exhaust energy, heat and emissions (particularly at low rpm and part throttle).

A Rotary engine with a rotary exhaust expander unit (**CREEV***) however overcomes these limitations. Firstly, by reducing overall engine noise and heat due to the expansion of the gas to near atmospheric pressure before leaving the unit. The unit then further acts as an "exhaust reactor" by continuing to consume unburned exhaust products while expansion occurs thus reducing overall emissions of HC, CO and NOx. Finally because the expansion is controlled within secondary rotor chamber the overall thermal efficiency of the engine package is also boosted by up to 20% by recouping otherwise lost exhaust energy back to the engine drive.

**Compound Rotary Engine for Electric Vehicles*



Scalable Power Range for **Your Platform**

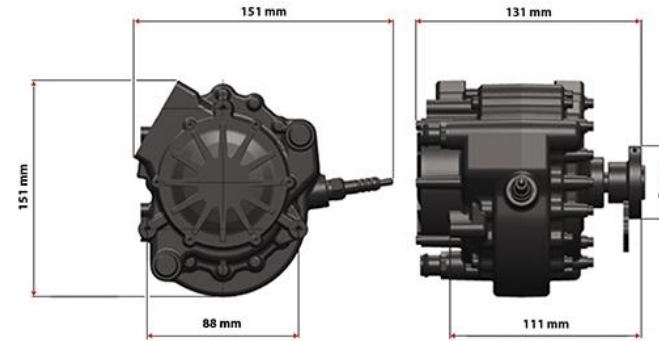


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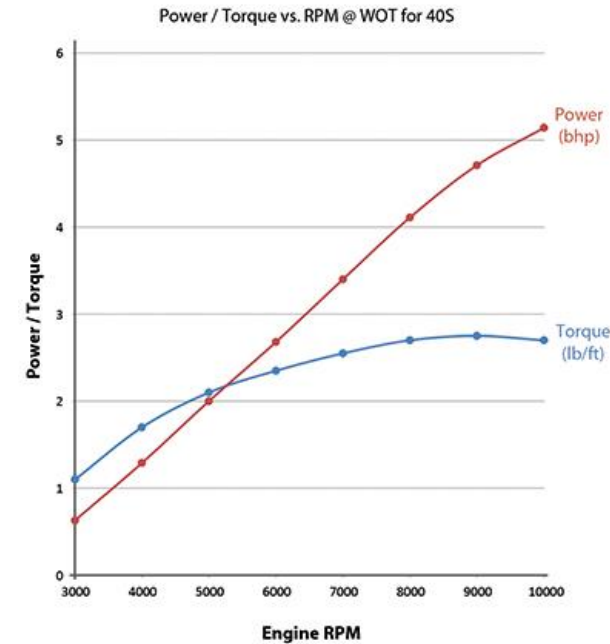


Wankel Rotary Engine 40S 5BHP



Engine Type	Single Rotor
Power Output	5 bhp (3.7 kW)
Weight	4.4 lb (2 kg) Core Weight
Displacement	2.4 cu in (40cc)
Torque	2.75 lb/ft @ 8000 rpm
Compression	9.6:1
Fuel Type	AVGAS / Gasoline / Heavy Fuels
Fuel Consumption	0.51 lbs/bhp/hr (310 g/kWh)
Cooling System	Liquid Cooled SPARCS*
Ignition System	Single Spark Plug / CDI
Engine Control System	Full Electronic Management
Oil System	Digitally Optimized Lubrication
Configuration	Pusher / Tractor
Options	Generator/Reduction Drive

*Self-Pressurising-Air Rotor Cooling System



Applications

- Series-hybrid Powertrains
- Automotive Range Extenders
- Small Tactical UAVs
- Hybrid Propulsion
- Near-silent Watercraft
- Unmanned Surface Vehicles



Fuel Consumption
0.51 - 0.57 lb/hp/hr
(310 - 350 g/kWh)



Cooling System
Liquid-Cooled
Patented SPARCS*



Engine Power Output
5 bhp (3.7 kW)



Time Between Overhaul
500+ hrs



Engine Core Weight
4.4 lb (2 kg)



Fuel Type
AVGAS / Gasoline
Heavy Fuels



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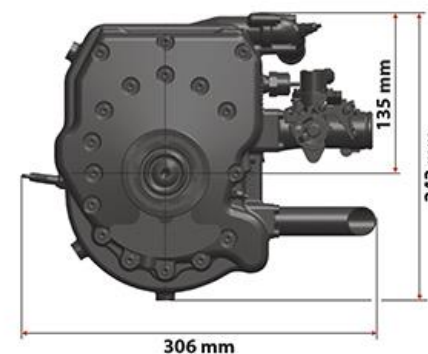
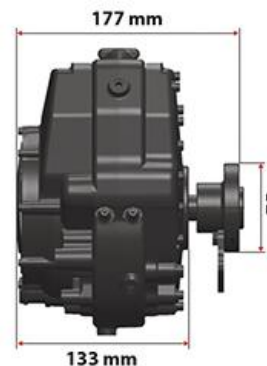
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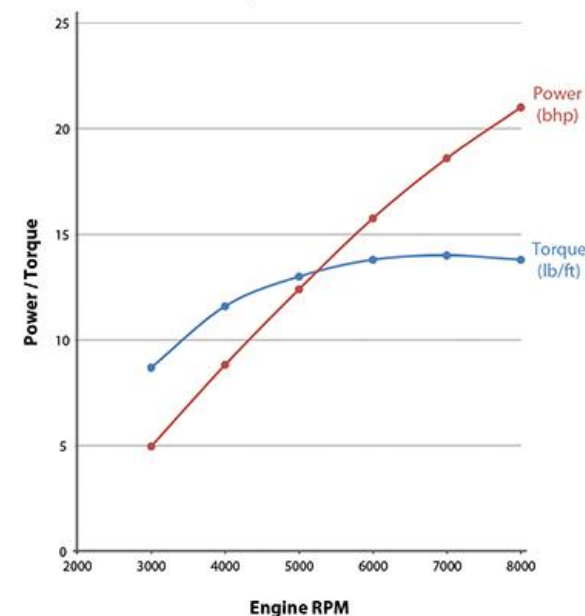
Wankel Rotary Engine 125CS 20BHP



Engine Type	Single Rotor
Power Output	20 bhp (15 kW)
Weight	15.4 lb (7 kg) Core Weight
Displacement	7.6 cu in (125cc)
Torque	14 lb/ft @ 8000 rpm
Compression	9.6:1
Fuel Type	AVGAS / Gasoline / Heavy Fuels
Fuel Consumption	0.51 lbs/bhp/hr (310 g/kWh)
Cooling System	Liquid Cooled SPARCS*
Ignition System	Single Spark Plug / CDI
Engine Control System	Full Electronic Management
Oil System	Digitally Optimized Lubrication
Configuration	Pusher / Tractor
Options	Generator/Reduction Drive

*Self-Pressurising-Air Rotor Cooling System

Power / Torque vs. RPM @ WOT for 125CS



Applications



- Small Vehicles & UGVs
- Range Extenders



- Small-Medium UAVs
- Auxiliary Power Units



- Unmanned Surface Vehicles
- Hybrid Watercraft



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Fuel Consumption
0.51 - 0.57 lb/hp/hr
(310 - 350 g/kWh)



Cooling System
Liquid-Cooled
Patented SPARCS*



Engine Power Output
20 bhp (15 kW)



Time Between Overhaul
500+ hrs



Engine Core Weight
15.4 lb (7 kg)



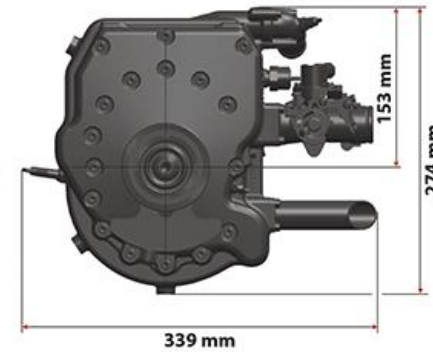
Fuel Type
AVGAS / Gasoline
Heavy Fuels



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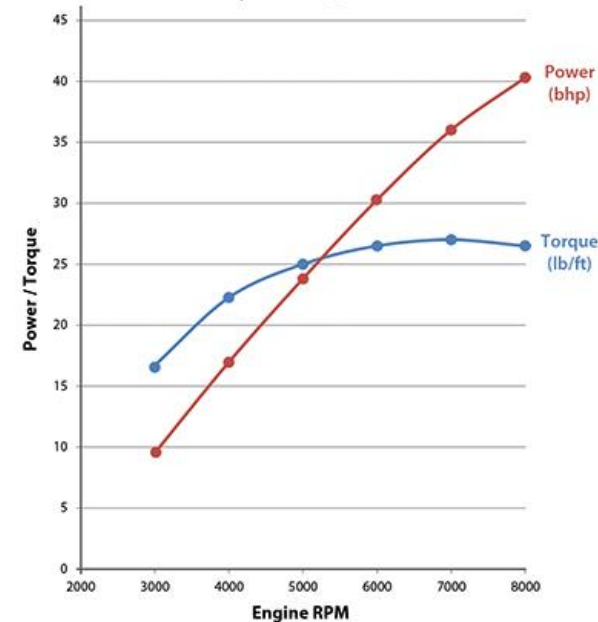
Wankel Rotary Engine 225CS 40BHP



Engine Type	Single Rotor
Power Output	40 bhp (30 kW)
Weight	22 lb (10 kg) Core Weight
Displacement	13.7 cu in (225cc)
Torque	27 lb/ft @ 8000 rpm
Compression	9.6:1
Fuel Type	AVGAS / Gasoline / Heavy Fuels
Fuel Consumption	0.51 lbs/bhp/hr (310 g/kWh)
Cooling System	Liquid Cooled SPARCS*
Ignition System	Twins Spark Plug / CDI
Engine Control System	Full Electronic Management
Oil System	Digitally Optimized Lubrication
Configuration	Pusher / Tractor
Options	Generator/Reduction Drive

*Self-Pressurising-Air Rotor Cooling System

Power / Torque vs. RPM @ WOT for 225CS



Applications



- Small Vehicles & UGVs
- Range Extenders



- Small-Medium UAVs
- Auxiliary Power Units



- Unmanned Surface Vehicles
- Hybrid Watercraft



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Fuel Consumption
0.51 - 0.57 lb/hp/hr
(310 - 350 g/kWh)



Cooling System
Liquid-Cooled
Patented SPARCS*



Engine Power Output
40 bhp (30 kW)



Time Between Overhaul
500+ hrs

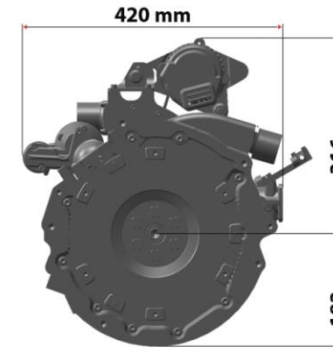
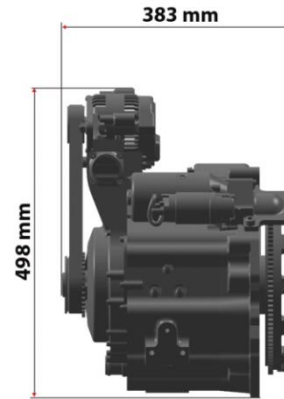


Engine Core Weight
22 lb (10 kg)



Fuel Type
AVGAS / Gasoline
Heavy Fuels

Wankel Rotary Engine 650S 120BHP



Engine Type Single Rotor

Power Output 120 bhp (90 kW)

Weight 62 lb (28 kg) Core Weight

Displacement 40 cu in (650cc)

Torque 80 lb/ft @ 8000 rpm

Compression 9.6:1

Fuel Type AVGAS / Gasoline / Heavy Fuels

Fuel Consumption 0.51 lbs/bhp/hr (310 g/kWh)

Cooling System Liquid Cooled SPARCS*

Ignition System Multiple Spark Plug / CDI

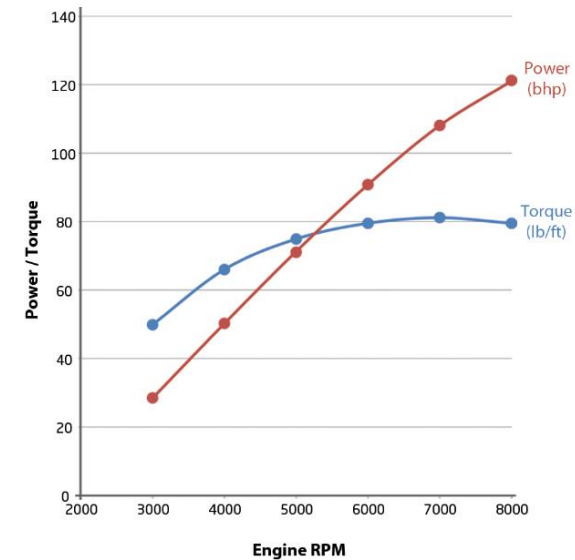
Engine Control System Full Electronic Management

Oil System Digitally Optimized Lubrication

Configuration Pusher / Tractor

Options Generator/Reduction Drive

Power / Torque vs. RPM @ WOT for 650S



*Self-Pressurising-Air Rotor Cooling System

Applications



■ Unmanned Ground Vehicles
■ Niche Vehicles & Motorsports



■ Medium/Large UAVs
■ Light Aviation



■ Unmanned Maritime Systems
■ High-Performance Watercraft



Fuel Consumption
0.51 - 0.57 lb/hp/hr
(310 - 350 g/kWh)



Cooling System
Liquid-Cooled
Patented SPARCS*



Engine Power Output
120 bhp (90 kW)



Time Between Overhaul
500+ hrs



Engine Core Weight
62 lb (28 kg)



Fuel Type
AVGAS / Gasoline
Heavy Fuels



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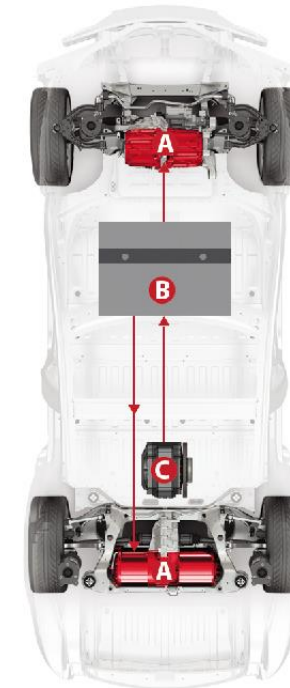
Technology: Rotary Series Hybrid Range Extender

AIE's high-speed, rotary-engine series hybrid solutions weigh less than 40% of existing units using reciprocating engines and are up to 50% smaller, offering much improved packaging possibilities along with significantly enhanced performance.

When integrating an IC engine into an electric vehicle for use as a generator in a series hybrid range extender configuration, there are a number of requirements that must be considered, which include packaging volume, overall weight, efficiency, noise and vibration levels.

The typical duty cycle for a range extender engine is particular in that the unit is either completely switched off or operating at high RPM and load. This means the engine effectively acts as dead weight for much of the time. However, during operation, the engine maintains a constant power output, allowing an optimal single-point operating condition. Another consideration is that the transition from "off" to high power may occur when the vehicle is moving slowly in almost total silence under battery power alone. It is essential in this situation that when the engine starts, it is extremely quiet and vibration-free. Requirements like these make the Series Hybrid application ideal for an AIE single-rotor Wankel IC rotary engine, incorporating both SPARCS* and CREEV** patented technologies.

The series hybrid application fully exploits the enormous strengths of the AIE engine with regards to its compact size, low weight, and extremely low vibration levels whilst mitigating any throttle inefficiency at low power levels.



A Geared Traction Drive

B Battery System

C Rotary IC Engine

*Self-Pressurising-Air Rotor Cooling System

**Compound Rotary Engine for Electric Vehicles





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The Advanced Propulsion Centre UK Limited (APC) is an industry wide collaboration of innovators and producers of low carbon propulsion systems with the objective of providing profitable growth and sustainable opportunities for all partners; ultimately positioning the UK as a centre of excellence for low carbon propulsion development.

Formed in 2013 as a £1 billion, ten-year commitment between government and the automotive industry, the Advanced Propulsion Centre fully supports AIE (UK) Ltd through access to funding and collaborative expertise within their Technology Developer Accelerator Programme (TDAP). The programme will enable AIE to transform innovative concepts for advanced propulsion technologies and hybrid-electric solutions to market ready products for the automotive industry.

As the UK's Innovation Agency and non-departmental public body, Innovate UK work with companies and partner organisations to identify and drive the science and technology developments that will help future economic growth in the UK. Through funding and support, Innovate UK work to remove barriers and risk surrounding research and development for businesses such as AIE (UK) Ltd, enabling innovation to thrive and business to grow. With generous funding grants, Innovate UK has supported AIE to develop market-leading technology for electric vehicle range extender units and reliable rotary engine developments for hybrid-electric vehicles.

Since 2007 Innovate UK have helped more than 7,600 organisations with projects estimated to add more than £11.5 billion to the UK economy and create 55,000 extra new jobs.



Supported by Innovate UK, the Office for Low Emission Vehicles and the Department for Business Innovation and Skills, the Niche Vehicle Network is an independent association of over 400 niche vehicle manufacturers, specialist technology and supply chain companies. With funded collaborative research and development activities in low carbon vehicle technologies, including electric and hybrid propulsion, lightweight chassis structures, engine efficiency, alternative fuels and aerodynamics, the Niche Vehicle Network is a valuable partner for AIE.

Through funded strategic and collaborative projects, the Niche Vehicle Network has supported AIE (UK) Ltd in validating new concepts, improving the efficiency and emissions of their world-class rotary engines and testing new innovations for low carbon sports vehicles



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Thank you for Listening



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