JOULE'S THERMOSCOPE AND THE SECOND LAW OF THERMODYNAMICS

Summary

This paper describes an instrument devised by Joule in 1863 to detect the energy of moonlight. It is extraordinarily sensitive to heat and must convert heat into mechanical energy with high efficiency. But since the temperature rise caused by moonlight is only 10^{-4}°F, the Carnot theorem would give a maximum efficiency of 10^{-6}.

JOULE'S THERMOSCOPE SHOWS THAT THE CARNOT EFFICIENCY LIMIT, THE MOST COMMON EXPRESSION OF THE SECOND LAW OF THERMODYNAMICS, IS WRONG

The thermoscope uses convection currents and involves an energy cycle at constant volume. These features form the basis of proposals I have made for the efficient conversion of solar energy into electricity that were placed on my website in March 2002, September 2002 and March 2003. Indeed Joule's thermoscope is identical to Figure 3 in the latter Simple Solar Engine. It is my view that heat from fossil fuels or from solar energy can be converted into mechanical energy or electricity with an efficiency of up to 100% using energy cycles at constant volume.

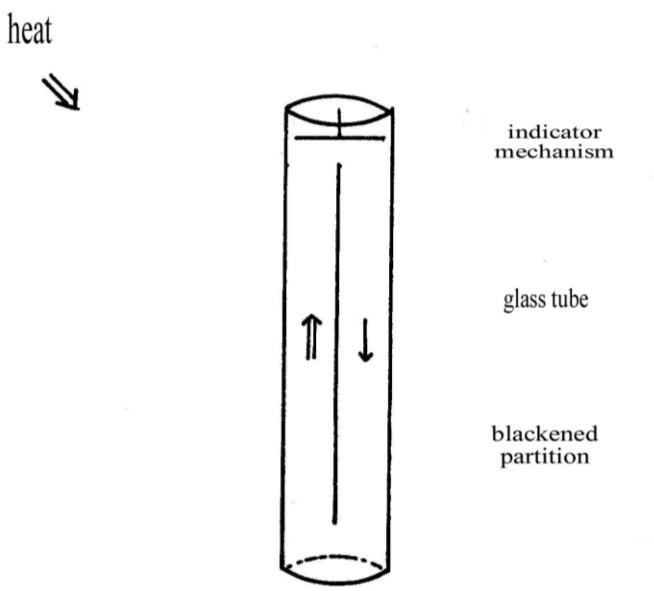
I would be very grateful for any comments. [E-mail address: williams.a(AT)globalwarmingsolutions.co.uk]

Joule's Thermoscope and the Second Law of Thermodynamics

In 1863 James Joule devised an instrument to detect the energy of moonlight[1, 2]. It was to settle an argument with an adversary John Tyndall over whether the moon was hot or cold. He described the thermoscope as "a sort of wind thermometer"[3].

I am grateful to the Museum of Science and Industry in Manchester for their efforts to track down the instrument but it does not survive nor is there any detailed drawing. The only other references found are in the introduction to a paper on the Convection Mill[4] and in a biography of James Joule[5].

The thermoscope is best described in a letter by Joule to his lifelong friend and colleague, William Thomson[2].



"A glass receiver 2 feet high and four inches in diameter[1] has a cardboard partition so as to divide it into two parts vertically, but leaving a space of 2 inches at the top and at the bottom. The cardboard is blackened and also two thin pieces placed in each side of the partition. It is evident that if one side is heated this least degree more than the other, the air in it will rise, descending in the other as in a bratticed coal pit shaft. The existence of such a current is made manifest by a magnetic needle an eighth of an inch long ----, furnished with a long glass index and hung by a single filament of silk.

"The delicacy of this thermoscope is such that a small blackened pan containing a pint of water heated 30°F placed at 2 yards distance makes the index go through 5°. I have increased the delicacy of the instrument by counteracting the magnetism of this earth, and now by placing it at 2 yards from a shutter with a slit in it and marking the effect of the moon as a beam of its light passes by, I find a distinct effect of about 4° which indicates, as far as I can estimate it at present, that the air on one side of this diaphragm was raised about $\frac{1}{10000}$ of a degree F. I intend to improve on the instrument and make it more useful by the next time we have a full moon."

Comments

The instrument devised by Joule is extraordinarily sensitive to heat – a pint of water heated 30°F placed at 2 yards produces a 5° deflection. The light of a full moon causes a 4° deflection. The energy supplied by the moon is five orders of magnitude less than that supplied by the Sun.

THE THERMOSCOPE MUST COVERT HEAT INTO MECHANICAL ENERGY WITH VERY HIGH EFFICIENCY

But the Carnot theorem tells us that the conversion of heat into mechanical energy has a maximum efficiency of $\Delta T/T$. Joule[1] estimates that "the air in the instrument must have been heated by the moon's rays a few ten thousandths of a degree." The Carnot theorem therefore gives a maximum efficiency of 10^{-6}.

THE CARNOT THEOREM IS WRONG

Over the decades I have always accepted the Clausius and Kelvin-Planck statements of the second law of thermodynamics. But the Carnot theorem which gives the maximum efficiency for conversion of heat into mechanical energy as $\Delta T/T$ has been taken by physicists to be equivalent to the second law of thermodynamics and has acquired the status of a universal law.

Clausius: It is impossible for a cyclical device to transfer heat continuously from a cold body to a hot body without the input of work or other effect on the environment.

Kelvin-Planck: It is impossible for a heat engine that operates in a cycle to convert its heat input completely into work.

The Carnot theorem gives the maximum efficiency that any heat engine could have when operating between temperatures T_H and T_L as $1 - \frac{T_L}{T_H}$ or $\frac{\Delta T}{T_H}$

Clearly the Carnot maximum efficiency does not apply to Joule's thermoscope. I believe it does not apply to Energy Cycles at Constant Volume (See earlier paper on this website – Simple Solar Engine, page 8, March 2003).

Joule Sensitive Thermometer 1859

Joule devised a thermometer capable of detecting temperature changes not exceeding one thousandth of a degree Fahrenheit[6]. It included a glass chimney-receiver which was sealed. Joule says, "With air in the receiver at the atmospheric pressure, the mere standing at the distance of two yards on one side of the instrument would in a short space of time cause the needle to travel through 10° in consequence of currents of air produced by the unequal heating of the walls of the glass receiver."

This again implies conversion of heat into mechanical energy with very high efficiency and in complete conflict with the predicted Carnot maximum efficiency. The instrument again involves convection currents in an energy cycle at constant volume.

The Convection Mill 1897

Alfred R Bennett[4] devised an instrument to demonstrate the existence of convection currents. A hollow metal cylinder painted black stands on legs inside a glass vessel which is sealed. When the instrument is placed in daylight, the metal absorbs solar energy warming air inside the cylinder which rises. It then descends in the space between the cylinder and the outer glass vessel. Vanes on the outside of the cylinder and in a window within the cylinder rotate in opposite directions demonstrating the path of convection currents. There is a Convection Mill on display in the Heat section of the Science Museum in London.

Addressing the Manchester Literary and Philosophical Society in 1897, Bennett[7] said that, "The delicacy of the motor is such that it is affected by the radiant heat of moonlight." Bennett devised many variations of his instrument that could be used for a range of physical measurements[4].

It is extraordinary that such an unsophisticated instrument as the Convection Mill could detect the energy of moonlight. It must mean that this extremely small amount of heat is converted into mechanical energy with very high efficiency.

But Carnot would predict a maximum conversion efficiency $\Delta T/T$ of about 10^{-6} for moonlight.

THE CARNOT EFFICIENCY LIMIT CLEARLY DOES NOT APPLY

The instrument is another example of the use of convection currents in an energy cycle at constant volume.

All the above are examples of Energy Cycles at Constant Volume (earlier paper on this website – Simple Solar Engine, March 2003). It is my belief that such configurations allow conversion of heat into mechanical energy with a theoretical efficiency of up to 100%. Indeed the configuration for Joule's thermoscope is identical to Figure 3 in my proposals for a Simple Solar Engine (March 2003).

The Second Law of Thermodynamics – Limits of its Application and How to beat Carnot

The second law of thermodynamics was developed by Clausius, Rankine and Thomson 1850-1854. It tried to reconcile the work of Carnot 1820-1832 with Joule's dynamical theory of heat 1840-1850 and the practical experience of working with steam engines. It was deeply controversial in its formulation and took over 20 years to be accepted. It has however stood the test of time. The Carnot theorem with its maximum efficiency $\Delta T/T$ has come to be regarded as the decisive statement of the second law of thermodynamics and has acquired the status of a universal law.

But when we look back to its founders – Joule never accepted the Carnot efficiency limit. Clausius was very hesitant about the reliability of his proof of the Carnot theorem. Rankine considered it "very unsatisfactory". No one understood Rankine's proof. Thomson found it difficult to disagree with Joule, reluctantly accepted $\Delta T/T$ but wouldn't accept Clausius' concept of entropy. The intellectual origins of the second law of thermodynamics and its embodiment as the Carnot efficiency limit are deeply unsatisfactory.

I believe Carnot's theorem has stood the test of time simply because the heat engines that we have produced have been very inefficient – fossil fuel power stations have an efficiency of 40%, motor vehicles 20%. We have been unable to devise machines that beat the Carnot limit.

The Carnot theorem was derived from an energy cycle where work is extracted during the expansion of a gas. All the classical thermodynamic cycles and all heat engines in operation today involve extraction of work during the expansion of a gas. In an open cycle the exhaust gases are simply discharged into the atmosphere with very large energy loss. In a closed cycle the expanded gas must be compressed to complete the cycle; the energy lost during compression goes into an energy sink. These are the sources of the inefficiency – large quantities of heat are simply dumped into the environment.

I believe there are two ways of beating the Carnot limit:

(1) Waste Heat Recovery

Rankine[8] tried to develop the 'perfect' air engine. He realised that the more we minimised 'the heat which is expended in elevating the temperature of the working substance, the more nearly we shall attain to the maximum theoretical efficiency of the engine'. He suggested use of a regenerator to recycle waste heat.

In his book 'Power Cycles and Energy Efficiency' Hoffman[9] elaborates multistage compression and expansion with total waste heat recapture as the way to beat Carnot and achieve a theoretical efficiency of up to 100%.

In my proposal on the Solar Chimney – would a regenerator improve efficiency? (see earlier paper on this website - December 2001) waste heat is infinitely recycled in a vertical heat exchanger driven by gravitation.

(2) Energy Cycles at Constant Volume

I believe there is something extraordinary about energy cycles at constant volume. If energy is received into a closed system and work is extracted from that closed system at constant volume the theoretical efficiency is up to 100%. There is no loss of energy to an energy sink or to exit gases.

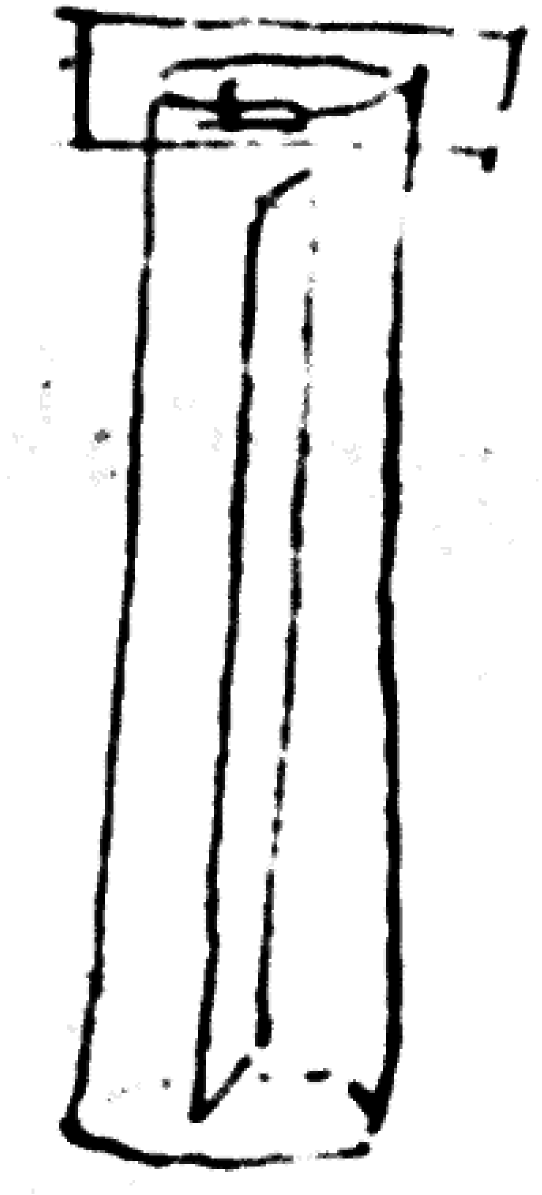
I believe that Joule's thermoscope, Joule's sensitive thermometer and Bennett's Convection Mill are examples of such systems. I have devised my website entries of March 2002, September 2002 and March 2003 using such Energy Cycles at Constant Volume. Carnot's theorem does not apply and the theoretical efficiency is up to 100%.

Dr Alan Williams *July 2003*

References

[1] Proceedings of the Literary and Philosophical Society of Manchester March 11th 1863 Volume 3, p 73-4 (See page 8)
[2] Joule's letter to Thomson, March 5th 1863 Manuscript Number MS Kelvin J171, Glasgow University Library (See pages 9-10)
[3] Joule's letter to Tyndall, March 23rd 1863 Manuscript Number RI MS JT/1/J/139, The Royal Institution of Great Britain (See page 11)
[4] A R Bennett, Engineering, Lond., 1897, Volume 63, p 239-241 (See page 12)
[5] James Joule, A biography by Donald S L Cardwell p 209-10 Manchester University Press 1989
[6] The Scientific Papers of James Prescott Joule Volume 1, p 416-9 London: Dawsons of Pall Mall, 1887 (See page 13)
[7] Proceedings of the Literary and Philosophical Society of Manchester January 26th 1897 Volume 41, pp xxvii-xxviii (See page 14)
[8] The Science of Energy by Crosbie Smith p 162-3 The Athlone Press, London, 1998
[9] Power Cycles and Energy Efficiency by E J Hoffman, Academic Press, 1996

JOULE'S THERMOSCOPE



Magnification of sketch drawn by James Joule

in his letter to William Thomson March 5th 1863

<u>Reference 1</u> **Proceedings of the Literary and Philosophical Society of Manchester**

March 11th 1863, Volume 3, p 73-4

Dr. Joule made the following communication respecting a new and extremely sensitive thermometer:—"Some years ago I remarked the disturbing influence of currents of air on finely suspended magnetic needles, and suggested that it might be made use of as a delicate test of temperature. I have lately carried out the idea into practice, and have obtained results beyond my expectation. A glass vessel in the shape of a tube, two feet long and four inches in diameter, was divided longitudinally by a blackened pasteboard diaphragm, leaving spaces at the top and bottom, each a little over one inch. In the top space a bit of magnetised sewing needle, furnished with a glass index, is suspended by a single filament of silk. It is evident that the arrangement is similar to that of a 'bratticed' coal pit shaft, and that the slightest excess of temperature on one side over that on the other must occasion a circulation of air, which will ascend on the heated side, and, after passing across the fine glass index, descend on the other side. It is also evident that the sensibility of the instrument may be increased to any required extent, by diminishing the directive force of the magnetic needle. I purpose to make several improvements in my present instrument, but in its present condition the heat radiated by a small pan, containing a pint of water heated 30°, is quite perceptible at a distance of three yards. A further proof of the extreme sensibility of the instrument is obtained from the fact that it is able to detect the heat radiated by the moon. A beam of moonlight was admitted through a slit in a shutter. As the moon (nearly full) travelled from left to right the beam passed gradually across the instrument, causing the index to be deflected several degrees, first to the left and then to the right. The effect showed, according to a very rough estimate, that the air i the instrument must have been heated by the moon's rays few ten-thousandths of a degree, or by a quantity no dou the equivalent of the light absorbed by the blackened surf on which the rays fell."

Reference 2 Joule's letter to Thomson March 5th 1863,

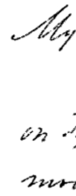
Manuscript Number MS Kelvin J171, by courtesy of

Glasgow University Library

92 Exmouth St Birkenhead
March 5th 1863

My dear Thomson

I feel now the amply revenged on Tyndall, for I find that the moon is hot not cold as he pretended. If you find space you & Tait must add something to your book on the wind produced by the action of our satellite. I have made my experiment as follows. A glass receiver 2 feet high



has a cardboard partition so as to divide it into two parts vertically, but leaving a space of 2 inches at the top and at the bottom. The cardboard is blackened and also two thin pieces placed on each side of the partition. It is evident that if one side is heated the least degree more than the other the air in it will rise, descending in the other as in a bratticed coal pit shaft. The existence of such a current is made manifest by a magnetic needle an eighth of an inch long or less, furnished with a long glass index and hung by a single filament of silk. The delicacy of this thermoscope is such that a small blackened pan containing a pint of water heated 30°F placed at 2 yards distance makes the index go through 5°. I have increased the delicacy of the instrument by counteracting the magnetism of the earth, and now by placing it at 2 yards from a shutter with a slit in it and making the effect of the moon as a beam of its light passes by, I find a distinct effect of about 4° which indicates, as far as I can estimate it at present that the air on one side of the diaphragm was raised about $\frac{1}{10000}$ of a degree F. I intend to improve the instrument and make it more useful by the next time we have a full moon.

I am returning from here on Saturday. I must contrive some means of getting an apparatus to work again but I fear it cannot be managed at Thorncliff & I shall have to find some other place in the neighbourhood.

Trusting Mrs Thomson has experienced no ill effects from her alarming accident and with kind regards to her

believe me
Yours very truly
James P Joule.

Typed transcript of Joule's letter to Thomson March 5th 1863

Gr Exmouth St
Birkenhead

March 5th 1863

My dear Thomson

I feel now to be amply revenged on Tyndall for I find that the moon is hot not cold as he pretended. If you find space you and Tait must add something to your book on the wind produced by the action of our satellite. I have made my experiment as follows. A glass receiver 2 feet high has a cardboard partition so as to divide it into two parts vertically, but leaving a space of 2 inches at the top and at the bottom. The cardboard is blackened and also two thin pieces placed in each side of the partition. It is evident that if one side is heated this least degree more than the other, the air in it will rise, descending in the other as in a bratticed coal pit shaft. The existence of such a current is made manifest by a magnetic needle an eighth of an inch long ----, furnished with a long glass index and hung by a single filament of silk.

The delicacy of this thermoscope is such that a small blackened pan containing a pint of water heated 30°F placed at 2 yards distance makes the index go through 5°. I have increased the delicacy of the instrument by counteracting the magnetism of this earth, and now by placing it at 2 yards from a shutter with a slit in it and marking the effect of the moon as a beam of its light passes by, I find a distinct effect of about 4° which indicates, as far as I can estimate it at present, that the air on one side of this diaphragm was raised about $\frac{1}{10000}$ of a degree F. I intend to improve on the instrument and make it more useful by the next time we have a full moon.

I am returning from here on Saturday. I must contrive some means of getting our apparatus to work again but I fear it cannot be managed at Thorncliff and I shall have to find some other place in the neighbourhood.

Trusting Mrs Thomson has experienced no ill effects from her alarming accident and with kind regards to her.

believe me

Yours always true

James Joule

<u>Reference 3</u> Joule's letter to Tyndall, March 23rd 1863,

Manuscript Number RI MS JT/1/J/139 by courtesy of

The Royal Institution of Great Britain

Old Trafford,
Manchester,
Mar 23/1863

My dear Sir

Many thanks for your kindness in sending me copies of your papers. I am sorry I have nothing of much importance to send by way of return. I send by this post the last number of Proceedings of our Phil. Society in which I profess to have detected the heat radiated by the moon by means of a sort of wind thermometer. *

Our Secretary, Mr Baxendell says that M[illegible] had observed the same thing, but I have not yet been able to refer to his paper.

You will observe the lucubrations of one of our local luminaries Mr Dyer. I was absent from the meeting or would have said something more than what is written in the little note appended, which note I intended as a protest.

Mr Dyer and I have disputed on these matters for a good share of 20 years but now he seems to be attacking higher games. I dare say you will not think it worth while to write or reply to his observations. I once invited him to go with me to Niagara and offered to pay our joint expenses if a higher temperature was not found at the bottom than at the top of the falls.

Believe me Dear Sir
Yours very truly
James P. Joule.

* MELLONI

<u>Reference 4</u> **A R Bennett, Engineering, Lond., 1897, Volume 63, p 239-241**

A CONVECTION SCOPE AND CALORIMETER.*

By Alfred R. Bennett, M.I.E.E.

There is an especial propriety in bringing my paper on this subject before the Manchester Literary and Philosophical Society, for in 1863 your great townsman, Joule, made a communication (reported in Volume III. of your Proceedings) on a thermoscope, which, so far as I am aware, is the only instrument which can in any sense be regarded as a forerunner of the one to be described to-night. Joule's apparatus consisted of a glass tube 2 ft. long and 4 in. in diameter, divided longitudinally into two compartments, but having openings about 1 in. wide at top and bottom. When either face of the instrument was exposed to a greater heat than the other a convection current started, flowing from the warmer to the colder division at the top and from the colder to the warmer at the bottom, a magnetised needle suspended by a silk thread in the upper opening serving by its deflections over a scale to indicate the difference of pressure existing between the two columns of air. With this thermoscope Joule was able to detect convective effects due to the heat of moonlight.

Although in no way suggested by Joule's instrument, with which I was unacquainted until quite recently, my own depends on the phenomenon of current convection generated in a confined area by the action of unequally heated surfaces. Instead of a suspended needle, my index consists of a light fan or vane, accurately poised, which is caused to rotate by the convective currents in such a way as to afford a measure of the heat employed.

The principle of my instrument will be clearly understood from Fig. 1, in which A is a metal funnel or chimney surmounting a glass or mica tube, open at the bottom, within which is pivoted an aluminium fan E. The whole is covered by a glass or mica shade G.

Another form of motor is shown in Fig. 2, where E is a vane with vertical blades, pivoted, like the other, in a transparent screen, which is surmounted by a metallic chimney A. In this case the air enters by a vertical opening O in the side of the screen and impinges on the vane, afterwards assuming a rotary motion in ascending the funnel. G is a glass shade, as before, covering the whole.

When such an instrument—which I have named a "convection mill"—is placed in the open air or in a room near a window, the radiant heat of the sun, if it is shining, or otherwise the diffused radiant heat of daylight, will

* Paper read before the Manchester Literary and Philosophical Society, January 26, 1897.

Fig. 1.

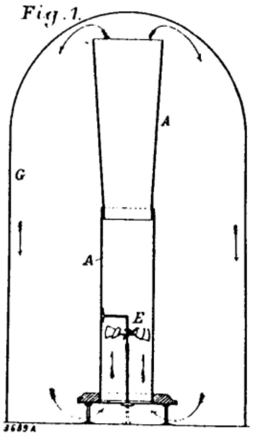
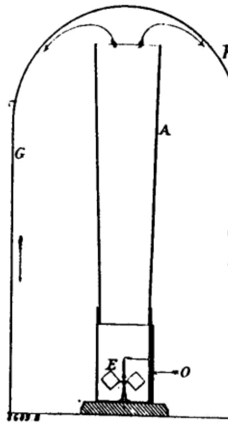


Fig. 2.

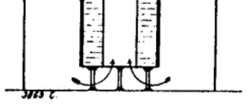


pass through the shade as through the glass of a greenhouse, and warm the fan, its supports, and the walls of the chimney. On these surfaces the high-temperature solar rays are degraded into obscure radiations which are unable to escape through the glass shade, so that the motor can only cool by conduction through its base and by the aid of convection currents, for direct molecular conduction through the gas may be neglected. On exposure to daylight, the air in contact with the motor surfaces becomes expanded, ascends, issues from the top of the chimney, and strikes against the glass, which absorbs and radiates outwards the excess of heat brought from the warmed surfaces by the air. Cooled and condensed, this sinks to the bottom of the shade, whence it is once more drawn into the tube and heated by contact with the fan and chimney surfaces, a cycle of operations which is indefinitely repeated. A column of warmed air is thus continually rising through the chimney, and a cascade of cooled air falling down the walls of the shade, as indicated by the arrows in the diagrams.

The fan, when well made and well balanced, will usually rotate all day in the open air, whatever the weather conditions may be. It is affected by variations in the barometrical pressure, and the speed of rotation depends on the difference of temperature existing between the motor surfaces and the glass shade, the height of the barometer, and the condition of the sky. A clear sky which permits of free radiation from the shade, together with a high barometer, induces the maximum speed of rotation, which, with a 3 in. fan, may be put at 160 revolutions per minute. In gloomy weather, when the radiation from the shade is intercepted by clouds, the difference of temperature between the motor surfaces and the glass is much reduced, and the speed of rotation falls off; but since April last, when the instrument was devised, it has never, except on one occasion, to which I shall refer later, entirely stopped during the hours of daylight.

In wet weather, motion ordinarily ceases at sunset; in gloomy weather, if the barometer be high, it will sometimes continue for several hours thereafter; but with fine weather and a clear sky it frequently persists all night. If the instrument has stopped about sunset owing to unfavourable conditions, it will recommence rotation should the sky become clear at any time during the night. The cause of rotation after sunset, when there is no longer any radiant heat to warm the motor surfaces, is chiefly due simply to a continuous fall in the outside temperature. However low this may sink during the night, the motor surfaces will always remain a little warmer than the shade, for they can only lose heat by convection and

Fig. 4.



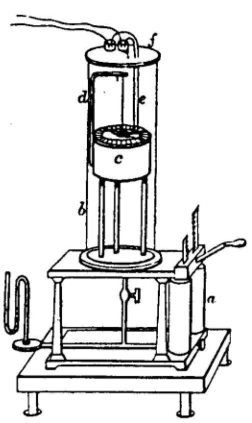
Reference 6 **The Scientific Papers of James Prescott Joule**

Volume 1, p 416-9 London: Dawsons of Pall Mall, 1887

6. At the outset it was obvious that a very delicate test of temperature would be required, and no means appeared to offer so many advantages as that of thermo-electricity. Professor J. D. Forbes had constructed a thermo-multiplier capable of detecting temperatures not exceeding one thousandth of a degree Fahrenheit. Adopting some of the re-

finements introduced by Melloni and Forbes, I have simplified the instrument so as to render its construction and management very easy, and also increased its reliability by immersing it into the vacuum of an air-pump. My thermo-multiplier is represented by the adjoining sketch (fig. 87), where *a* is an air-pump firmly clamped to a strong stool, the legs of

Fig. 87.

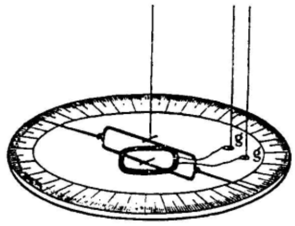


which pass through holes in the laboratory-floor and are driven into the ground beneath; *b* is a glass chimney-receiver; *c* a block of wood supported on feet which rest on the pump-plate; *d* a piece of glass rod fixed to the block, over which is thrown the filament which supports the astatic needles. Two thick copper wires (*e*) dip into mercury-cups formed in the block, and, being carried out of the receiver through holes drilled in the ground-glass plate *f*, are bent into two mercury-cups placed on the top of the instrument. Pitch was employed to close all orifices air-tight.

7. The details of the astatic needles, which are poised according to the plan first suggested by Professor Thomson,

will be better understood by inspecting fig. 88. The needles are parts of one sewing-needle magnetized to saturation, one part being a little longer than the other, so as to exceed it in magnetic moment and give direction to the system. A piece of glass tube drawn very fine, and bent as represented in the sketch, is attached at right angles to the upper magnetic needle and serves as the pointer. The lower needle is hooked to the pointer by means of the fine glass tube to

Fig. 88.



which it also is attached. The coil consists of twenty turns of silked copper wire, $\frac{1}{40}$ of an inch in diameter, the ends of which dip into the mercury-cups *g g* formed in the block of wood.

8. In order still further to increase the sensibility of the instrument, a steel magnet one yard long, the permanency of which had been tested, was placed so as to counteract and almost entirely overcome the action of the earth's magnetism in the locality of the needle. A small telescope placed at the distance of a few yards, and looking obliquely downwards through the chimney-glass at the graduated circle, completed the apparatus.

9. With air in the receiver at the atmospheric pressure, the mere standing at the distance of two yards on one side of the instrument would in a short space of time cause the needle to travel through 10°, in consequence of the currents of air produced by the unequal heating of the walls of the glass receiver. But when the air was reduced to a pressure of only half an inch in the mercury-gauge, this did not take

place, though still, when the hand was put in contact with the receiver, a very considerable deflection of the needle was speedily produced.

10. On working with my instrument, I was agreeably surprised to find that when the bar-magnet was placed so as to make the needle take up one minute in being deflected to a new position, no perceptible return swing of the needle took place, even when the rarefaction of the air was carried to half-an-inch pressure. If a small magnet was suddenly placed where it could deflect the needle 30°, the pointer would steadily travel towards that degree of deflection, and on arriving there would remain settled without any previous oscillation that could be discerned. When the time of a swing was reduced to 30 sec., a return swing was observed amounting to $\frac{1}{150}$, $\frac{1}{25}$, and $\frac{1}{18}$ of the first swing, according as the gauge was reduced to 1, $\frac{6}{10}$, and $\frac{1}{2}$ inch respectively.

Reference 7 Proceedings of the Literary and Philosophical Society of Manchester

January 26th 1897, Volume 41, pp xxvii-xxviii

General Meeting, January 26th, 1897.

Professor Harold B. Dixon, F.R.S., in the Chair.

Mr. J. Grossmann, Ph.D., Harpurhey Chemical Works, Manchester, and Mr. J. F. Tristram, M.A., Hulme Grammar School, were elected ordinary members.

Ordinary Meeting, January 26th, 1897.

Professor Harold B. Dixon, F.R.S., in the Chair.

The thanks of the members were voted to the donors of the books upon the table.

Mr. Alfred R. Bennett, M.I.E.E., read a paper entitled: **"A Convection Scope and Calorimeter,"** which was communicated by Mr. William Thomson, F.C.S.

Mr. Bennett described how he had devised a small and exceedingly sensitive motor, which begins to revolve the moment it is exposed to daylight in the open air, whether the sun be shining or not, and which will also work all night in clear weather. The delicacy of the motor is such that it is affected by the radiant heat of moonlight. The motive power is due to convection currents caused by the radiant heat of daylight striking through a glass shade, with which the instrument is covered; the glass is not heated, but the metal surfaces of the instrument are, and air is consequently expanded on the motor surfaces, and condensed on the glass, the resulting difference of temperature setting up a convection current which does not cease so long as the instrument is exposed to the radiant heat due to visible rays.

Descriptions were given of modifications by which surplus heat is automatically stored during the day and employed to

drive the instrument at night. During the months of May, June, and July last, such a storage instrument continued in motion without stopping day or night; and in fine climates, like Egypt, much longer periods of continuous movement could undoubtedly be secured. The speed of the instrument is affected by barometrical pressure and hygroscopic conditions. It is capable of marking the dew-point, and works well, even when its glass shade is completely coated with ice, or half-buried in snow. Mr. Bennett has succeeded in adapting the instrument to act as a calorimeter by first cooling the whole of the instrument to a given temperature, when rotation ceases, and then suspending pieces of heated metal inside. In this way the specific heats of substances can be accurately compared, since the number of rotations caused is in direct proportion to the amount of introduced heat. The instrument can also be used to measure the comparative heat-retaining power of textile fabrics, boiler compositions, &c., and the relative heat conductivities of thin threads and wires. Mr. Bennett has also instituted a series of experiments, as yet incomplete, into the comparative sensitiveness to convection effects of various gases, which promise interesting results, since the differences already noted are unexpectedly great, and, moreover, do not bear any direct relation to the densities or other known physical properties of the gases tried.