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# inside:technology

The Technology Partnership: Journal of technologies and business innovation

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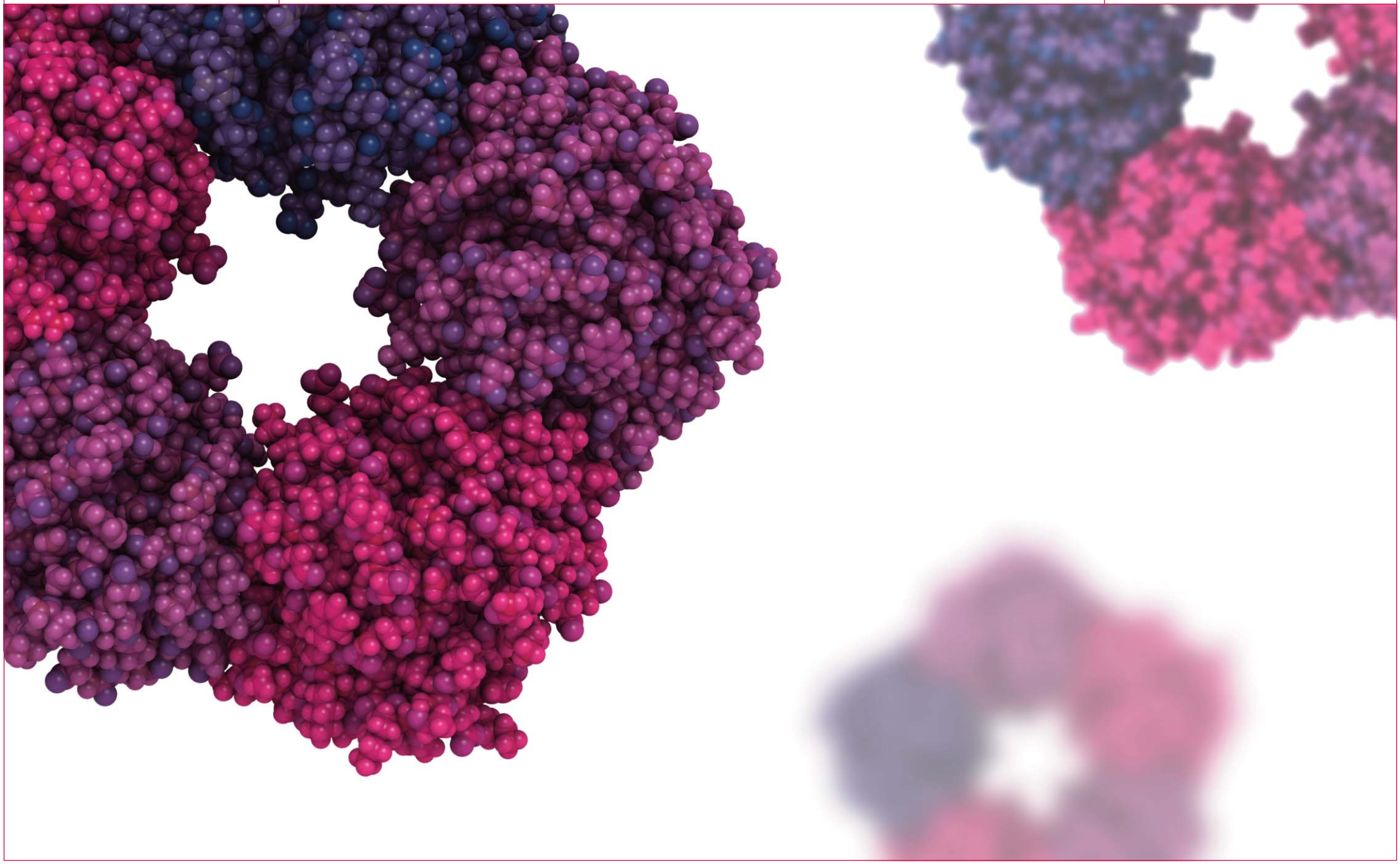

# inside: issue 19

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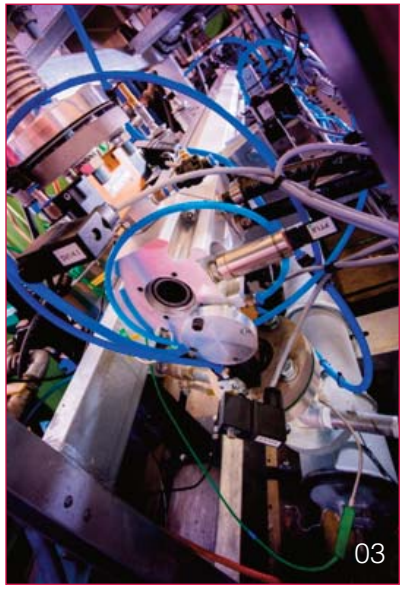
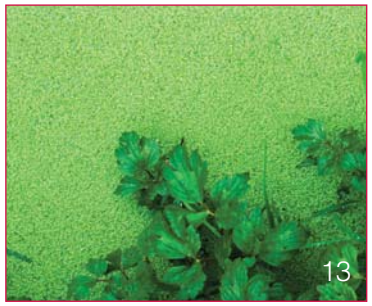













Produced by The Technology Partnership plc
Researched and written by Alex Stewart

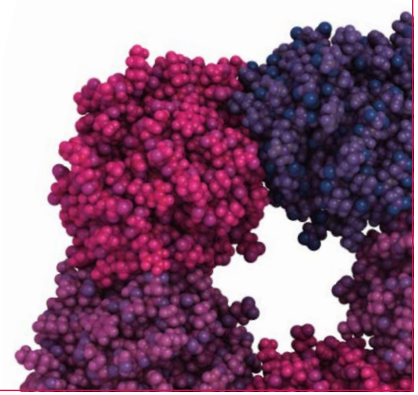

I'm very pleased to introduce issue 19 of inside:technology, TTP's regular review of new technologies and innovation from the UK's universities and start-up ventures.

In addition to the usual broad spread of topics, from a new sodium ion battery technology and bio glues, through to a new tool for protein characterisation, we have a review of additive manufacturing or 3-D printing technologies. TTP has witnessed a strong and growing interest in new technologies for manufacturing, from printing adhesive through to production of metal components, and I hope that this overview of UK activity will prove valuable to all readers regardless of industry sector.

Do please use the contact details provided for any follow-up interest, but needless to say we would be delighted to hear from you should you want to contact us directly.

Enjoy reading issue 19.

Sam Hyde, Managing Director
The Technology Partnership plc



# Libertine FPE Ltd

## Linear power systems technology could transform engine efficiency

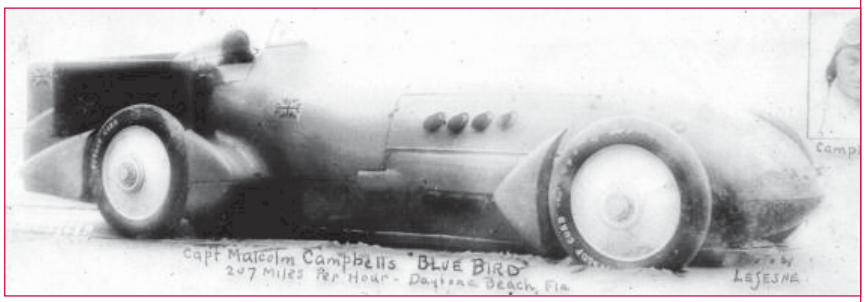


LIBERTINE FPE

## Libertine FPE was established to address the greatest challenge inhibiting the take-up of Free Piston Engine technology – motion control.

The founder of Libertine FPE, Sam Cockerill, has a strong engineering skill set. After graduating with a degree in mechanical engineering from Cambridge University he joined motor sports specialist, Cosworth, working on Indycar race engine development; then worked for TTP as a new product development technology consultant; he moved to Bain Consulting to gain management consultancy experience; and latterly worked for Ensus, a bio-ethanol producer. His great-uncle Harry Leech was Malcolm Campbell's foreman engineer through the 1920s and 30s bagging multiple land speed records along the way before ultimately breaking the 300 mph barrier in 1935; engineering therefore is also in his blood.

While at Bain he began to develop the idea to establish his own company making use of his engineering skills to address the big problems like carbon emissions. The idea to focus on Free Piston Engine technology came to him while working for Ensus. Ethanol, like the methanol used to power the Cosworth Indycar engines in the 1990s, offers the potential for very efficient combustion due to the knock-resistant qualities of alcohol fuels that permit much higher compression ratios. This potential cannot be realised in conventional flex-fuel engines (which must also operate on gasoline) since their piston motion is governed by a crankshaft which defines a single, fixed compression ratio. This requirement for engines to accommodate a range of different fuel compositions is not unique to car engines – for example biogas engines face this problem too. As the role of renewable fuels grows, distributed power generators will therefore also require a more flexible solution.




Sir Malcom Campbell & "Blue Bird"
Courtesey of Richard LeSesne / State Archives of Florida, Florida Memory

### Key facts/data:
**Libertine FPE Ltd**

- Technology: Linear power systems
- Established: 2009
- Type: Start up
- Location: York, Oxford
- Employees: 5
- CEO & co-founder: Sam Cockerill

A chartered mechanical engineer and INSEAD MBA graduate, Sam Cockerill has over 20 years' experience in technology development, general management and strategy consulting roles, including Cosworth, TTP, and Bain Consulting. Prior to founding Libertine he worked as Business Development Director for bio-ethanol producer, Ensus. He graduated with a degree in Mechanical Engineering from Cambridge University.

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### Free Piston Engine (FPE) technology

Free piston technology is so called because there is no crankshaft to determine the motion of the piston. Instead the pistons are free to move back and forth under the action of combustion pressures. Unlike a conventional internal combustion engine, there are no connecting rods or crank shaft to govern each piston's movement and convert this into rotary motion, so in a free piston engine the compression ratio is not fixed. Instead, by coupling a linear electrical machine to each piston to generate power from combustion, the piston motion and compression ratio can be controlled dynamically and optimised for the fuel in use at any moment in time.

### Long history

The concept of FPE technology was first developed in the 1920s. General Motors developed a free piston gas generator for an automotive gas turbine in 1957 with an overall efficiency comparable to that of a high compression ratio diesel engine. But the technology has not been adopted, largely because of the difficulty of controlling free piston motion to deliver the right compression ratio each cycle. Without this control, free piston engines tend to be too inefficient and polluting to compete with today's modern engines.

### Co-founder

True to his TTP roots Cockerill believed the problem must be solvable using the right technical approach. He talked his solutions through with a former colleague from his Cosworth days, Ed Haynes, who has also worked at TTP. Haynes was by now working at Williams F1, the motorsports engineering company, and was responsible for KERS (Kinetic Energy Recovery System) development for the F1 car. He agreed to work with Cockerill in his spare time as a technical advisor although he remained at Williams until 2014, while Cockerill continued working at Ensus until 2013. Haynes joined full time as CTO in 2014 following the decision by Williams to purchase its engines and KERS from Mercedes High Performance Powertrains in Northamptonshire rather than continue investing in its own F1 KERS development.

### Universities

During this phase Libertine built relationships with UK universities in Sheffield and Newcastle which had previous experience with free piston engine technology development. Sheffield University had been a participant in a large EU funded programme in the early 2000s led by Volvo. Libertine also secured funding from Innovate UK under a programme for Low Carbon Vehicles to develop the concept together with Newcastle University and the engineering consultancy, Ricardo.


Sam Cockerill and Chairman, Derek Shepherd, receiving Shell Springboard Award

### Pivot decision

By 2013 it had become clear to the founders however that focussing on making free piston engines was not a viable model for a start up business with limited funding. The level of investment in free piston technology by major car companies and research consortia over the previous decade made it clear that the development journey would be prohibitively expensive. In addition, at the end of this journey there is no precedent for car makers buying completely new engine designs from 'garage inventors'. They decided therefore to focus on Libertine's core enabling 'Linear Power Systems' technologies: Linear electrical machines, and free piston devices. They would aim to become a

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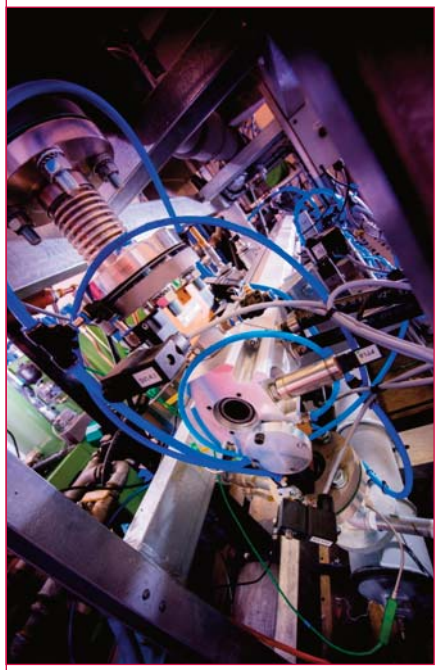

University of Brighton test rig

leader in linear force and motion control technology. Becoming experts in this field would allow Libertine to license technology to larger companies and research institutes who were already working on free piston engine development – turning potential competitors into collaborators and customers. Instead of working like Cosworth therefore they would aim to work more like ARM, says Cockerill, helping their clients to apply Libertine's core technology in a new generation of technologically leading products.

### Prototype

They succeeded in securing funding from Innovate UK to build a prototype so that they could develop and validate the simulation tools that would be needed later for client application development. They partnered with Brighton University, whose Sir Harry Ricardo Laboratories is a recognised global centre for automotive engine research, and Nidec SR Drives Ltd., the world leader in switched reluctance technology. Nidec SR Drives is based in Yorkshire, having been spun out from the universities of Leeds and Nottingham in 1980 and later acquired by the Japanese company Nidec in 2010.

### Methodology

In Free Piston Engines, Libertine's technology permits each piston's compression ratio to be optimally controlled via an ECU which accommodates start up, transient and flex-fuel operation [See box Advantages]. Libertine's linear electrical machines allow this optimisation by varying the electromagnetic force that is applied to each piston during the power generation stroke, which can be changed cycle-by-cycle if required. Taken together the company says this technology has the potential to produce 45% efficiency from an engine compared with around 35% for the most efficient small engines today. Cockerill believes the advent of what Libertine calls 'digital piston motion control' will be as significant a step forwards for engine designers as the introduction of ECUs for the digital control of fuelling and ignition in the 1990s.

### Advantages

- The powertrain from piston to generator is greatly simplified as gudgeon pins, connecting rods, the crank shaft and flywheel are not required. The oil lubrication system can be replaced with air bearings which reduces the engine's heat and friction losses, and reduces the engine's cost.

- The piston is not constrained by the crankshaft to follow a fixed sinusoidal motion, but can be tailored according to the fuel being used, and the required output. This is especially important for flex-fuel and dual-fuel vehicle engines, and also for biogas power generators (high octane fuels like bioethanol and biogas can operate at higher compression ratios).

- When the free piston's movement is controlled electronically, compression and expansion rates and ratios can be altered to optimise efficiency, power or emissions.

- Whereas in crank engines the piston's stroke is defined by the crankshaft, in a free piston engine the piston motion can be considerably extended allowing over expansion of burned gases to extract the maximum possible work before these are released. A further benefit of this over-expansion is that the exhaust noise is reduced.

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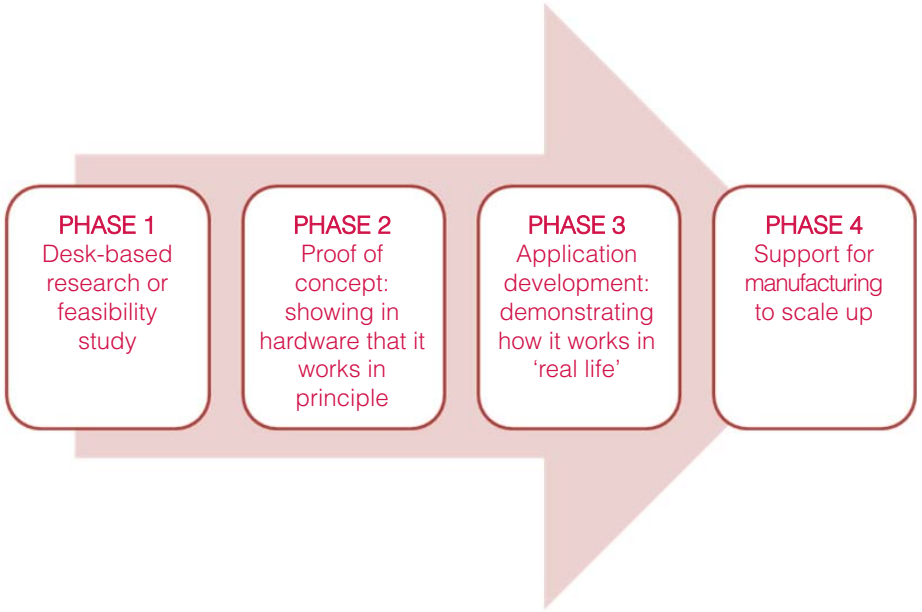
### New opportunities

By taking a step back from car engine design they found many new opportunities opened up. For example, expanding solvents or steam in an Organic Rankine Cycle engine for waste heat recovery. Here they found an opportunity for small-scale waste heat recovery plants which do not have a cost-effective way of recovering heat for conversion to electric power. As a result, Libertine is now working with a diverse range of customers including developers of linear test actuators, pumping systems, hybrid power packs as well as free piston engine developers.

### Service model

Libertine works with customers to help them apply their Linear Power Systems technology in their new products through multi-phased development work packages:

Bioenergy opportunity




Libertine gives its customers access to a 'developer toolkit' of lab-validated simulation tools. This makes it possible for customers to develop initial designs to make best use of Libertine's technology before physical hardware is produced, and in later phases the same tools can be used to optimise further production designs. In the final phase Libertine plans to manufacture small batches of up to several hundreds of units so that customers can transition more easily to volume manufacture. Sales of the units will also provide a further income stream, while the experience gained from manufacturing will feed back into improved designs: a value often lost to license-only companies.

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### Growing interest

During the development programme with Nidec SR Drives and Brighton University the partners held 'Linear Power 2015', an open event at the University in September 2015, which was promoted as the world's first technology forum for linear power systems technology researchers and application developers. Speakers included representatives from leading centres of FPE technology, such as: Sandia National Labs in the US, PETRONAS Technical University in Malaysia, and the German Aerospace Centre (DLR).

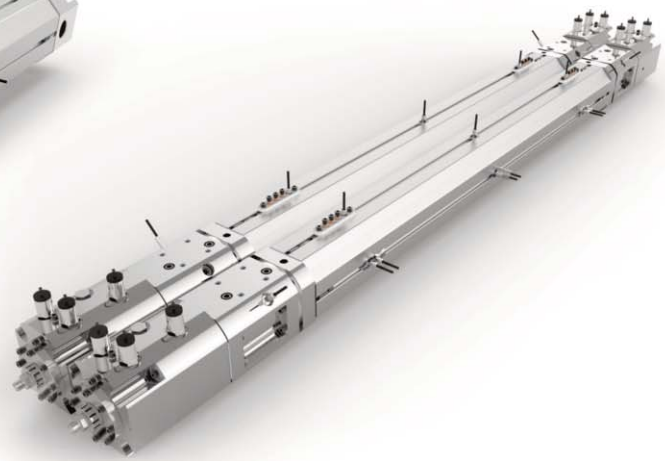
### Soft start up

Libertine has reached its current stage by stretching its limited equity funding through the use of research grants and latterly customer development fees. Its shareholders include Sir Robin Saxby, one of the founders of ARM Holdings who was attracted by the parallel between Free Piston Engine technology enabling distributed power generation and ARM's own low power RISC processor architecture that has spurred the creation of a distributed computing revolution from smartphones to the 'Internet of Things'. ■

www.libertine.co.uk

The stator core of one of Libertine's linear electrical machines

A 5kWe free piston research engine, incorporating one of Libertine's linear electrical machines



A 20kWe free piston expander, incorporating four of Libertine's linear electrical machines

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TTP would like to thank all those who have contributed to inside: technology with text, images and their time.

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