The doublethink science of heat engines

Courtney, William
Cheshire Innovation Engineering Consultancy
17 Vale Road, Timperley, Altrincham, Cheshire, WA15 7TQ, UK
Tel/Fax +44 (0) 161 980 5191,
E-mail bill.courtney@cheshire-innovation.com

Summary
George Orwell invented the word 'doublethink' to describe a process of indoctrination, whereby the subject is conditioned to simultaneously accepting as true, two mutually contradicting beliefs. In this paper it will be argued that since Mid-Victorian times, our understanding of heat engines has amounted to doublethink But, if we can clearer our minds, a new prosperous, carbon free future awaits us.
Fluid flow heat engines that run on fossil fuels generate most of the greenhouse gases that are overheating our planet. These engines include internal combustion vehicle engines, jet engines and the steam and gas turbines that generate the bulk of our grid electricity. There is also a second class of heat engines that obey the same laws of thermodynamics, but do not produce any pollution. These are the natural heat engines that drive the Earth's weather systems. 'Doublethink science' refers to the fact that although they obey the same laws of thermodynamics, engineers and meteorologists seem to view manufactured and natural heat engines as though they have little in common and obey different rules.
Manufactured heat engines run hot at typical temperatures of around 600^{o}C, but are only around 50% efficient. In contrast, natural heat engines run cool, typically at 30^{o}C or lower, yet they have thermal efficiencies approaching 100%. It will be argued that by imitating nature, a new era of cool running heat engines that deliver clean, low cost electricity is possible.
Illustrative examples to encourage the open source development of cool running heat engines will be provided.
The contradictions to be discussed have their origin in Victorian thermodynamics research, especially that of William Thompson (Lord Kelvin) who worked at Glasgow University. So, with the COP26 Climate Change Conference scheduled to be held in Kelvin's home city of Glasgow in November 2021, now would be good time to learn from this doublethink.

Key index words and phrases: Bernoulli's equation, Bernoulli's principle, Carnot's equation, doublethink, heat engine, global warming, Kelvin.

1 Background

In 1959 William Courtney was a thirteen year old junior member of Manchester Astronomical Society. Using the society's 8 inch refractor telescope, he saw the planet Jupiter for the first time. He learned from older members that the surface temperature of Jupiter was an incredibly cold -145^{o}C and that its most distinguishing feature, the Great Red Spot was the largest atmospheric storm in the solar system. This huge storm cloud could engulf the whole Earth and had existed since at least 1832. The members also explained that the Great Red Spot was a very efficient natural heat engine that converted low temperature thermal energy into mechanical storm energy.
In rainy Manchester where the skies were often obscured, astronomy morphed into an interest in meteorology and cloud formation. Courtney gained a basic understanding of the Earth's atmosphere as a system of reversible heat engines where thermal energy was lost or gained depending on whether the water droplets in clouds were evaporating or forming.
By the time Courtney went on to study thermodynamics as part of an Applied Physics course at Hull University, his dominant response on hearing the term 'heat engine' was to visualise a cool running but highly efficient system for reversibly converting thermal energy to mechanical energy.
This mindset enabled the undergraduate Courtney to spot several examples of doublethink in the conventional teaching of heat engine theory. These examples will be discussed below and are obvious once attention has been drawn to them.

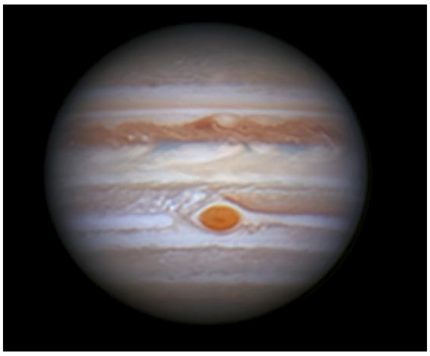

Figure 1. Jupiter's Great Red Spot is a cool running heat engine.

2 The first case of heat engine doublethink science

During the Victorian era, Kelvin was responsible for many of the key concepts that still remain at the heart of modern thermodynamics. These include a statement of the second law of thermodynamics, a dynamic explanation of the nature of heat and the invention of a thermodynamic temperature scale, now called the Kelvin temperature scale in his honour.

We can be confident in the quality of the nineteenth century thermodynamics work of Kelvin et al. because it has stood the test of time. But nevertheless, its interpretation has led to doublethink.

For example, engineers are taught that for maximum thermal efficiency, manufactured heat engines must run well above the normal boiling point of water, yet are limited by the laws of thermodynamics to efficiencies of 60% or lower. In contrast, meteorologists are taught that the atmospheric heat engines that produce our weather all run well below the normal boiling point of water, yet have thermal efficiencies approaching 100%.

A second difference between natural and manufactured heat engines is that phase changes between the liquid and vapour states of water are common in weather system, but are discouraged in manufactured engines because of the mechanical problems they cause. This difference is important because it limits the choice of heat engine efficiency equations available when comparing the two types of systems. Two efficiency equations are commonly used in heat engine theory, but only one of them applies to natural heat engines.

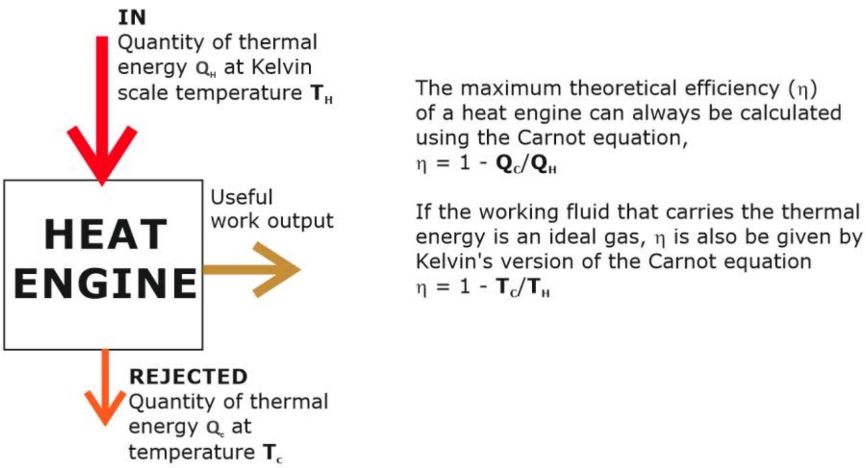

Figure 2. Heat engines accept thermal energy from a hot reservoir and convert some of it into work.

The laws of thermodynamics prevent the complete conversion of thermal energy into work inside the heat engine. Consequently, some thermal energy must always be rejected into a cold reservoir at a lower temperature. The maximum theoretical efficiency of a heat engine is always given by the equation $\eta = 1 - \mathbf{Q_C}/\mathbf{Q_H}$.

In the case where the working fluid is an ideal gas, the maximum thermodynamic efficiency is also given by $\eta = 1 - \mathbf{T_C}/\mathbf{T_H}$. (Zemansky, M., 1959 [1], Cengel et al, 2019 [2].)

Dry steam and all the gases found in manufactured heat engines are fairly good approximations to an ideal gas.

The following table compares the engineering and meteorological concepts of a heat engine by treating them as a set of informal rules.

'The Hot Rules' accepted by engineers	**'The Cool Rules' accepted by meteorologists**
A heat engine is separated from its environment by solid walls, with a working fluid passing through it from a hot reservoir to a cold reservoir.	Natural heat engines are part of the atmospheric environment and have no need for solid walls.
They are high kinetic energy density systems The low density working fluid can still exhibit a high kinetic energy density because of the high fluid speeds within the heat engine.	**They are low kinetic energy density systems** The absence of solid walls to channel the air flows imposes limitations on the maximum air speed and kinetic energy density of natural heat engines.
Engineers commonly use Kelvin's version of the Carnot efficiency equation, $\eta = 1 - \mathbf{T_C}/\mathbf{T_H}$. This tells them that $\mathbf{T_H} - \mathbf{T_C}$ must be as large as possible for maximum efficiency. But the lowest possible value of $\mathbf{T_C}$ is that of the environment.	Kelvin's version of the Carnot equation rarely applies to natural heat engines because it does not allow for working fluid phase changes. So that assumption that $\mathbf{T_H} - \mathbf{T_C}$ must be as large as possible is rarely true.
Heat must enter the heat engine at the **highest possible temperature** for maximum thermal efficiency. Typically, a high temperature means around 600^{o}C.	Heat engines **can run cool** and still be highly efficient. Typically, 'cool' means up to about $+30^{o}$C for tropical hurricanes, but possibly as low as -145^{o}C on the planet Jupiter.
They are **high pressure difference** systems. Even achieving around 50% efficiency involves gas pressures at least an order of magnitude higher than atmospheric pressure.	They are **low pressure difference** systems. Higher levels of efficiency than manufactured heat engines are achieved, even though the working fluid only suffers modest fractional atmospheric pressure changes.
Rejected heat can be permanently removed from a heat engine by the processes of conduction, convection and the ejection of the used working fluid.	If the atmosphere is considered as an assembly of heat engines, conduction, convection and ejection cannot remove heat from the assembly. These processes can only shuffle the rejected heat between individual atmospheric heat engines.
Heat recycling is **impossible** because the second law of thermodynamics tells us heat cannot flow back from the cold exit reservoir to the warmer heat input reservoir. Instead, the rejected heat has to be dumped into the environment.	Heat recycling is **inevitable** Natural heat engines are part of the atmospheric environment. So the rejected heat has to go back into the environment it came from.
Nature has dealt us a cruel hand The laws of thermodynamics have doomed humanity to live in a world where heat engines are inherently wasteful and shift us towards the heat death of the universe.	**Nature has dealt us a good hand** All life on land only exists because natural heat engines do work, pumping water from the sea to the land via the atmosphere. The rejected heat is recycled, so the heat death of the universe comes no closer.
CONCLUSION Manufactured heat engines are hot running, high temperature difference, high pressure difference systems limited to around 50-60% efficiency. Since mid-Victorian times inventors have failed to find a way of internally recycling the rejected heat and believe that this quest is impossible because it defies the laws of thermodynamics.	CONCLUSION Natural heat engines are cool running, low temperature difference, low pressure difference systems that efficiently recycle their rejected heat. Inventors should look to nature's heat engines for inspiration.

Two key Victorians provide evidence to support both sets of these informal rules. Fitzroy established science based weather forecasting in the 1860sand Brayton invented the petrol powered internal combustion engine in 1876.

Tesla, who invented the AC generator in 1896 falls into neither camp because generators can be powered by internal combustion engines, steam, wind and water turbines. But wind and water power are unreliable, so the birth of the electricity age led to a worldwide increase in the use of hot heat engines and the climate crisis that we face today.

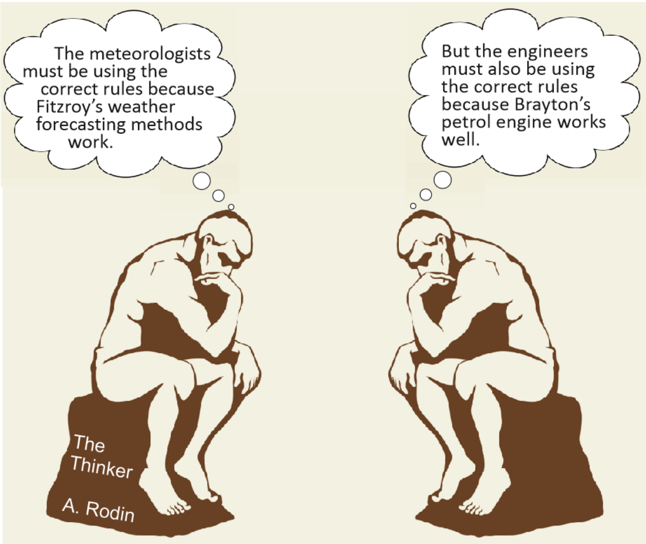

Figure 3. Heat engine doublethink has existed in plain sight since Victorian times.
So, Rodin's thinker would be forgiven for concluding that doublethink is the truth.
(Schrödinger's cat would sympathise!)

A Venn diagram comparison tells us that the meteorologists' rules are more robust because they encompass all of the engineers rules plus more as well.

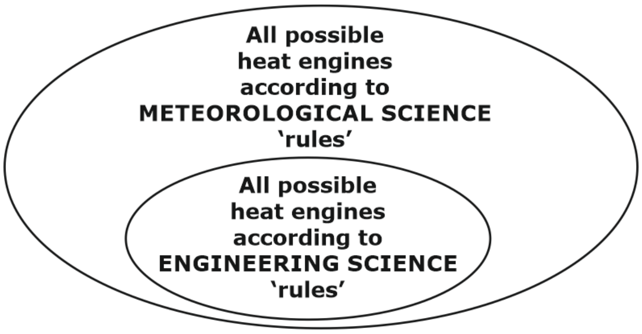

Figure 4. A Venn diagram shows that the engineers informal 'rules' can be considered as a subset of the meteorologists 'rules.'
This nesting of concepts tells us that if engineers were willing to think outside their own Venn diagram element, radically different types of manufactured heat engines might be possible.

3 The second case of doublethink: Fluid flow heat engines are not heat engines

The term *heat* is often used carelessly when *internal energy* should be used. This can lead to misunderstandings about how heat engines work. In particular, it encourages the belief that the temperature difference between the hot and cold reservoirs of a heat engine is the cause that allows them to do work. However, on closer examination, the temperature drop is a consequence of the engine doing work.
For example, consider this comparison between two turbo-generator type heat engines used to produce electricity. The first includes a combustion chamber where an air-fuel mixture is ignited to produce high pressure, high temperature combustion gases. These are then allowed to expand into the surrounding atmosphere, via the turbine, which spins and does external work. The maximum work output is dictated by the fact that the exiting gases must still be above atmospheric pressure, so that they can do additional work, pushing back the surrounding air to make space for them. The temperature of these exiting gases is a secondary factor and can be far higher than ambient.
In the second case, the turbine is driven by highly compressed air flowing from a tank of compressed air that has been allowed to settle to ambient temperature. Again, the limiting condition on the work done is that the exiting air must be slightly above ambient pressure. But in this case, the exiting air will be cooler than ambient.

According to the second law of thermodynamics, heat processes involve two bodies at different temperatures with heat being the net energy flowing from the warm body to the cooler body. Whereas *internal energy* only has to involve one body and is the total energy associated with the random, disorder motion of the molecules inside the body and *temperature* is the detectable measure of the mean energy level of these molecules.

Heat engines that rely on a transiting fluid to do work contradict their own name because only one body needs to experience a direct temperature change. This is most obvious in the case of natural atmospheric 'heat engines' where no solid walls suffer a temperature change.'

The working fluid that passes through the engine is typically a gas and is made up of molecules. For analytical purposes, we can consider the molecules as having two types of motion. There is their random movement which collectively creates internal energy and superimposed on this is their bulk or drift movement in the direction of gas flow. When molecules lose momentum in the direction of flow as a result of doing external work, (for example, spinning a turbine rotor), this has to be immediately regained, to prevent the molecules piling up in front of the turbine rotor. As the molecules regain momentum in the direction of flow, their kinetic energy due to bulk movement is also restored. But the law of conservation of energy has to be obeyed. So, the sum of the microscopic kinetic energies of individual random motions has to fall, as the macroscopic kinetic energy associated with bulk movement is recovered. As a consequence, the temperature of the fluid falls.

This is the opposite of a heat flow process, where two bodies are required and it is the temperature difference between them that causes the heat to flow.

Thus, in a true heat flow process, the greater the temperature difference between the hot and cold bodies, the greater the rate of heat flow. Whereas, in our turbo-generator 'heat engine' example, the greater the pressure difference between the input and output, the greater the rate of working.

Heat plays no direct part in this so called heat engine process, so using the term *heat engine* amounts to doublethink. A speculative guess is that this name is an accident of history, perhaps from the pre-Victorian era, when the term heat had a different meaning, with heat being envisaged as an invisible, weightless fluid called caloric. This hypothesised pre-Victorian association with fluids might also explain the origin of other heat engine terms such as 'hot reservoir' and 'cold reservoir'.

But, since only one body is strictly involved, all references to hot and cold 'heat reservoirs' is also inappropriate. However, we will retain all of these traditional terms, rather than cause confusion by being too pedantic.

In the next section it will be argued that by considering 'heat engines' as 'internal energy to mechanical energy conversion engines', the potential of cool running 'heat engines' can be harnessed.

4 The third case of heat engine doublethink: Pressure is not energy

During his 1964 pre-university school year, Courtney was taught Bernoulli's equation and was baffled by it. He encountered it again at university and was still baffled by it. The problem was that it appeared to contradict the law of conservation of energy. None of his tutors were able to provide a satisfactory explanation, and the course textbooks were equality unhelpful.

Bernoulli's equation (alternatively referred to as Bernoulli's principle), states that for an incompressible, non-viscous fluid undergoing steady flow, the pressure (**p**) plus the kinetic energy per unit volume (½ x density, **ρ** x velocity, $\mathbf{v}^2$) plus the potential energy per unit volume (density, **ρ** x acceleration due to gravity, **g** x height **h**) is constant at all points on a streamline [3].

Thus,

$$\mathbf{p + \tfrac{1}{2}\rho v^2 + \rho g h = constant}$$

This equation is dimensionally correct but baffling because it suggests that the sum of two types of energy (potential and kinetic) plus pressure (which is not a form of energy) is always a constant. So, students have to believe that energy can be transmuted into pressure and vice versa at different points along a moving fluid. Any student or teacher, who is prepared to accept this, while also believing in the law of conservation of energy, is practising doublethink.

Pre-university textbooks tend to cope with this dilemma by simply ignoring it. For example, see the British textbooks by Muncaster [3] and Noakes [4].

University textbooks in the 1960s commonly tried to ensure compatibility with the law of conservation of energy by explaining that **p** is actually a form of energy called '*pressure energy*', with pressure energy being defined as "the energy stored in a fluid due to the force per unit area applied onto it."

Authors employing the *pressure energy* explanation included Starling and Woodall [5] and Newman and Searle [6].
But the *pressure energy* interpretation is also confusing because the student has to accept several conflicting assumptions when deriving the equation.
First, before verifying Bernoulli's equation, the boundary conditions are specified, with students being told that the fluid is incompressible. Then, during the derivation the student is required to accept that somehow, the application of pressure to an incompressible fluid can be used to store energy. This means that the fluid must be both elastic and incompressible at the same time.
Then, when reinforcing their learning by doing calculations, the student has to insert values of **p** using units of pressure, while also accepting that **p** is not pressure, but energy.

Bernoulli's equation evolved in the period 1730-1750, at a time when our understanding of the concept of energy was poor. So, provided that the equation was consistent with observations, any violations of the law of conservation of energy would have been irrelevant.
It was only in the Victorian era, a century later that our modern understanding of conservation of energy evolved. This knowledge should have allowed the contradictions in the teaching of Bernoulli's equation to be spotted and resolved.
In November 1965 a spectacular example of Bernoulli's equation hit the British headlines when three of the eight cooling towers at Ferrybridge power station collapsed during a gale [7]. Gusting 136 km/hour winds were funnelled between the cooling towers so that wind speeds and pressures suffered large changes over short distances. As a consequence, vortices developed which ripped three towers apart. Courtney was intrigued by this incident and made an informal study of it. He came to the conclusion that the mechanical work done in destroying the towers ultimately came at the cost of a drop in the internal energy of the wind. This conclusion was supported by a British Meteorological Office paper published in 1967 [8].

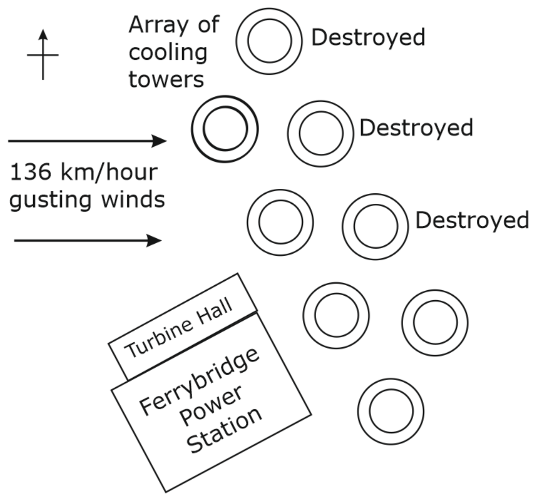

Figure 5. The Bernoulli Effect caused large air speed variations and pressure gradients in the gaps between the cooling towers. These gradients created swirling movements with sufficient energy to destroy three of the towers.

The implications for Bernoulli's equation became clear: when fluid speed and kinetic energy increase along a streamline, there is a compensating drop in internal energy. This results in the fluid temperature falling, and as a consequence, fluid pressure **p** also falls.
Thus, *fluid pressure,* **p** = ***k*** x *internal energy per unit volume,* **U,** where ***k*** is a dimensionless constant.

So, Bernoulli's equation usually gives numerically satisfactory answers, even though pressure **p** is just a convenient dummy for the more elusive internal energy **U**. (The justification for adding the word 'usually' will be provided in Section 6 below.)
This common failure to recognise the role of internal energy in Bernoulli's equation mirrors the equivalent failure to recognise its role in fluid flow heat engines.
In 1959 Newman and Searle [6] had puzzled a generation of students by stating that,

"Pressure energy is the energy required to move the liquid against the pressure, without imparting any velocity".

An online search reveals that students are still being taught and baffled by this explanation [9]. However, the teaching is changing, with some authors at least, making reference to the involvement of internal energy [10].
For many years, the role of Bernoulli's equation in aircraft wing design has misled students in an entirely different way. Perhaps acknowledging this error will make it easier for teachers to revisit the role of **p** in the present case. Thus, popular technology articles commonly follow the older basic physics textbooks by explaining that the uplift caused by air flowing over an airfoil shaped wing keeps aircraft in the sky. But our modern understanding is that Newton's third law of motion also plays a key role, with the down thrust of air under an upward tilting wing causing a complimentery up thrust on the moving aircraft [10].
It is surprising that the internal energy explanation for the **p** term in Bernoulli's equation did not become accepted in Kelvin's day, when the kinetic theory of gases was being developed. According to this theory, there are only two ways in which the pressure at a point inside a gas can be changed. Either the number of molecules hitting unit area of a test surface in unit time must change, or the mean speed with which a fixed number of randomly moving molecules hit unit area per unit time must change. According to the assumptions made in deriving Bernoulli's equation, the first option cannot be true, because it requires the gas density to change. So the second option, which requires the gas temperature to change, must be true. That is, the internal energy of the gas must change.
By the mid-Victorian era, scientists working at the leading edge of fluid flow science were using new and more powerful analytical tools such as the Navier-Stokes equation. So perhaps the century old Bernoulli equation was considered as too passé to be worthy of close examination.

The internal energy explanation for Bernoulli's equation can be verified in the laboratory, using a converging-diverging section of insulated conduit. Inside the conduit, the fluid speeds up as the walls taper inwards, then slows down as the walls diverge.
At a molecular level, the converging taper of the walls can be seen as having a limiting effect on the random motion of the forward drifting molecules. For molecules closer than one mean free path length from the walls, their number of degrees of freedom is limited, because the molecules cannot pass through the walls.
The closer the walls are together, the more the drifting molecules are affected. Consequently, random motion is increasingly converted into directed or bulk motion in the direction of drift. This means that the pressure **p** drop is a consequence of random motion being gradually converted into bulk movement, rather than being a cause of it.

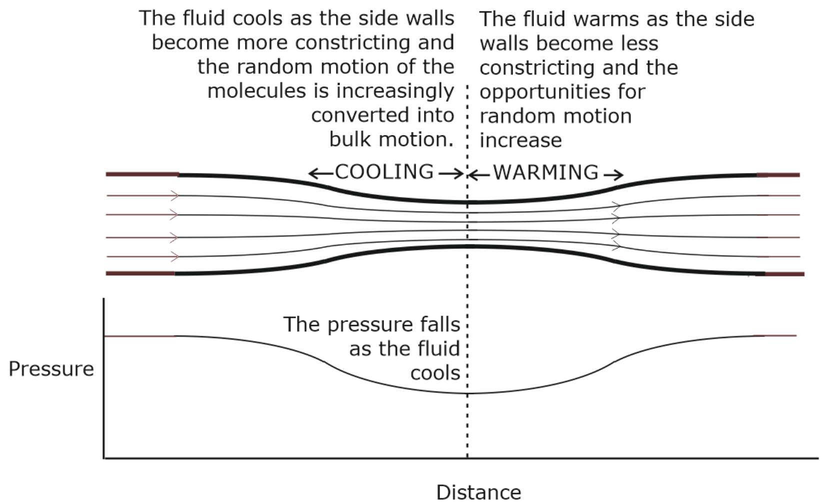

Figure 6. Changes in the pressure, **p** can now be accounted for as a consequence of changes in the internal energy of the fluid. This makes the concept of '*pressure energy'* redundant.

The internal energy interpretation implies that the flow of an incompressible fluid along converging-diverging streamlines can be seen as a form of two way heat engine. In the converging section, kinetic

energy increases at the expense of a reduction in internal energy, with the reverse occurring in the diverging section.
The term 'two way heat engine' implies that internal energy can be converted into kinetic energy and vice versa, depending on whether the streamlines are converging or diverging. It can only be described as a 'reversible heat engine' in the specific case that no external work is done by the engine
The equivalent of Bernoulli's equation that describes the reversible form of this heat engine could be stated as,

'For unit volume of incompressible fluid in steady flow
Internal Energy (U*)* + Kinetic Energy ($\frac{1}{2}\rho v^2$+) + Potential Energy (ρgh) = Constant'

This is essentially a simple partially integrated form of the Navier-Stokes equation as used by engineers since Mid-Victorian times. However, its simplicity makes it easy to use as a creative thinking tool, helping to bridge the divide between cool running natural heat engines and their hot running manufactured counterparts.

For an ideal gas flowing along the streamlines, the maximum theoretical efficiency of this type of heat engine is still be given by both versions of the Carnot equation, that is, $\eta = 1 - \mathbf{Q_C}/\mathbf{Q_H}$ and $\eta = 1 - \mathbf{T_C}/\mathbf{T_H}$. However, the increase in kinetic energy can also be calculated from the change in the perpendicular cross section of the streamlines.

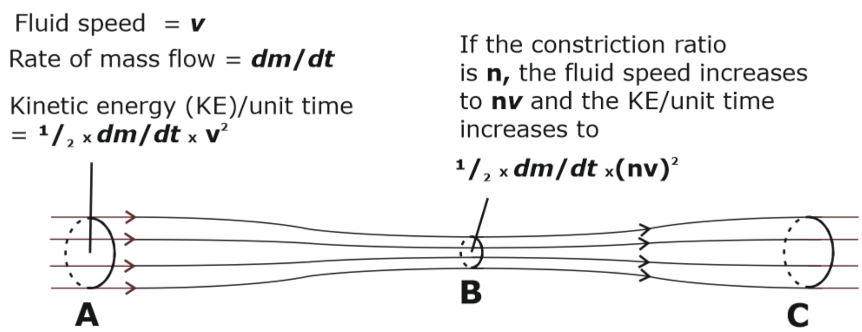

Figure 7. This diagram assumes that there is no heat flow across the outer streamline boundary.

The efficiency with which internal energy is converted into kinetic energy only depends on the square of the constriction ratio, **n** of the streamlines. So, for a single phase fluid, the Carnot efficiency of the engine is independent of the temperature $\mathbf{T_H}$ of the hot reservoir.
For convenience, this type of heat engine, which, (apart from the working fluid), requires no moving mechanical parts, will be referred to as a 'Bernoulli heat engine'.
In its basic reversible form, this heat engine is trivial, because there is no output of work. But, if it does work ***W*** on another body, for example, ripping apart the Ferrybridge cooling towers, then it becomes irreversible.

If external work ***W*** is done at **B,** then, in accordance with Newton's laws of motion, the bulk movement of the molecules will tend to fall. But this slowing down has to be reversed by restoring the speed to ***nV*** (for an incompressible fluid), to prevent the molecules piling up at **B**. Steady flow can be maintained by doing work on the fluid at **C** (for example), by restoring the speed to ***V***. Importantly, kinetic energy changes with speed squared. So, in restoring the speed to ***V*** at **C**, it is only necessary to do an amount of work $\boldsymbol{W}/\mathbf{n}^2$ on the fluid.
The net external work done between **A** and just after **C**, is $\boldsymbol{W}(1 - 1/\mathbf{n}^2)$. This is done at the cost of the internal energy at **C** being lower than at **A**. Consequently the temperature at **C** is lower than at **A**.
In the case of the Ferrybridge cooling towers, the restoring work would have been done on the wind by a jet pump effect involving adjacent sections of the wind front, at a distance from the towers. This explanation is analogous to the jet pump effect behind the derivation of Betz's Law for wind turbines.
For manufactured Bernoulli heat engines, the restorative work could be done (for example) by inserting a fluid accelerating fan at **C**.

The equivalent of Bernoulli's equation that describes the *irreversible* form of this heat engine could be stated as,
'For unit volume of incompressible fluid in steady flow
Internal Energy + Kinetic Energy + Potential Energy+ + Net Work done = Constant EQUATION 1

Equation 1 tells us that if the potential and kinetic energies are restored to their original values along a streamline, after the fluid has done net work, the internal energy of the fluid must fall.

Some twenty years later Courtney used this equation as the inspiration for his power generating refrigerator. According to the design, the refrigerant fluid is forced to travel along converging streamlines so that its kinetic energy increases. The fluid then does work, spinning a generator armature, causing the internal energy to irreversibly fall. This design is discussed briefly in Section 6 below.
For dry air, atmospheric or manufactured Bernoulli heat engines would be equally efficient, running in the midday heat of the Sahara Desert, or the midwinter cold of Siberia.
Using different gases, the temperature independence of this type of heat engine would also hold true in the far colder atmospheres of the outer planets.

5 A Bernoulli heat pump

The internal energy can also be changed without doing external work if the Bernoulli heat engine operates as a heat pump.
For our illustrative example, this requires the removal of the insulation from around the conduit so that heat can flow through the walls. In the following diagram the compressibility of air is taken into account because it warms when it is lightly compressed by the fan.

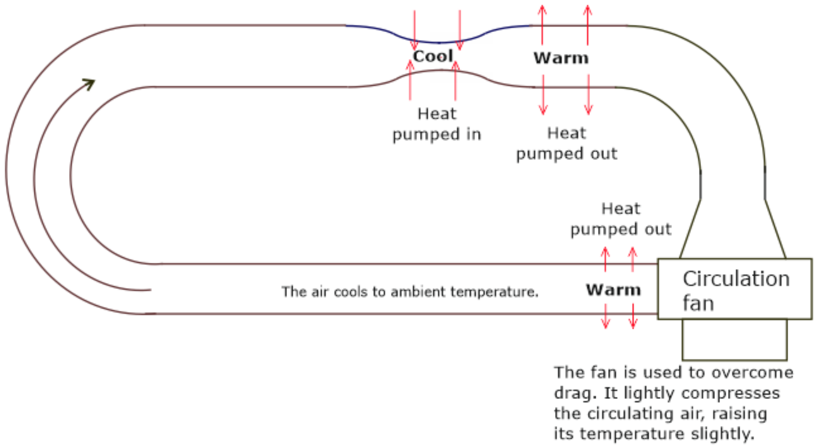

Figure 8. The streamlines need to be bounded by conducting metal walls, to allow the two ways pumping of heat.

The temperature changes are localised and quite modest. But, as explained in section 10 below, they can be used in the construction of a cool running heat engine.
The Bernoulli heat pump is counter-intuitive in a manner analogue to existing indoor space warming heat pumps. In both cases, a superficial inspection suggests they are defying the second law of thermodynamics by pumping heat from cold to hot. But closer inspection tells a different story because in both cases, the working fluid has to be pre-cooled below ambient, so that it can absorb heat.

6 A phase change Bernoulli heat engine

We know from the Ferrybridge study that at least some atmospheric heat engines will be Bernoulli heat engines. But, if they include water vapour that condenses out or water droplets that evaporate, the latent heat released or absorbed will have to be allowed for.
The following diagram predicts how the static pressure should change inside an insulated phase change Bernoulli heat engine.

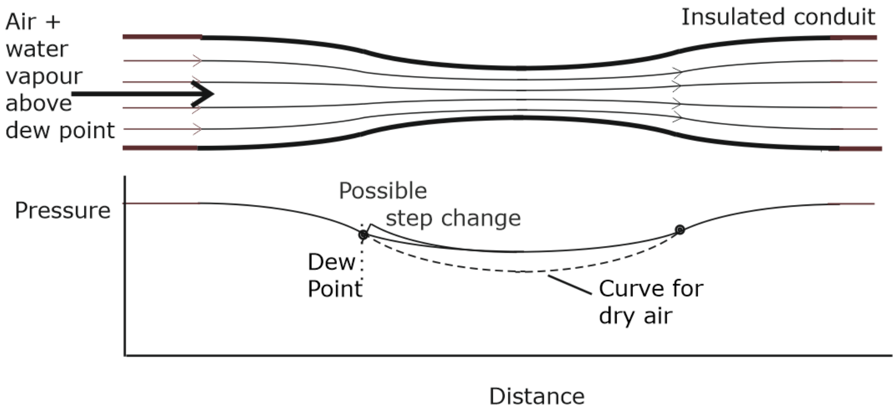

Figure 9. Below the dew point, a water droplet aerosol condenses out and latent heat is released. This heat reduces the temperature and pressure drops compared with the flow of dry air under similar conditions. If the vapour becomes super-cooled before releasing its latent heat, a pressure spike is predicted. On passing through the diverging section, the latent heat processes are reversed, with heat being absorbed as the water droplets evaporate.

In order to produce a version of Bernoulli's equation that allows for the release of latent heat, an additional term $\mathbf{dQ_L /dV}$ needs to be added. The term $\mathbf{dQ_L /dV}$ represents the latent heat lost/gained per unit volume of static fluid. Thus, the generalised form of Bernoulli's equation is

$$p + \tfrac{1}{2}\rho v^2 + \rho g h - dQ_L /dV = \text{A constant}$$

Volume is used as part of the correction term, to ensure dimensional consistency. To be of any practical use over a range of temperatures, the $\mathbf{dQ_L /dV}$ term would require elaboration, to take into account the variation of latent heat with temperature.

When condensation occurs and latent heat is liberated, the minus sign is retained in front of the latent heat term. A positive sign is used if evaporation occurs and latent heat is absorbed. The assumption that the fluid is incompressible becomes even more of an approximation for the phase change version of the equation because liquids have a far higher density than vapours. However, predictive accuracy is not an important issue because the simple form of the phase change equation was never intended for use as a tool for engineers.

Courtney first stated this equation as an undergraduate student in 1965. His aim was to identify a testable hypothesis that was less controversial than the concept of a manufactured cool running heat engine. He hoped to be able to test the hypothesis as a post-graduate PhD student.

Unfortunately, the skill set which led to his investigations into doublethink heat engine science was also his undoing. He was dyslexic, making conventional study difficult and his tendency to pursue whatever line of inquiry took his fancy led to him drifting far away from the examined curriculum. As a consequence, he only gained a lower second class honours degree in Applied Physics and failed to win a place as a Ph.D student.

Until the 1980s, Courtney's attempts to expose doublethink science were low key because of the ridicule that they generated. But by 1986, four problems and an opportunity galvanised him into action. The four problems were global warming, acid rain, the depletion of the Earth's ozone layer and the need for a new type of portable, mains free refrigerator, for storing vaccines in remote parts of the developing world. The opportunity was the need for a new type of refrigerator that could cool the newly discovered 'high temperature' superconductors to around the temperature of liquid nitrogen. Courtney responded by designing a power generating refrigerator based on the Bernoulli heat engine concept as summarised in equation 1 in Section 4 above.
This design is published on Courtney's website and is now out of patent, meaning that anyone is free to develop it without seeking his permission [11]. The invention of a new class of COVID-19 and other messenger RNA based vaccines that require storage at cryogenic temperatures would create a market for this type of refrigerator and probably attract research funding.

7 Employing the Bernoulli heat engine concept to improve crash protection

During the years 1965 to 1985 Courtney made many attempts to interest academic and industrial engineers in the concept of a cool running heat engine. Their responses ranged from ridicule to anger because of the entrenched belief that all efficient heat engines must run hot.

So, from 1986 onwards he tried a different approach, employing the Bernoulli heat engine principle in an entirely different field of engineering. His aim was to develop a non-controversial 'cash cow' invention based on what he had learned about Bernoulli heat engines. Then, use royalties generated by licensing the cash cow to finance research into cool running heat engines.
The invention that emerged was named **S**hock **A**bsorbing **Li**quid (**SALi**). This was a novel form of crash protection technology based on a miniaturised version of the Ferrybridge power station cooling tower array. SALi is referred to as a 'technology' because of the many different ways the SALi concept can be employed [12].

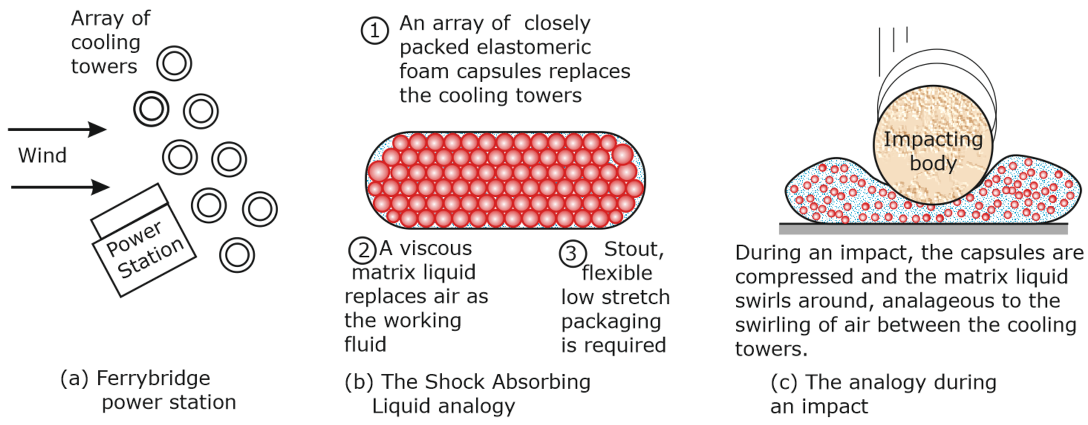

Figure10. Understanding the Ferrybridge incident as a Bernoulli heat engine phenomenon provided the inspiration for the invention of **S**hock **A**bsorbing **Li**quid (**SALi**).

Both versions of the Bernoulli heat engine have the facility to store potential energy, but they do so in different ways. In atmospheric Bernoulli heat engines, potential energy increases as masses of moving air rise against gravity. In SALi filled bags, the elastomeric foam capsules store potential energy when they suffer bulk compression during an impact.
To a first approximation, the hydraulic pressure exerted by the liquid is transmitted uniformly and work is done as the fluid compresses the capsules. The matrix liquid also swirls round them in a manner analageous to the swirling air movements that destroyed the Ferrybridge cooling towers. However, unlike the Ferrybridge incident, the geometry of the capsules is in a state of rapid change throughout the impact. The adjacent layers of viscous liquid shearing over each other permanently convert the kinetic energy of the swirling liquid into internal energy. So the many hundreds of miniature Bernoulli heat engines work irreversibly and the impact is highly damped. This is a two way heat engine system because the bag recovers its shape after the impacting body has been removed.
In order to minimise the weight of liquid involved, nested sets of elastomeric capsules are employed. Typically, the largest capsules are expanded polystyrene beads several millimetres in diameter, with sub-millimetre capsules residing in the voids between them. This void nesting can include a range of smaller sized capsules, with the smallest capsules being nanoparticles. In order to maximise the swirling and resultant damping, the compressive stiffness of each decreasing size of capsule needs to increase. If the nano are effectively rigid, the SALi composite fluid offers shear thickening properties [12].
In order to ensure effective hydraulic pressure transmission during an impact, low stretch packaging is essential. If the packaging stretches, the capsules suffer minimal compression and viscous damping is minimised.
From 1986 onwards, Courtney lived frugally for ten years and by 1996 he had sufficient savings to enrol at University A, as a mature 50 year old engineering student. When the commercial arm of the university became interested in the commercial potential of SALi, he happily allowed it to take legal control of the marketing rights for SALi and also take 50% of the royalties generated by future commercial applications of the invention.
In the years 1996 -2004, SALi was tested at several different institutions and shown to have excellent, impact, vibration and blast mitigation properties [12]. Research at Nanjing University in China also demonstrated that it had excellent potential for use as a new type of car suspension [13]. Over a period of years, this resulted in Courtney writing nine SALi patent applications, including four on behalf of University A.

In the mid-1990s, the European Commission introduced draft legislation that would oblige automobile manufacturers to fit soft pedestrian friendly front car bumpers. But this caused a heated debate between the Commission and the manufacturers, because their customers preferred stiff bumpers that protected vehicle bodywork during low speed crashes. The Dow Chemical Company (Automobile Division) were aware of the development of SALi at University A and recognised that bags of SALi inside a thin walled car bumper would have smart properties that could keep both the EU Commission and the car makers happy. Dow's optimism was supported by papers published by Courtney and his university A supervisor [14, 15], and also independently by Davies at Cardiff University [16]. Essentially these papers reported that when a simulated human tibia (shin bone) impacted on a 100 mm wide SALi filled bag, the braking forces were low and the bag acted as a soft cushion. But wider impacting bodies such as other car bumpers generated far larger braking forces and the bag acted as a stiff cushion.

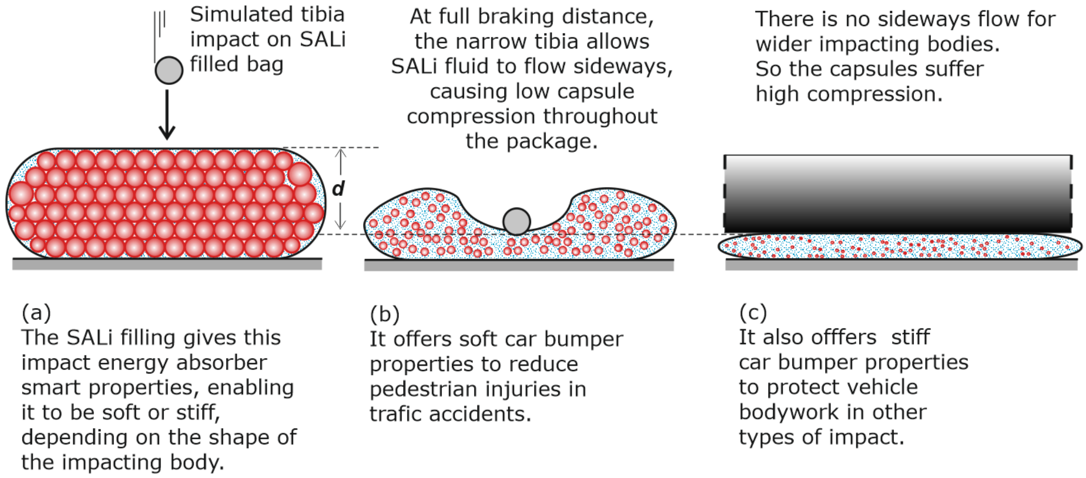

Figure 11. A low stretch SALi filled bag offers smart impact cushioning properties, being soft for lower leg impacts, but stiff for impacts with wider objects. This difference emerges because, for the same braking distance, ***d***, the capsules are only slightly compressed during a tibia impact, but highly compressed during an impact with a wider body.

A collaboration involving Dow Automotive, Courtney and University A received UK government funding to develop the smart car bumper concept. It was known as the PedSALi project and is referred to in the UK parliamentary records, Hansard [17].

Unfortunately, Courtney's research supervisor at University A was unhappy about being overshadowed by his student. He became disruptive at commercialisation meetings and was eventually banned from them. He responded by creating false evidence which suggested that SALi filled bumpers were ineffective. For example, he breached confidentiality by presenting two misleading conference papers in America where tests were described using elastic packaging, thus rendering the SALi ineffective [18, 19]. This behaviour le to the collapse of the PedSALi project and then eventually, to all SALi research [20]. There was no alternative car bumper design that would keep both the EU Commission and the car makers happy. So the Commission eventually gave in to pressure from the car makers and the EU pedestrian friendly car bumper requirement was abandoned.

This sabotage of Courtney's smart bumper design may have cost many thousands of European pedestrians either their lives or at least the use of their lower limbs. The research fraud also destroyed his cool heat engine financing plans. The international humanitarian consequences of this academic misbehaviour meant that it became too big to expose. Consequently it has been covered up at a national level. The most surprising collaborator in this cover-up is the United Kingdom Research Integrity Office (UKRIO) [21].

The academic misbehaviour involving University A and the UK Research Integrity Office has been written up as two journal papers [23, 24], with very comprehensive supporting evidence being published online [21]. The first paper provides details of the cover-up and the second makes recommendations for avoiding similar abuses of research funding in the future.

By 2006, Courtney's whistleblower activities had damaged his health and he became partially sighted [22]. As a consequence he had to give up experimental work.

When the UK House of Commons Science and Technology Committee decided to hold an enquiry into research integrity in British science in 2018, Courtney applied to appear as a witness. He also

submitted copies of both of his papers to demonstrate his insider knowledge as a victim of research fraud. But the Committee refused his request to appear before them and declined to cite his papers in their final report [25].
Copies of Courtney's correspondence with the Committee are published online [21].

8 The campaign to expose doublethink heat engine science

In 2006 a chartered engineer, Richard West agreed to work with Courtney and act as his eyes in a campaign promoting cool running heat engines.
This is a summary of their fourteen year campaign.
They:

(i) Made numerous live presentations in all four countries of the United Kingdom.

(ii) Held face-to-face, telephone and email discussions with potential partners on all five inhabited continents plus others on large islands from Greenland in the north, to Tasmania in the south.

(iii) Presented the concept at public events including those organised by Shell Springboard, Innovate UK, Energy Catalyst and the Knowledge Transfer Network (KTN).

(iv) Made webinar pitches to companies and universities in China, Brazil and Malaysia.

(v) Contacted editors and journalists with science, business and environmental interests.

(vi) Requested help from green energy innovation hubs including The Tyndall Centre, The Carbon War Room, The Carbon Trust and The Centre for Alternative Technology.

(vii) Telephoned and/or emailed over a hundred charities and environmental pressure groups worldwide, including The Sierra Club, Greenpeace, Friends of the Earth and Extinction Rebellion.

(viii) Held face to face, telephone and email discussions with local and national politicians from all of the UK wide political parties, apart from those who operate on the fringes of the law. In particular, they supplied information and lobbied councils, prior to them holding Climate Emergency debates.

(ix) Wrote to celebrities who boasted of a commitment to fighting climate change.

(x) Submitted details of their proposals for consideration by the UK Citizens Assembly on Climate Change.

(xi) Co-wrote a Short Letter to the science journal Nature with a professor at Hull University, where the doublethink science problem had been identified 50 years earlier [26]. It was rejected.

(xii) Published details of cool running heat engines on the Cheshire Innovation website [27] which receives approximately 350 visitors per day.

With the possible exception of three people, engineers and scientists worldwide have treated the cool heat engine concept as irrelevant, unworkable or foolish. To quote one of them, "I can't spot the flaw in your argument, but my guts tell me that you are wrong. And I trust my guts".

9 The Mk 1 Latent Power Turbine

In 2009 West and Courtney obtained partial funding from the UK Technology Strategy Board (subsequently rebranded as Innovate UK) for a strictly limited one year's worth of research at a British university [28]. But there was a problem; none of the universities they approached was interested in a project that challenged conventional heat engine theory. They eventually got round this with University B by commissioning four progressive bench top experiments, with the challenges to conventional thinking gradually increasing with each experiment.
The first experiment was designed to test for a phase change correction to Bernoulli's equation as illustrated in Figure 8 above. This would be followed by an experiment to simulate energy extraction from a tropical hurricane. Then, the last two experiments would verify cool running heat engine designs that could be scaled up for commercial electricity production.
This was the planned sequence for bench top experiments two, three and four.

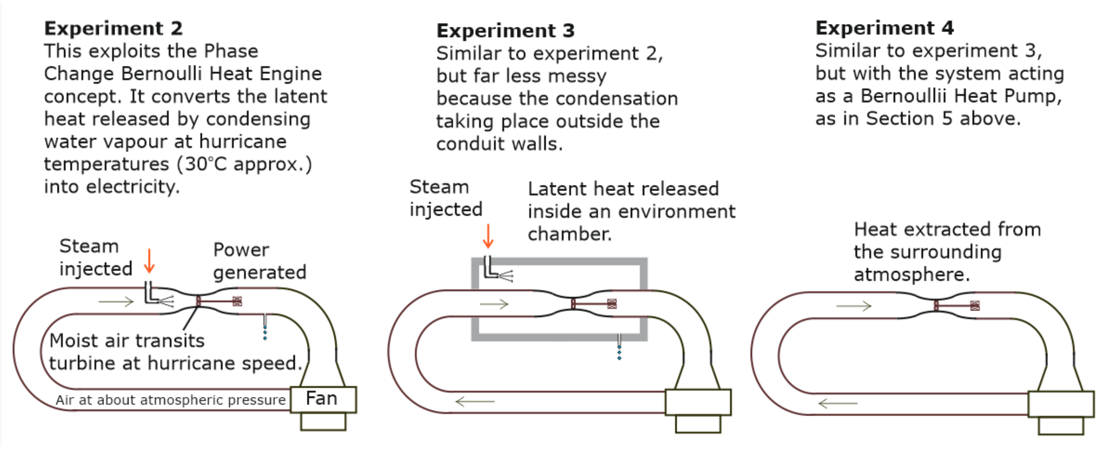

Figure 12. In this series of three experiments, a plausible proposal for extracting thermal energy from a simulated tropical hurricane evolves into a more contentious proposal for running a heat engine on thermal energy extracted from the atmosphere.

There was a technician shortage at University B and no technician was appointed for the project. More seriously, eight months into the allocated one year, the research assistant had still not produced technical drawings for the test rig. Complaints fell on the deaf ears of her line manager who was initially busy organising his three month retirement cruise, and then went away, cruising.
Courtney had been legally registered as partially sighted for four years [22] and it took him four hours by public transport to reach University B. All his visits to review progress had to be booked in advance because, for health and safety reasons, he was barred from entering the university engineering laboratory without an escort. Consequently, given the management indifference, it took several months to establish firm evidence of the research assistant's absences. Matters were not helped because Courtney's role as a whistleblower at University A was well known and he was labelled as a troublemaker who was disloyal to the university research establishment. With only a few weeks of contract time left, the post-doctorate research assistant was replaced by an undergraduate student, who could only work a few hours per week because he was also busy studying for his finals. To their great credit, the student and an overworked technician managed to build a very basic Mk 1 Latent Power Turbine in a few days. But it was all far too late.

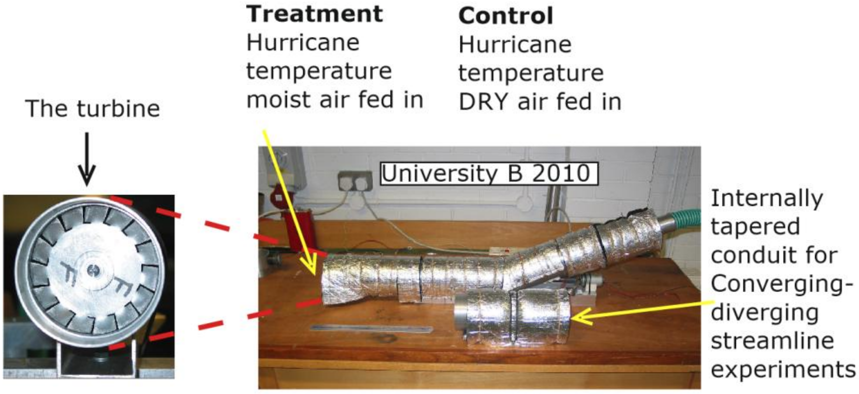

Figure 13. The key components the Mk 1 Latent Power Turbine.

Very basic results for the experiments 1 and 2 were obtained; sufficient to confirm that the Bernoulli Heat Engine theory was valid, but insufficient for journal publication [29].
The poor conduct at University B set the heat engine work back by at least another three years.

10 The Mk 2 Latent Power Turbine [30]

After another three years the partners persuaded Innovate UK to part fund a project that built on the very limited results from University B. Again, the conditions of the grant required the work to be completed within a year. It was decided to move straight to experiment 4, as illustrated in Figure 12 and build the rig on a far larger scale so that a usable output of power could be generated. In order to

sidestep academic scepticism, the rig was built and the testing done by a private research company, C-Tech Innovation Ltd [31].
Here are the key features of the test rig.

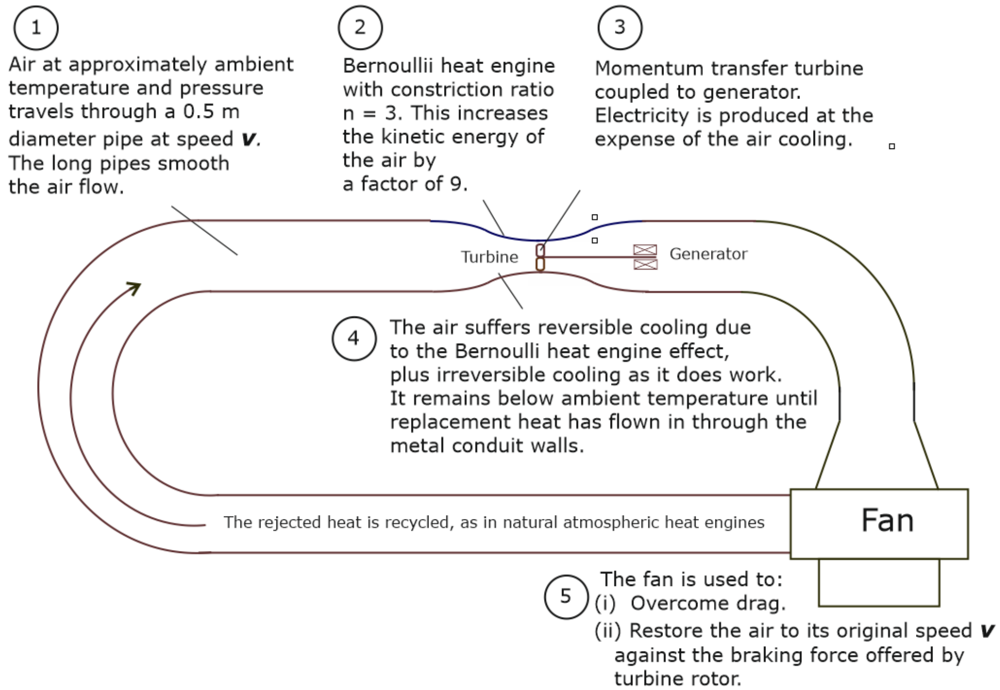

Figure 14. The MK 2 Latent Power (LP) Turbine test rig.

This rig is essentially a heat pump as illustrated in Figure 7 above, with a turbo-generator type heat engine inserted into the throat of the converging-diverging section.
The moving air enters the turbine at a temperature below ambient, and leaves at an even lower temperature. In principle, a commercial version of the Latent Power Turbine could extract heat from the atmosphere and convert it into electricity anywhere on the planet. However, because the exposed parts of the conduit are below ambient temperature, icing up is likely in cool damp weather. This problem has already been solved for heat pump based space heating systems by alternating short defrosting and longer heat extraction phases. An equivalent solution for LP Turbines is discussed on the Cheshire Innovation website [27].
The natural tendency of the moving air is to slow down when it transfers momentum to the turbine blades. But this does not happen because the fan does work maintaining the rate of mass flow **dm/dt**. Assuming that the working air acts as an incompressible fluid, its kinetic energy per unit time on exiting the turbine needs to be restored to ½ x **dm/dt** x $(\mathbf{nv})^2$. But in the wider section of the conduit, the kinetic energy only needs to be restored to ½ x **dm/dt** x $\mathbf{v}^2$. In the steady state, the balance of ½ **x** **dm/dt** x $(\mathbf{n}^2\mathbf{-1})\mathbf{v}^2$ is drawn in from the environment as heat.
So, under ideal conditions, where there are no drag losses, the net power output $\mathbf{P_o}$ is related to the power input to the fan, $\mathbf{P_i}$ by

$$\mathbf{P_o = P_i(n^2-1)}$$

On transiting the turbine, only a small fraction of the internal energy of the working air is converted to work. Consequently, the Carnot efficiency of the internal turbo-generator type heat engine is very low, of the order of 2%. But, because the rejected internal energy is being recycled for as long as the unit is running, the overall efficiency of conversion of internal energy into electricity tends towards 100%.

11 The turbine rotor problem

C-Tech Innovation freely admitted that they did not have the specialist skills to design a bespoke turbine rotor. So this work was subcontracted to University C.
Unfortunately, the research focus at University C was wind turbine design and their research engineers were not convinced that a cool running heat engine that operated in the manner of a gas turbine was possible. So, instead of producing a turbine rotor design that employed the momentum transfer

principles of gas turbines, they delivered a blade design based on aerodynamic lift, as used for wind turbines.
However, as Figure 15 explains, a turbine that relies on aerodynamic lift is unable to fully exploit the increase in kinetic energy produced by a Bernoulli heat engine.

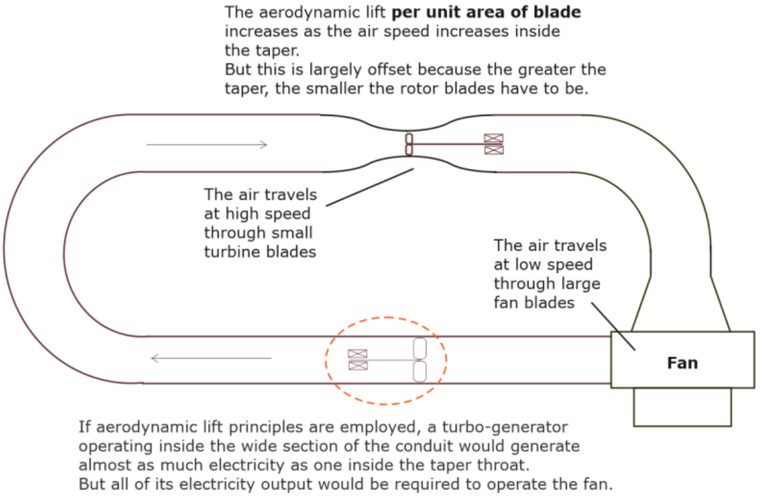

Figure 15. The turbine rotor designed by University C was unable to exploit the increase in kinetic energy produced by the Bernoulli heat engine.

The project was time limited to one year by the funding body. So a decision was made to go ahead with the construction of the shell of the test rig, in the hope of finding additional funding and an alternative turbine blade designer at a later date.
Courtney already had a reputation as a whistleblower and was worried about the consequences of entering into yet another dispute with a university. So he paid University C for its work, even though their design was never used.

Figure 16. C-Tech Innovation constructed the test rig to the best of their ability, but it was handicapped by the lack of a bespoke turbine rotor.

After the shell of the test rig had been constructed, a makeshift turbine rotor consisting of a set of air cooling fan blades was installed. This arrangement was used to verify that the air speed, pressure and temperature varied around the loop in line with expectations. However, desktop fan blades cannot cope with high speed air approaching them because air deflected by the front face of each rotating blade clips the rear face of the following blade. Consequently the turbine blades produced a lot of resistance, vibrations and turbulence, resulting in a failure to collect meaningful efficiency results [32].

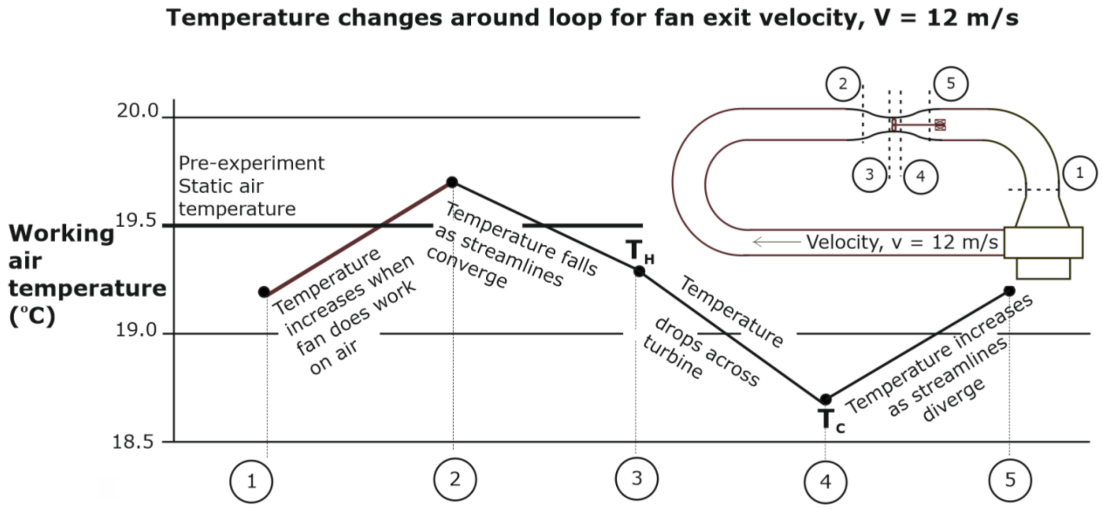

Figure 17. The temperature rose and fell around the loop in line with predictions. The turbo-generator type heat engine also broke with conventional practice, by running at a lower temperature than the ambient atmosphere. The rig had been designed with the intention of delivering a power output of 4 kW, but the vibrating makeshift turbine rotor problems reduced the maximum power output to 300 Watts.

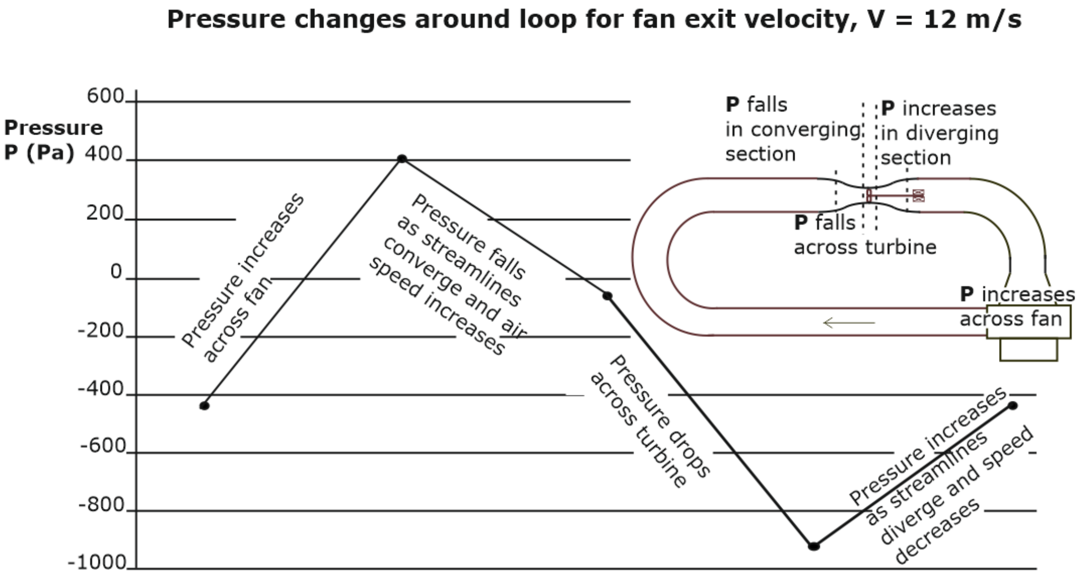

Figure 18. The pressure also rose and fell around the loop in line with predictions.

A constriction ratio of **n** = 3 was used. In pre-tests, without the turbine present, a fan exit speed of 20 m/s produced a throat sped of 60 m/s. But when the turbine was introduced into the throat, the air speed in the wider conduit fell to 12 m/s and all the pressure readings became noisy. The rotor also vibrated violently. Consequently it was impossible to verify the formula $\mathbf{P_o = P_i(n^2-1)}$ which relates the fan input power $\mathbf{P_i}$ to the net power output from the generator $\mathbf{P_o}$. Nevertheless, the temperature and pressure results verified that the basic theory was valid.
The following diagram shows the planed rig improvements for the final stage of the project.

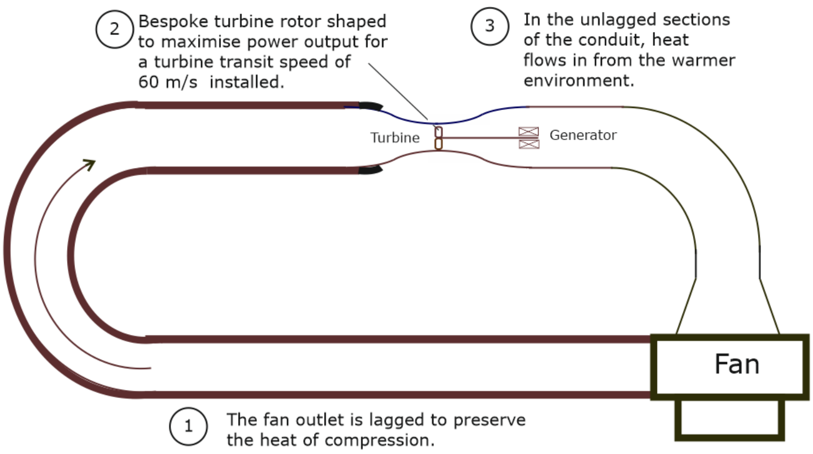

Figure 19. Latent Power Turbines naturally run at a lower temperature than their environment. They draw in heat to offset the net output of electricity, so are true heat engines.

The temperature of the working air entering the turbine falls on each successive transit until a state of dynamic equilibrium is reached, with the rate of heat flow though the conduit walls being equal to the net power generated, $\mathbf{P_i(n^2\text{-}1)}$. Thus an LP Turbine is a genuine heat engine, because it relies on heat flowing from the warmer environment to restore the internal energy level of the circulating air. The Carnot efficiency of the turbo-generator can be calculated using the equation $\eta = 1 - \mathbf{T_C/T_H}$. Inserting the values of $\mathbf{T_C}$ and $\mathbf{T_H}$ from Figure 14A gives us η = 0.24%, with this predicted to increase to around 2%, with a bespoke turbine rotor fitted. This low efficiency is not a problem because the internal energy in the ejected air is recycled indefinitely instead of being dumped into the environment. In addition, any internal waste heat generated by drag or electrical resistance cannot leak into the warmer environment and is recycled.
Thus LP Turbines obeys similar informal rules to the atmospheric heat engines discussed in Section 2 above. They employ air at around atmospheric pressure and temperature, and have a similar high level of thermal efficiency.
The Gdansk Engineering Institute in Poland offered to design a bespoke turbine to complete the project. So submissions for additional funding, to pay for the work were made to Innovate UK and other British funding bodies. But all of them were rejected.
Courtney also continued with his calls for the UK Research Integrity Office (UKRIO) to investigate its collaboration with University A in hiding the research fraud which had cost him his £140,000 SALi research investment [21]. His hope was that a fair settlement with University A would provide at least this amount. This would pay for the Gdansk Institute’s work and the completion of the project.

Unfortunately his appeals have been ignored, because, the UKRIO appears to be more interested in protecting its reputation, than in fighting climate change or protecting the integrity of British science. For example, during the last year, Courtney has been in email communication with the current chairman of the UKRIO [33] on four occasions, calling for an investigation into the UKRIO’s role in hiding research fraud. In these communications, the chairman was reminded that this cover-up is holding back the fight against climate change. So far, the chairman’s mailbox has sent out automated acknowledgements, but otherwise he has remained silent. These communications can be verified using the UK Freedom of Information Act.
Shortly after the test rig was built, a referendum was held in the United Kingdom, in which there was a majority vote in favour of leaving the European Union. This decision delivered the terminal blow for the project.
British companies were effectively cut off from EU Framework funding and the long term future for British engineering businesses became uncertain. The quest to find partners and investors continued for four years after the referendum, but was abandoned in 2020.

Conclusion
The fossil fuel powered modern world that we live in was not inevitable because the cool running heat engines described in this paper could have been built at least as early as 1896, when Tesla invented his power generator. In addition to producing cheap clean electricity, they could have been used for hydrogen production by the electrolysis of water. Thus make a hydrogen based economy possible.

Courtney first realised that doublethink science was handicapping the development of clean efficient heat engines in 1965. His early vision had been that by learning from nature, a clean power revolution was possible. And that this would echo the first industrial revolution, by being launched in Britain. But, by 2020, he had reluctantly come to the conclusion that his native country had acquired a hubristic science culture that preferred maintaining the status quo and hiding research fraud to defending the integrity of science.
Britain lost at least four opportunities to lead the clean energy revolution, all thanks to short term, self interest thinking. Two opportunities were lost due to academic misbehaviour at Universities A and B. The third was lost when the UK Research Integrity Office failed to live up to its name. Then finally, with project success in sight, all was lost, as an unintended outcome of the Brexit referendum.

Meanwhile, global temperatures have increased faster than at any other time in human history.

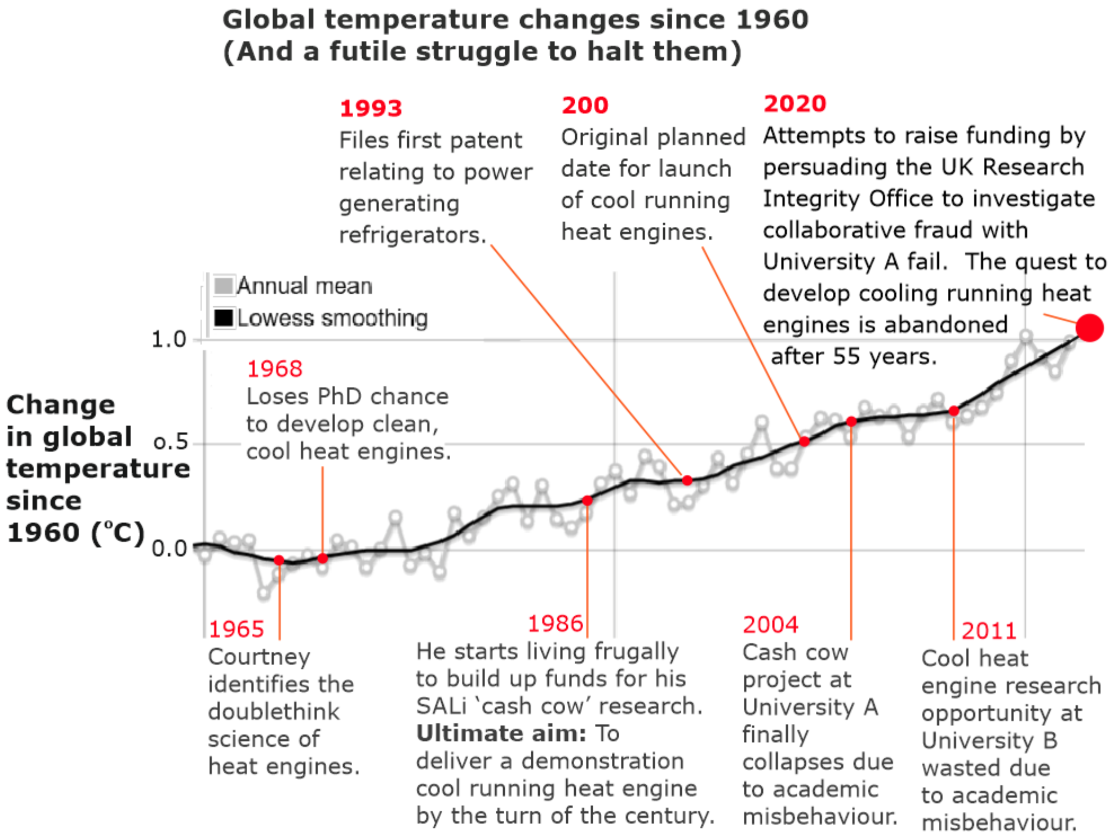

Figure 20. The temperature data for this graph is taken from the NASA Global Climate Change website [34].

West and Courtney would up their company Latent Power Turbines Ltd in 2020, gave away their Mk 2 Latent Power Turbine test rig and abandoned their intellectual property portfolio.
Engineers, academics, businesses and inventors are now welcome to freely exploit this intellectual property.
A wide range of suggestions for doing so are published on the Cheshire Innovation website [26].

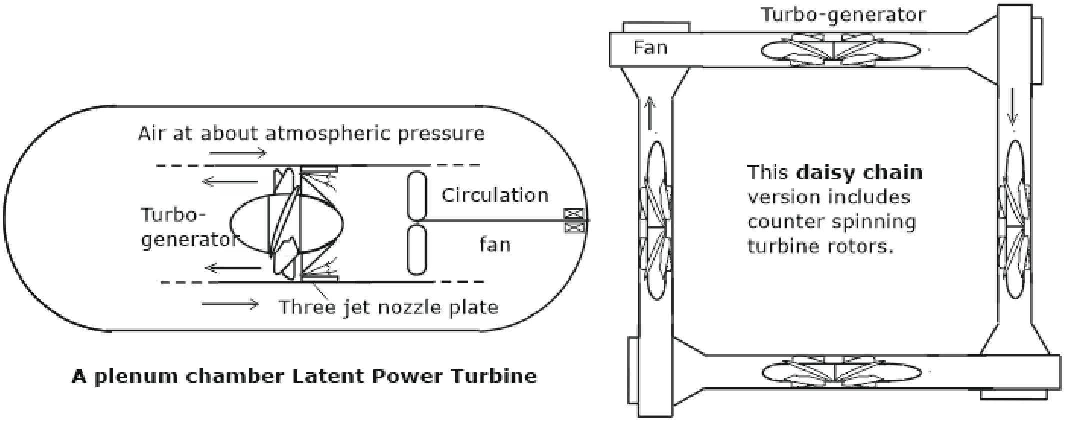

Figure 21. Two examples of possible mass production power generator designs.

Standard gauge automobile bodywork steel can be used for the shell because the thermal conductivity of the walls is not critical. Using steel instead of say copper, simply forces the internal air to circulate at a slightly lower temperature, which is probably beneficial.

Hopefully, Latent Power Turbines will be developed in the next few years as an open source project. Installed units will operate for many years, provided that they are regularly serviced and there are no fuel costs involved. In addition to fighting climate change, they could play an important role in rebuilding the world economy in the aftermath of the COVID-19 pandemic.

A failure of integrity in British science has held up the development of cool running heat engines by at least 20 years and counting. But, Courtney is not a defeatist and believes that British science has the inner strength needed for integrity reform. His own suggestions for reform have been published as a journal paper [24.]

References

1 Zemansky, M. *Heat and Thermodynamics4th ed*., McGraw-Hill Book Company Inc, New York, 1957. P157.

2 Cengel et al. *Thermodynamics-An Engineering Approach*, *9th ed*., McGraw-Hill Book Company Inc, New York 2019, p 297.

3 Muncaster, R. *A Level Physics, 2nd* ed, Stanley Thornes, Cheltenham 1985, p 151.

4 Noakes, G. R. *New Intermediate Physics, 5th ed*., Macmillan, London, 1970, p 132.

5 Starling, S. G. and Woodall A. J. *Physics, 2nd ed.*, Longmans, London, 1957, p 97.

6 Newman, F. H. And Searle, V. H. *The General Properties of Matter, 5th ed*., Edward Arnold, London, p 363.

7 *Ferrybridge 1, November 1965, Collapse of cooling towers in a gale*. https://rmets.onlinelibrary.wiley.com/doi/abs/10.1002/j.1477-8696.1967.tb02927.x

8 Shellard, H. G. (1967). *Collapse of cooling towers in a gale, Ferrybridge 1, November 1965,* RMetS Weather, Volume 2, Issue 6, June 1967, p232-240.

9 *What is pressure Energy?* https://physics.stackexchange.com/questions/216342/what-is-pressure-energy

10 *Bernoulli's principle.* https://en.wikipedia.org/wiki/Bernoulli%27s_principle

11 Courtney, W. *Clean, low-running-cost-refrigerators*, http://www.cheshire-innovation.com/other-innovations/more-innovations-for-a-green-environment/clean,-low-running-cost-refrigerators.html

12 Courtney, W. *What is Shock Absorbing Liquid*, http://www.cheshire-innovation.com/shock-adsorbing-liquid-sali/what-is-shock-absorbing-liquid,-sali-technology.html.

13 Teng, H.D. and Chen, Q. Study on vibration isolation properties of solid and liquid mixture. *Journal of Sound and Vibration* **326** (2009) 137–149.

14 Courtney W. A. & Oyadiji S O (2001). *Preliminary investigations into the mechanical properties of a novel shock absorbing elastomeric composite*. Journal of Materials Processing Technology **119** (2001) 379-386.

15 Courtney W A. and Oyadiji S O. *Characteristics and potential applications of a novel shock absorbing elastomeric composite for enhanced crashworthiness*. International Journal of Crashworthiness **5:4** (2000) 469-490.

16 Davies, H. et al. (Cardiff University School of Engineering).Pedestrian protection using a shock absorbing liquid (SALi) based bumper system (paper no 09-002). *ESV Conference, Stuttgart*, June 2009.

17 *House of Commons written answers: Car safety* [http://www.publications.parliament.uk/pa/cm200102/cmhansrd/vo011025/text/11025w18.htm] (25 October 2001).

18 Oyadiji, S.O. et. al. (University of Manchester). Characteristics of deformable cylindrical beams filled with a shock absorbing composite. *SAVIAC 75th Symposium*, 17–22 October 2004, Virginia Beach, Virginia.

19 Georgiades, G. et. al. (University of Manchester). Impact response of flexible cylindrical tubes filled with a shock absorbing composite. *SPIE Conference*, 7–10 March 2005, Sam Diego,

20 Courtney, W. *The CrashSALi Project* http://www.cheshire-innovation.com/shock-adsorbing-liquid-sali/crashsali-project.html

21 Courtney, W. *Why the UK Research Integrity Office needs reform*., http://www.cheshire-innovation.com/shock-adsorbing-liquid-sali/why-the-uk-research-integrity-office-needs-reform.html

22 Trafford Social Services, *Certification of Partial Sight*. Registration No. 10039942, 15 June 2006.

23 Courtney, W. *A private researcher's struggles against research fraud***. I.** *A case study*, Journal of Biological Physics and Chemistry **16** (2016) 142–156

24 Courtney, W. *A private researcher's struggles against research fraud.* ***II****. Suggestions for reducing the fraud problem* Journal of Biological Physics and Chemistry **17** (2017)

25 The Parliamentary Inquiry into research integrity, July 2018

26 Courtney. W, et. al., *A heat engine inside a mechanical engine*. Submitted to Nature 20 September 2017 (rejected without peer review.)

27 Courtney, W.A. *Latent Power Turbines*, http://www.cheshire-innovation.com.

28 Technology Strategy Board. *Latent Power Turbine: Proof-of-concept experiments*, TSB Project Number: 130037 (2010)

29 Courtney, W. and West, R., *Project Report for the Technology Strategy Board, Project Number: 130037*, March 2011.

30 Courtney, W.A. *A heat engine inside a mechanical engine*, Patent Application GB 1418029.3., Filing date 12 October 2014.

31 C-Tech Innovation. http://www.ctechinnovation.com

32 Innovate UK (TSB). *Power generation and cooling using LP Turbines*, Project. File number 131512, October 2013.

33 Professor Sir Ian Boyd. ilb@st-andrews.ac.uk.

34 NASA. *Global Climate Change*. https://climate.nasa.gov/vital-signs/global-temperature/