ELECTRICITY *without* MAGNETISM?

Straight thermocouples produce electricity very inefficiently. Harold Aspden and John Scott Strachan claim to have invented a generator system which performs many times better. Is it true thermocouple action or is there a piezo-electric factor producing the power? This article is based on their hypothesis developed from a practical experiment which, they say, produced unexpected amounts of power.

Physicists know that thermoelectric bimetallic circuits have nothing practical to offer in design of devices aimed primarily at converting heat to electricity. Too much heat is lost by thermal conduction through the metal conductors linking the junctions in the circuit. Also, though an EMF is developed in the circuit when the junctions are at different temperatures, the power it can apply to current flow is swamped by heat conduction along the current flow path.

Semiconductors can increase the EMF ten-fold and decrease the heat conductivity a thousand fold. But the result is a device that is still poor in efficiency and, worse still, which cannot sustain a high power throughput rate for its size and cost. Such thermoelectric heat pumps, though commercially marketed as electronic circuit components, have a limited utility.

But instead of trying to avoid that heat conduction, why not try to harness it?

In the Thomson effect, a temperature gradient in a metal causes the free electrons to migrate under thermal pressure so as to set up an EMF in the axis of heat flow. Some 87μV of EMF is set up per °C of temperature difference.

The Aspden hypothesis

On the face of it the Thomson effect is a scientific curiosity with no specific practical application because it goes hand in hand with the standard design property of a substance known from its heat conductivity.

That, at least, is how things stood until we hit upon the idea of using audio or low radio frequency electronics to set up transverse current oscillations across bimetallic surface coatings on a dielectric substrate.

The Thomson effect has a positive coefficient in some metals and a negative one in others (as if electrons are the heat carriers in one and positrons or holes in the other). We believed that advantage could be taken of this by constructing a dielectric sheet material coated with vapour-deposited layers of aluminium and nickel, metals of opposite-polarity Thomson coefficients. A temperature difference between two opposite edges of the sheet material means that a current will flow one way in the nickel and the other way in the aluminium. The current will circulate – powered by the heat transfer – and would cross the bimetallic junctions at the interface, but in opposite directions.

The Thomson effect promotes current circulation; the task then is to draw power from the EMF set up normal to the sheet by Seebeck action resulting from excess of Peltier cooling on the hot side over Peltier heating at the other (see box below right).

All heat flow through the metal from the hot side would be intercepted, somewhere in its passage through the metal layers, by Peltier cooling – cooling promoted by a transverse current from discharge of the capacitor built from the dielectric sheets and their metal coatings.

Heat would also be blocked from easy transfer to the cold side by a staggered arrangement of heat sink contacts with the bimetallic coatings, forming an alternating sequence of capacitor plates in what would be a series-connected capacitor stack.

On the charge cycle, the cooled state of the junction on the heated side would result in a lower reverse transfer of energy by Peltier heating so that over a full AC excitation cycle a net output power would be delivered.

The capacitor dielectric may possibly be involved thermodynamically owing to its own special properties and serves as a thermal barrier to direct heat transfer through the main body of the device.

"Astonishing" performance

John Scott Strachan built a working system based on these principles. To stimulate oscillation of the capacitor current in what must – owing to the Peltier EMF – be a capacitor with a negative resistance, a piezoelectric oscillator system operating at 500kHz was built into the system powered by the heat-generated electrical output. The piezo material comprised the PVDF dielectric material sandwiched between the bi-metal plates. In September 1988, the first device was finished and ready for test.

One face of the device was cemented to a heat sink so that to extract power the upper exposed face had to be cooled rather than heated relative to the heat sink on the underside. Instead of feeding in a measured amount of heat from an electrically powered resistor the device was operated by placing a melting piece of ice from a domestic refrigerator upon its upper face.

Almost unbelievably, the device performed immediately and was astonishingly effective, spinning an electric motor connected to its output leads.There was no electrical input for test or other purposes. Electronics in the device were all powered by the electricity generated by the small piece of melting ice.

If an ice cube were placed on the surface with the motor disconnected it took seven times as long to melt as it did with the motor connected – hinting that the conversion efficiency had to be extremely high. Unfortunately that efficiency could not easily be measured because the device was powered by cold rather than heat! But what could be measured was enough to suggest that the device was operating on principles that were not quite those we originally had in mind.

We had built an electronic device that more than met our objectives but we did not fully comprehend its operating principles. The device delivered power by operating at 500kHz. It had no more than a 20°C temperature drop across its 8cm square heat surfaces yet was delivering useful output electrical power that scaled up to levels of kW/m^2.

Device details

The device demonstrated, 5mm in thickness and 8cm square, comprises a capacitor assembly bounded by two aluminium plates. One plate is in contact with a heat sink at room temperature, the other supports a small piece of ice from a domestic refrigerator. As the ice melts it absorbs room heat to power 500kHz oscillations which deliver output power through a ferrite transformer and a rectifier to spin an electric DC motor.

When the ice has melted a battery is connected to its output leads and this revolutionary solid-state electronic heat engine operates in reverse mode. The water left on the aluminium plate freezes almost instantly.

Laboratory testing reveals a 70% of Carnot efficiency factor in energy conversion.

Cold spot explains high EMF

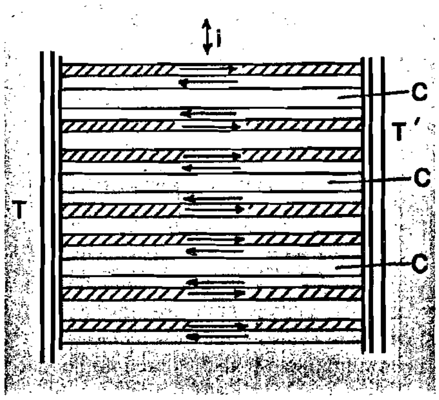
Diagnostic tests and extensive theoretical analysis carried out as we tried to reverse engineer our own product, showed that the thermoelectric EMF being produced by the aluminium-nickel junctions was about 20 times greater than textbook data indicated. Since the factor of merit of a thermoelectric device increases as the square of this EMF and the metals used were good electrical conductors, the finding indicated a major discovery.

Eventually, it was reasoned that this was not some new strength in activating the thermoelectric power of bimetallic junctions, rather a technique for avoiding a weakness that had beset the normal metal thermoelectric devices. The difference was that we were operating at a high frequency and interrupting the current flow at that frequency, whereas a conventional thermocouple circuit is invariably DC operation.

Classical thermodynamic principles say the thermoelectric EMF across a junction should be of the order of 260μV/degree of absolute temperature (Kelvin) – the high EMF we realised in our experimental device. But tests on an aluminium-nickel thermocouple circuit operating under normal DC conditions reveal only a fraction of this power.

Perhaps the higher levels of thermoelectric EMF obtained in semiconductors hold the key. Semiconductors suited to thermocouple use have a resistivity decreasing with increased temperature – the converse behaviour to base metals. At a point in the junction interface between two metals at which Peltier cooling is

STRACHAN-ASPDEN ELECTRONIC HEAT ENGINE: Bimetallic coated dielectric layers, C, are assembled in a capacitor stack and interleaved with uncoated dielectric layers. The circulating DC current i in each coating is powered by the EMF set up by the Thomson effect and AC oscillations allowing a transverse AC current i are powered by the EMF set up by the Seebeck effect. Upon superimposition of these current components there is a cooling junction current 2i at the hot side (T′) for one AC half cycle and a heating current 2i on the cool side (T) during the other half cycle. Result is an AC thermoelectric pile of panel form having very low internal resistance to AC current throughput.



occurring there is a concentrated cooling action confined to that interface which must, of necessity, cool rapidly.

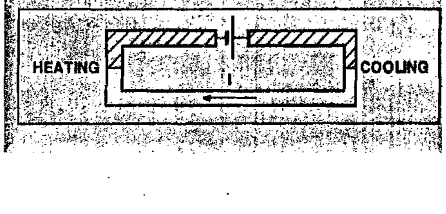
If some points in the interface surface cool faster than others, conductivity will probably increase at those points and current will follow the path of least resistance: the more current flowing at a Peltier cooled spot in the junction surface, the greater the rate of cooling.

The action escalates and in the normal situation of DC flow the current will tend to form a filamentary flow path and cross the junction at a temperature far lower than that believed to exist at the externally heated junction. The result is that the actual effective junction temperature drops until it almost equals that at the Peltier heated junction and so very nearly sup-

The Peltier effect

Peltier, in 1834, advanced on Seebeck's work by establishing that a current across a bimetallic junction can cause either local heating or cooling at a junction, according to the direction of current flow.

Peltier discovered that flow of current across a junction between two different metals will cause cooling at one junction and heating at the other. The effect is proportional to the current strength and reverses when the current reverses.



THOMSON EFFECT:
Even with no current flow, a temperature difference between the ends of a metal strip will set up an electric potential of the order of 87μV/°C. The effect is positive in some metals and negative in others.

presses all current flow.

In short, the normal DC all metal thermocouple strangles itself by choking off almost all its power capacity.

The way to avoid the situation seems to be to switch the current on and off so rapidly that the current filaments cannot form for long enough to be trapped in the cold spot positions – the analogy is spot formation on the mercury pool in the old-fashioned mercury arc rectifiers. Current tends to break up into filamentary flow paths and maybe that is just what is happening even in metals, so that the current must be kept moving across any boundary surfaces.

Second device

Whatever the truths of this phenomenon, a second device was built relying on this discovery and the principles exploiting the Thomson effect. It also worked immediately and performed as well as the first system. However, this device was intended for diagnostic testing and efficiency measurement and included no piezoelectric oscillator or magnetised tape and had no staggered construction features.

Output was gated through a low impedance switch under the control of a function generator feeding negligible switch control power. Design was simple (see figure) in the extreme, relying on the Thomson effect to circulate current and the Seebeck and Peltier Effects to set up a thermally induced negative resistance in the low resistance AC throughput channel of the capacitor stack. The device operated over a wide range of frequencies but optimum performance was at 1 kHz and a 70% of Carnot efficiency was measured for generation of electricity from heat supplied at water temperatures. The efficiency is not deemed optimum and can almost certainly be improved.

Status of the invention

No R & D project funded by a government body or a corporation led to this technological breakthrough; it is the product of individual effort addressing the challenging question of alternative energy sources. To see the potential for generating electricity efficiently from heat, look at the heat wasted at water temperatures in the steam condensers of electric power plants. Or contemplate setting up a small temperature differential between the inside and outside of a greenhouse by trapping the ambient radiation (even under cloudy conditions) to realise that a thermoelectric panel fitted in that structure could become a source of electricity.

A US patent application on the device has been granted – the US patent examiner first declared that it was impossible for a melting piece of ice to generate electricity as suggested in the patent specification. But he did accept the evidence presented and the patent was allowed.

Now it remains to be seen whether the invention will attract interest and be developed to its true potential.

About the inventors
Dr Harold Aspden is a visiting senior research fellow in the Department of Electrical Engineering at the University of Southampton. He is a former Director of European Patent Operations in IBM but retired to pursue private research in the energy field.

John Scott Strachan is a research scientist, formerly with the Pennwalt Corporation researching piezoelectric applications of PVDF material, now engaged on research as a director of Optical Metrology Ltd and located at the Technology Transfer Centre at King's Buildings of the University of Edinburgh

There are problems. The dielectric PVDF material with the bimetallic coating is no longer available commercially, as far as we know. The aluminium coating was bonded to the PVDF by a nickel layer and technological progress has allowed the industry PVDF material to be manufactured in a single coating stage, making the intervening nickel layer unnecessary. So the essential bimetallic material used in prototype test construction can not be easily obtained and this scales up the R & D funding requirement for the invention to develop further. As a result development is currently in limbo owing to the curious situation where technological advance in one industry has blocked progress in an entirely different field. ■

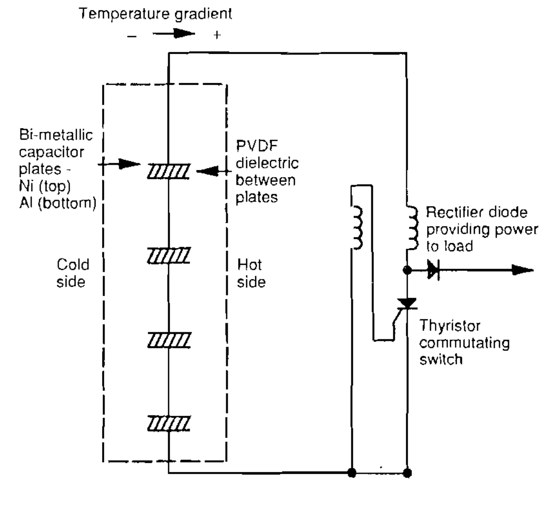
SUPER THERMOCOUPLES – THE MAGAZINE'S VIEW

Editor Frank Ogden and consultant Derek Rowe write: If the authors' observations are correct, there is definitely a mechanism worth investigating although the generating effect may have more to do with the highly piezo-active nature of PVDF plastic than with thermo-electricity.

During lenthy conversations with the authors, it emerged that the generating device comprised a stack of up to 1000 PVDF metalised film discs effectively connected in series with the whole assembly – which forms a giant piezo-active capacitor – connected across a ferrite transformer via an SCR. The gate of the SCR is driven via a small feedback winding on the transformer. The authors report that the assembly self-oscillates when subjected to a heat gradient orthogonal to the bi-metal layers. Surplus power can be drawn off by rectification from the top of the thyristor. A 20°C temperature gradient across the stack causes it to deliver a rectified output of around 50mA at 2V.

Strachan emphasises that the device requires a kickstart to commence oscillation; he originally employed a separate piezo oscillator element physically attached to the top of the stack. He also states that the oscillator frequency is determined by resonance between transformer primary inductance and the intrinsic stack capacitance.

Trapping highly piezo-active material between metals of differing thermal expansion coefficients could produce enough stress to power a commutating system. This doesn't explain the authors' observation that power flow could be reversed leading to a Peltier style cooling effect. How they achieved this with the general arrangement shown in our drawing isn't too clear.



Our interpretation of the authors' test circuit