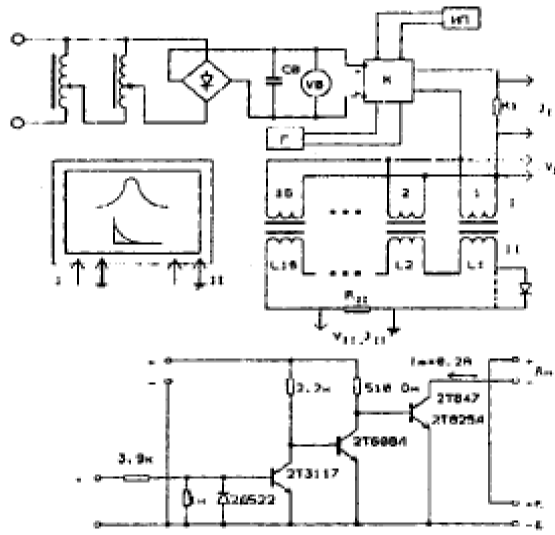
Rediscovering Zaev's ferro-kessor [1)]

You can cool a rubber band as follows. First stretch it isothermally. That means, stretch it slowly, so that it has lots of time to lose any heat that is generated. Then, suddenly de-stretch it, and before it has time to gain any heat from its surrounding, measure its temperature by immediately holding it up to your lips. You will find that it has cooled by adiabatic de-stretching (11).



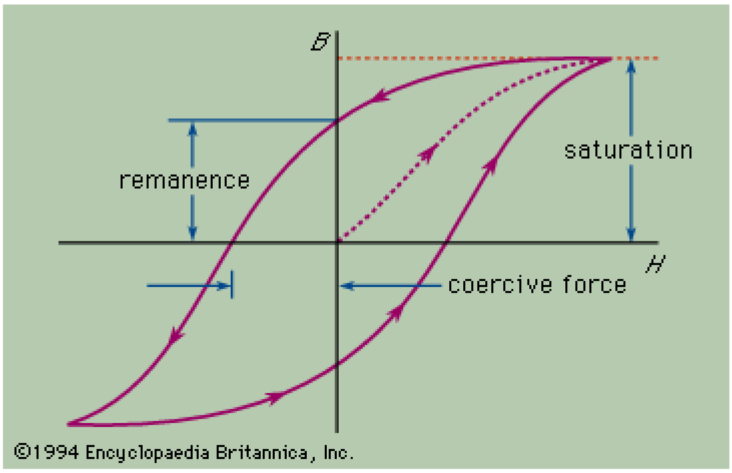
pic. Test setup described in (2)

History notes

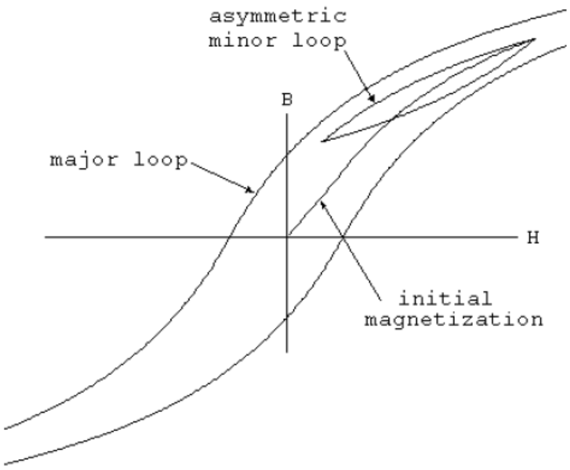
N. E. Zaev's article about using environmental heat to generate electricity was published somewhere in 1991. According to some internet resources, N.E. Zaev was researching this concept since 1960s, probably in cooperation with P.K. Oshepkov, founder of Public Institute of Energy Inversion. I heard first time about Zaev's idea of conversion of environmental heat to electricity about ten years ago. Since that time I made a lot of experiments and attempts to build such device without any significant progress. In desperation, I started studding everything related to magnetic properties, BH curves etc. And accidentally, last year a chain of unexpected events was triggered, which brought me to understanding and some experimental results. Here, in this short summary, I am trying to document a path which one have to follow in order to be able understand and build such device.

[1)] kessor – "environmental energy concentrator" - device which can convert low potential energy from environment to some useful form e.g. electricity, originally was introduced by Pavel K. Oshchepkov.

1. Typical BH curve



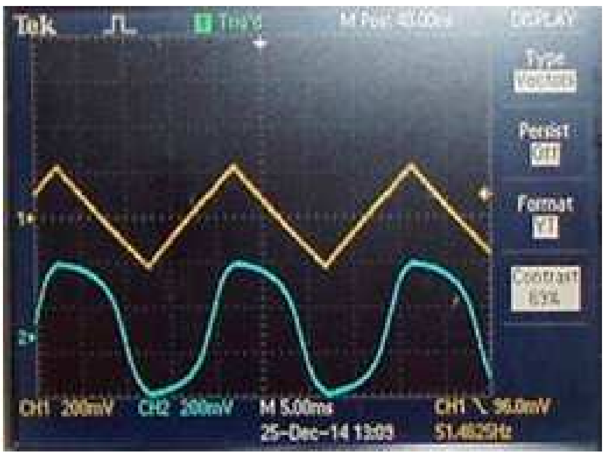
pic. typical BH curve with specified directions how it is traversed in usual applications.



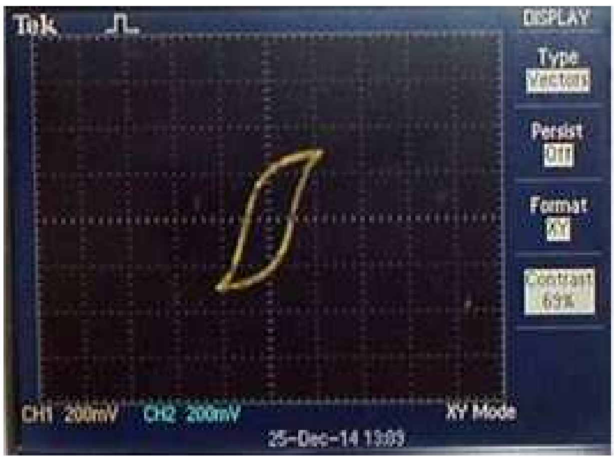
pic. Typical asymmetric minor loop (direction is same as above)

Picture source – LTSpice manual.

It is easy to obtain such curves in practice with a core tracer, here an example of experimental BH curve (5)



current and flux (integrated voltage)



experimental BH curve for N30 ferrite

2.Less known properties of BH curves

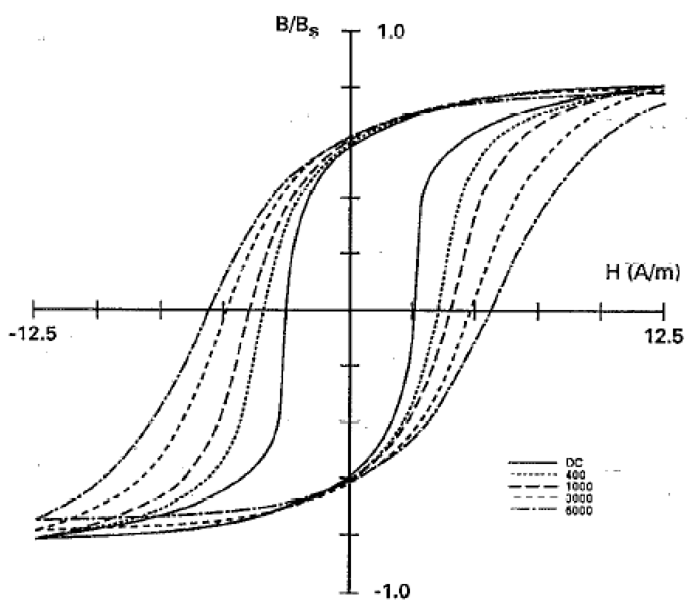
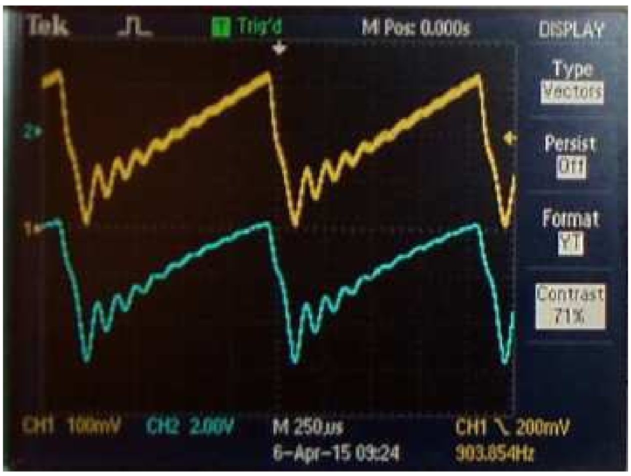


FIG. 3. Modeled hysteresis curves of Permalloy 80 at dc, 400, 1000, 3000, and 6000 Hz calculated by incorporating effects of both classical and anomalous (or excess) eddy current power losses into the hysteresis equation.

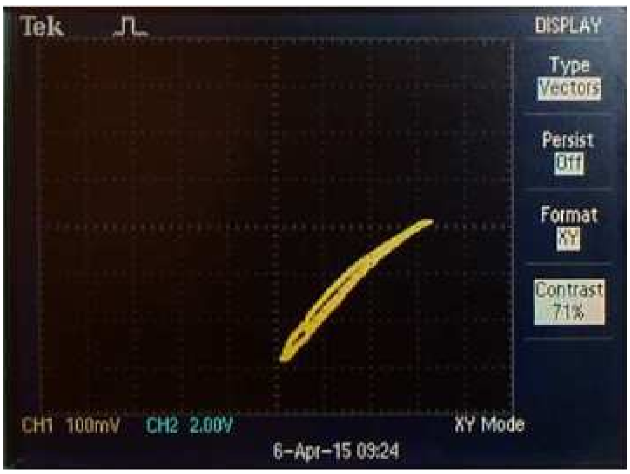
pic. from (6)

Shape (or curvature) of BH characteristic depends on frequency, or in other words, on “speed”, the faster we move the more curvature is.

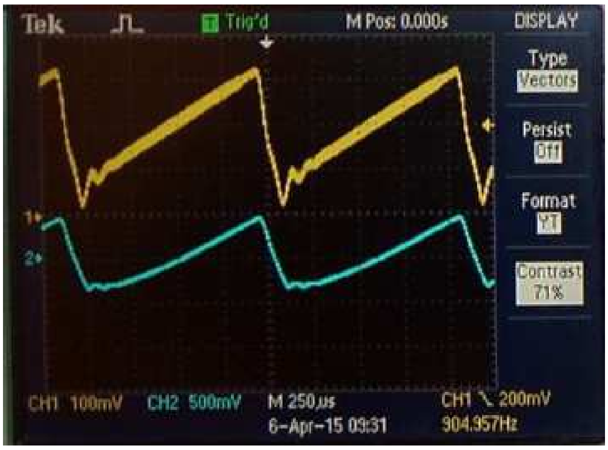
This was also demonstrated in practice (5), here example BH curves for saw-shaped magnetization current.



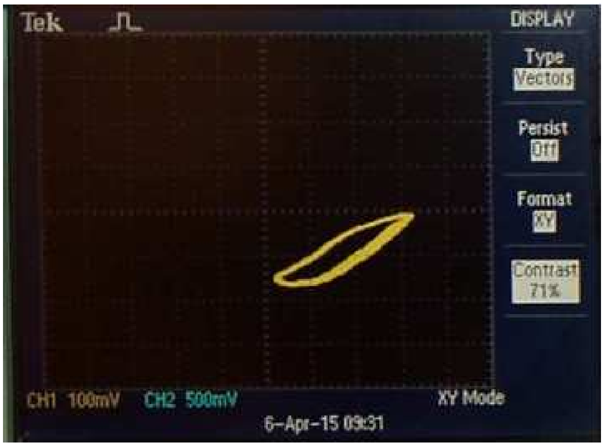
top – current, bottom – core flux



corresponding BH curve (ferrite)



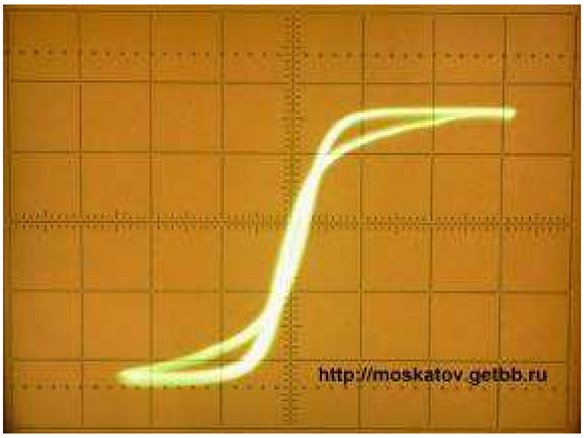
top – current, bottom – core flux

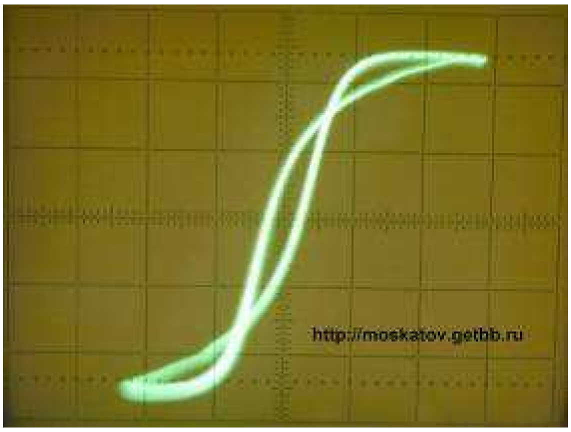


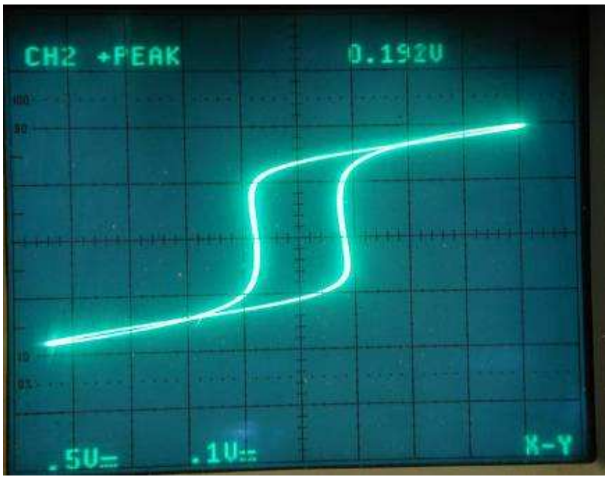
Corresponding BH curve (laminated iron core)

3.Non-typical BH curves

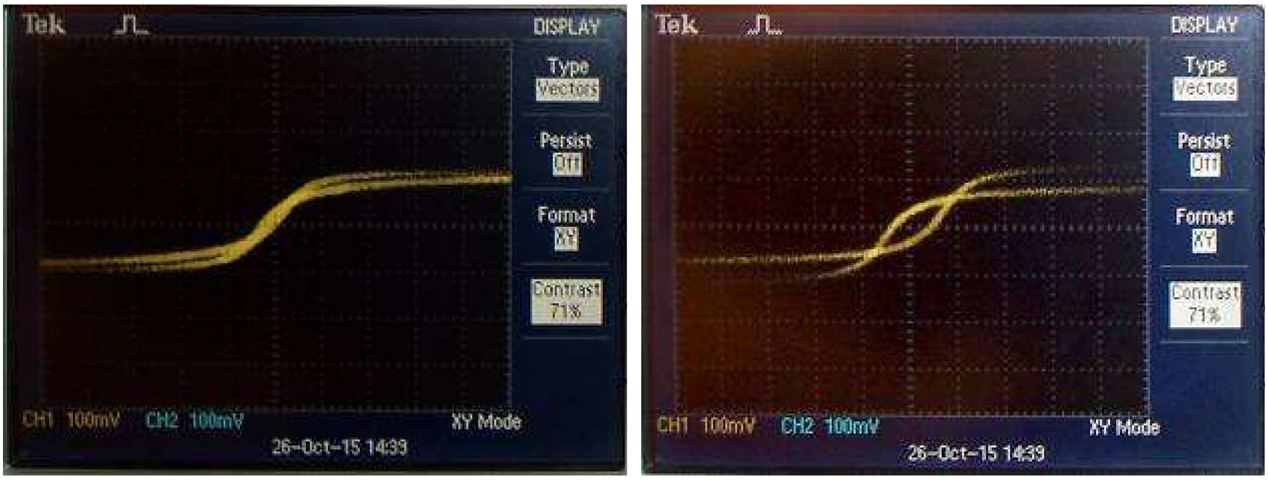
More interesting curves were found on the internet. Some people call it “over-saturation” and others did not even noticed this effect in their results.





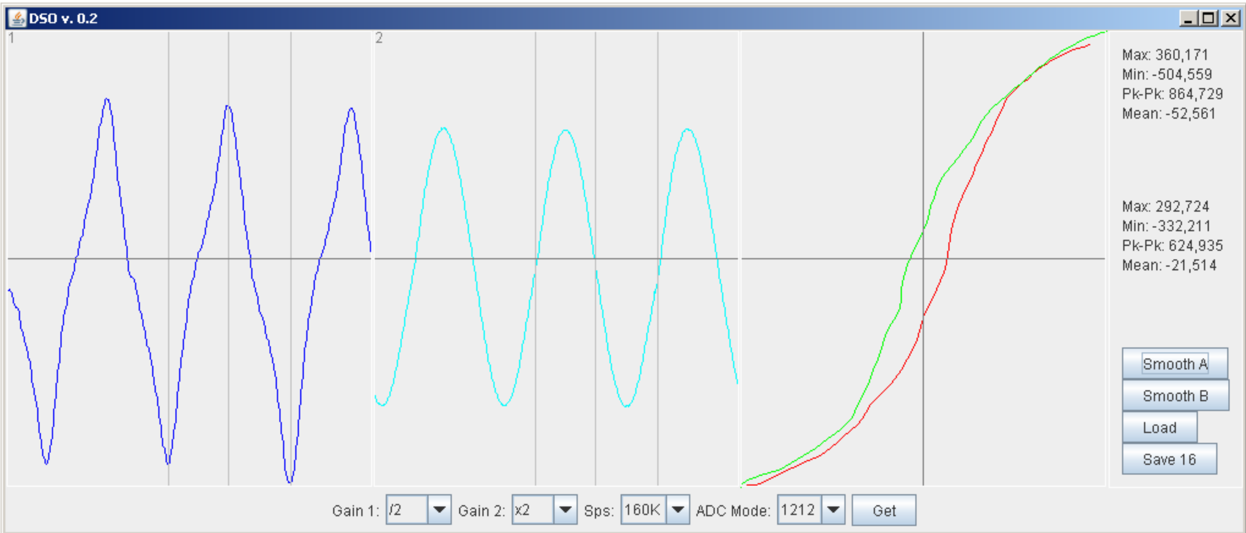


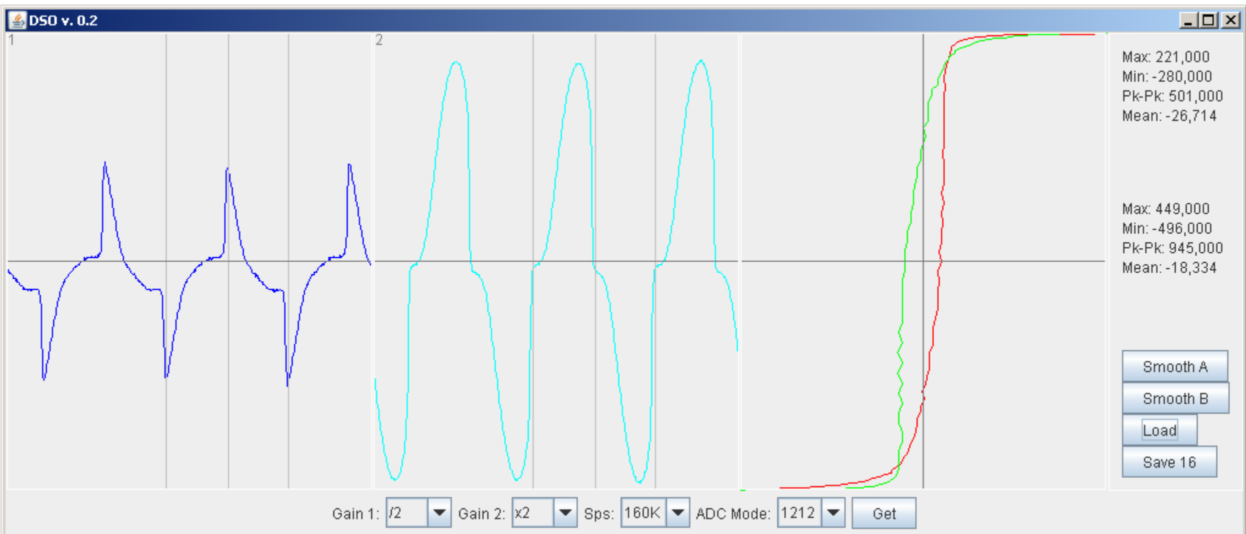
pic. Fair-Rite Type 43 Material
source (9)



N30 ferrite (5)

I even made digital core tracer in a hope to study these curves in more details and avoid any possible analog integration artifacts.





The ”strange” effect seems still in place.

4. Condition to obtain energy

As we know, in usual transformer BH loop traversed counter-clockwise and loop's area corresponds to energy loss in transformer core. But if we manage to create such device where BH curve traversed clockwise, area of the loop will represent an energy gain.

Of interest to OU researchers is the concept of negative resistance, since this represents a source of energy rather than a sink. The next figure shows the Φ v I plot for an inductor shunted by a negative resistor.

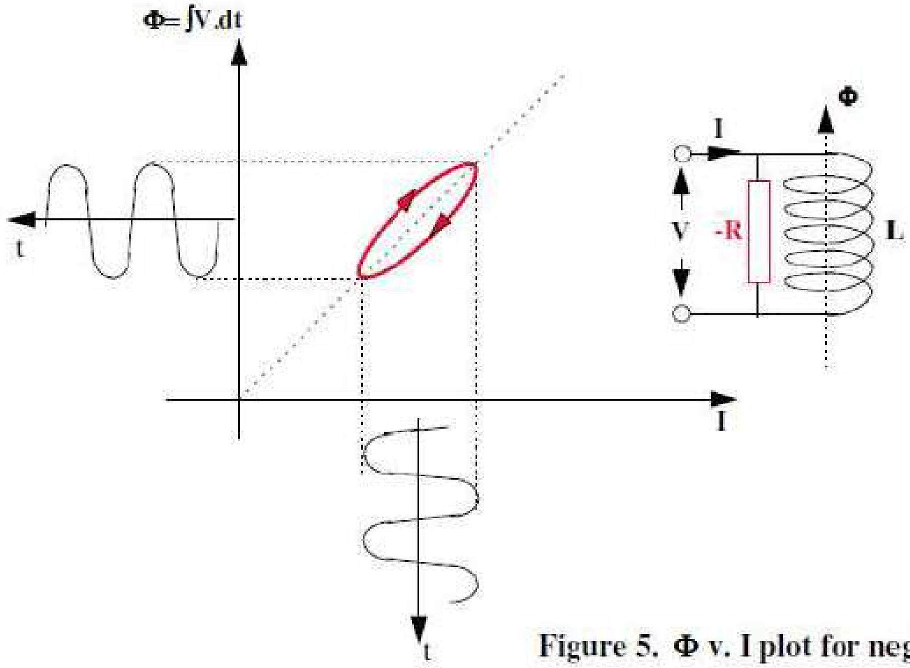
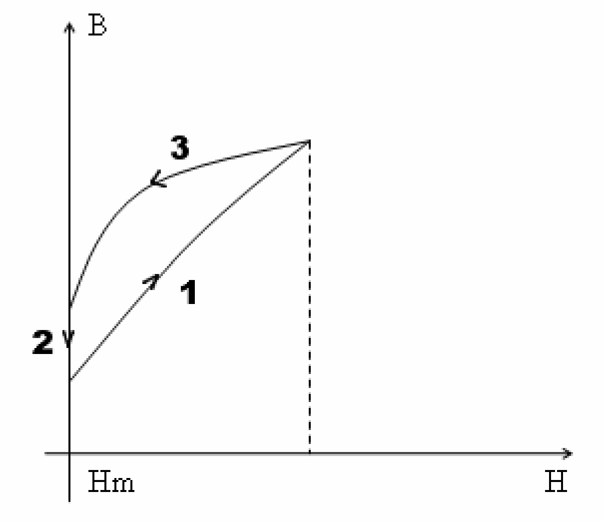


Figure 5. Φ v. I plot for negative resistor

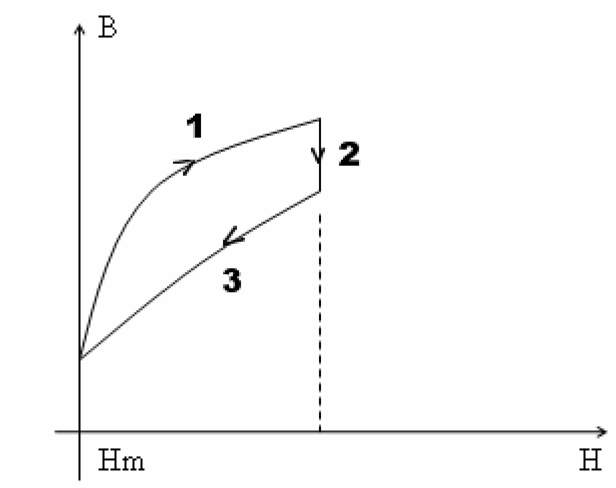
pic. A quote from Cyril Smith "A New look at the MEG" page 3 (8)

5. BH loop for energy gain considerations

So is it really possible to “construct” such clockwise BH loop?



pic. A this is not interesting for us (wrong loop direction)

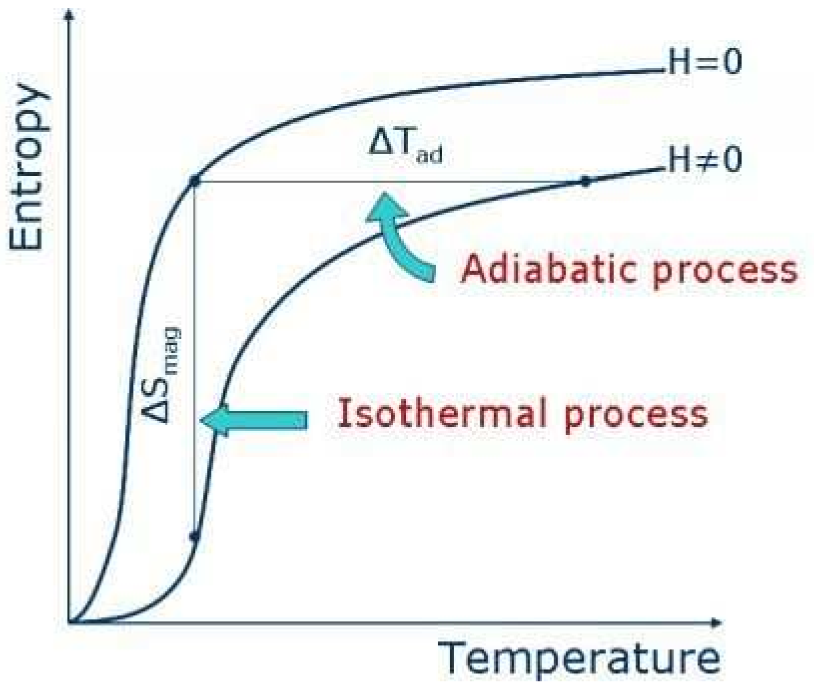


pic. B It seems that we found force which will make work for us? It’s environmental heat!

1 – magnetization
2 – heating
3 – demagnetization

I was thinking how to implement such loops for quite a while. If we use saw-shaped current, we got loop which looks properly, but how we can be sure that it is traversed in proper direction. Some efforts were made to verify this (4) but still no rock-solid proof were found.
Theoretical consideration suggests that BH loop should look like one on the pic. B, but there is a problem, in order to implement transition 2 somebody have to perform work against magnetic field. If we do it ourselves, e.g. mechanically increase a gap in magnetized core, it is unlikely that we gain any energy in such cycle.

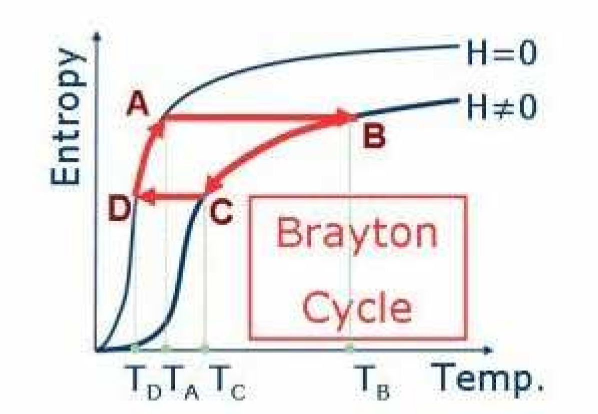
6. Thermo dynamical point of view

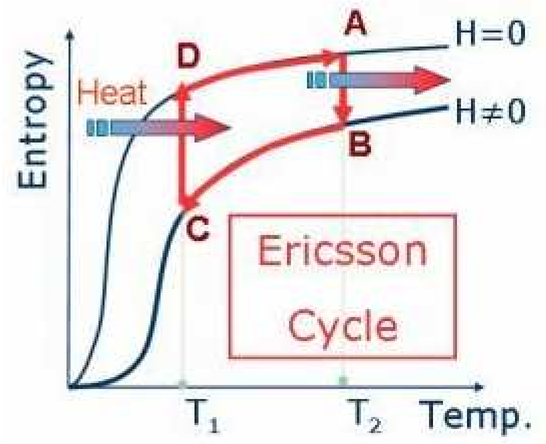


The Magnetocaloric Effect (MCE), discovered in 1881 by E.Warburg, is an exciting propriety of magnetic materials. This effect can be seen from either an adiabatic or an isothermal process; both due to a change of the applied magnetic field. Considering an adiabatic process, the magnetic material changes its temperature, whereas from an isothermal process, the magnetic material exchanges heat with a thermal reservoir.
From the quantitative point of view, the MCE is measured trough the magnetic entropy change DS (=DQ/T, where DQ is the amount of heat exchanged between the thermal reservoir and the magnetic material), when the isothermal process is considered; or adiabatic temperature change DT, when the adiabatic process. These quantities can also be seen when the magnetic entropy is expressed as a function of temperature for both, with and without applied magnetic field. (12)

In a simpler words, magnetic field re-arrange internal structure of core material, magnetic domains align along field lines, i.e. entropy is decreased when magnetic field is on. So we can control cores entropy by switching magnetic field on and off.

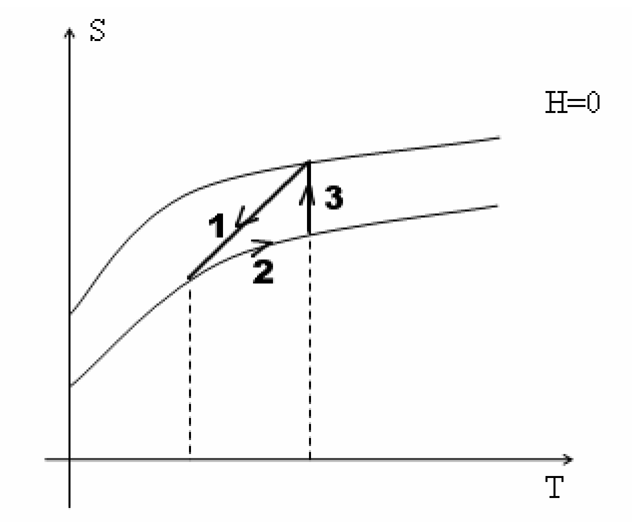
7. Magnetic cooling





It is straightforward the idea to produce a thermo-magnetic cycle based on the isothermal and/or adiabatic processes (like Brayton and Ericsson cycles); and indeed this idea begun in the late 1920s, when cooling via adiabatic demagnetization was proposed by Debye and Giauque (12).

8. Generating power



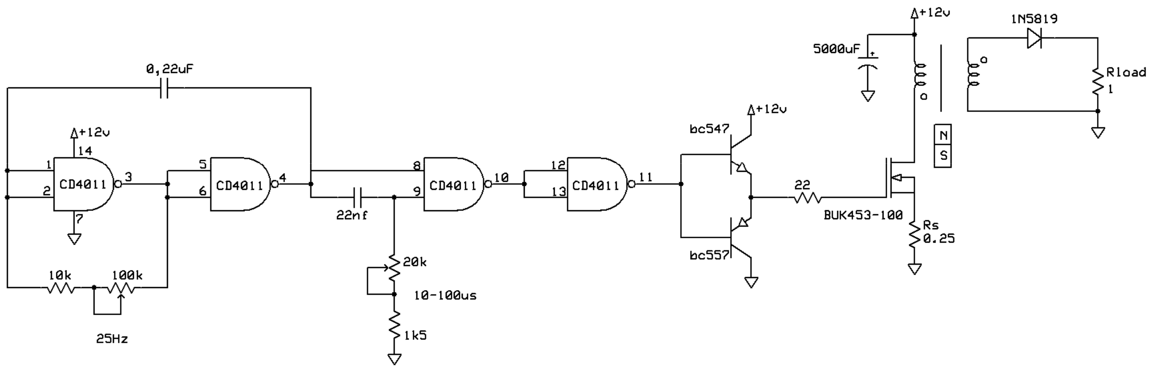
By analogy we can also propose a cycle for power generation. First, we magnetize core very fast (1). This cause entropy decrease and core's temperature drop. Then, since we do not thermally insulate our device, heat exchange occurs and core being heat up back by surrounding environment (2) (this where we can use environmental heat to produce work). On stage (3) we switch magnetic field off and collect energy from collapsing magnetic field.
Surprisingly this process looks very similar to one which I described in 5. on pic. B.

9. Required conditions – Summary

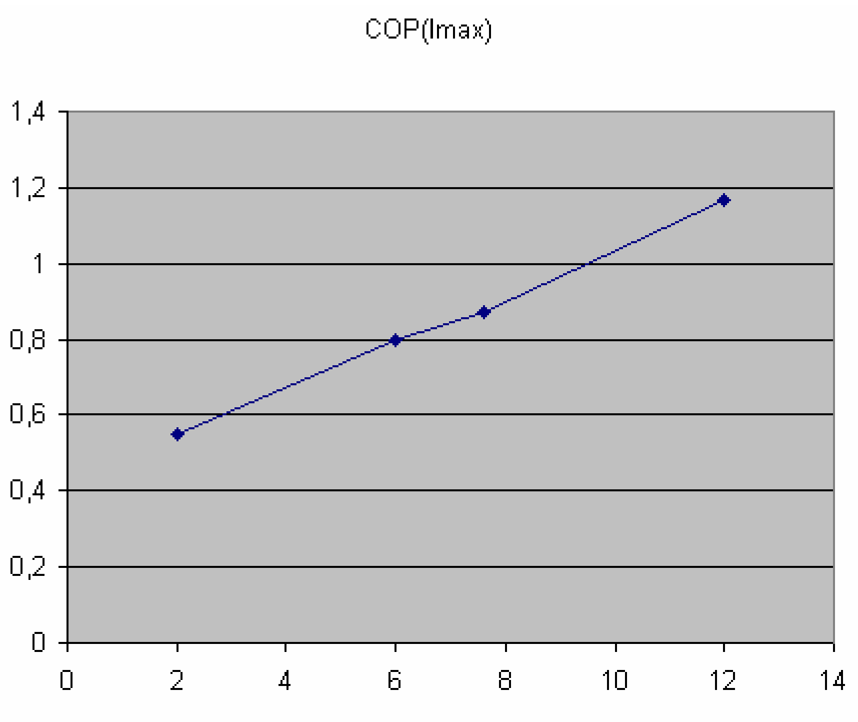
Summarizing conditions which are required to implement the ferro-kessor:
- Proper core working point offset
- Fast magnetization (t_m)
- Core should be saturated
- Slow demagnetization ($t_d >> t_m$)
- Some pause before next cycle to allow core gain temperature

10. Experiment

In order to verify my conclusions I made simple experiment with one of my MEG cores (with permanent magnet).



pic. Experimental setup, flyback with saturation



pic. COP vs maximum current thru primary coil

And results are quite interesting. I made very rough measurements with oscilloscope, but over all trend is clearly visible. Despite ”common” sense expectation that while increasing current and core being saturated performance should be decreasing due to higher loses, above schematic demonstrates an opposite behavior. COP increasing proportionally to maximum magnetization current.

11. Analogy with capacitors

In conclusion, I would like to say that just now, while compiling this document I realized that there are very similar processes in capacitors. We can control entropy in dielectric with electric field. Indeed, there is known effect, called “dielectric absorption” which can be very nice explained from the thermodynamical point of view. And we know that N.E. Zaev explored capacitors based kessors also. They have an advantage that there is no need to maintain high current thru the coil. This probably can lead us to more practical solution, but need to be explored further.

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