Using Natural (thermally driven) Demagnetization to Create Electrical Energy

1. Introduction

The use of Fe based transformer core material that has been treated in such a way that its remanent magnetization (usually known to be permanent magnetism with a decay time in tens or hundreds of years) has a natural decay time constant of a few milliseconds is something quite new to science. It has been brought to our attention by the South Korean SEMP Research Institute [1] who claim to have obtained a decay time constant measured in milliseconds in specially heat-treated pure iron. This has led them to produce equipment that they claim has efficiency that exceeds 100%, and they demonstrated this at the COP28 Summit held in Dubai. Using natural (thermally driven) reduction of “permanent” magnetism to induce current into a load resistor is not something that has been considered of any value, since normally such reduction takes place over many years hence virtually zero voltage in any practical coil. What little work has been done to create materials with reduced decay times has produced time constants in tens of hours, so again no significant voltage would occur. Thus throughout the last 200 years of improving knowledge of magnetic effects there is no evidence to call upon, until now! Not surprisingly the SEMP claims have been viewed with scepticism by the scientific establishment. Clearly, during such a small decay time the field change can induce significant voltage into a coil to drive current through a load resistor, hence deliver a pulse of energy. This paper offers a theoretical means of establishing the quantity of energy delivered.

2. Theory

The first thing to establish is what form does this natural decay take. In chapter 3 of “Paleomagnetism” [2] entitled *Origins of Natural Remanent Magnetism* [3] the physical processes leading to acquisition of natural remanent magnetism are presented, along with a formula for natural decay that shows it to be of exponential form. It requires the magnetic material to have small grain size that become single domain (SD) grains. (It may be noted that some ferrite materials are manufactured by grinding down to SD grain size then sintering the material in the presence of a magnetic field so that the magnetization of the grains become aligned, thus producing anisotropic material with maximised characteristic along the easy axis.) The formulae in [3] use the symbol *J* for magnetization but generally that symbol is used for a surface or volume current density. In the following extract we show those formulae with the more common symbol *M* for magnetization (we also correct a typing error and start the equation numbering at (1) for this treatise). Capital *M* applies to the bulk material of composite grains while small *m* applies to individual grains, this differentiation being important in the study of rock samples where the grains form only a small percentage of the material. In our case the grains are 100% of the material so remanent magnetization M_r of the material is equal to magnetization m of each grain since at that remanent point all the grains are aligned.

> Exponential decay of remanent magnetization, $M_r(t)$, after removal of the magnetizing field is
>
> $$M_r(t) = M_{r0}\exp(-t/\tau) \quad (1)$$
>
> where M_{r0} = initial remanent magnetization, t = time (s)and τ = characteristic relaxation time (s) at which $M_r = {}^{M_{r0}}/_{e}$.
>
> Magnetic relaxation was studied by Louis Néel, who showed that the characteristic relaxation time is given by
>
> $$\tau = \frac{1}{C} exp\left(\frac{vh_c j_s}{2kT}\right) \quad (2)$$
>
> where C = frequency factor ≈ 10^8 s^{-1}, v = volume of SD grain, h_c = microscopic coercive force of SD grain, m_s = saturation magnetization of the ferromagnetic material and kT = thermal energy. In Equation (2), the product vj_sh_c is an energy barrier to rotation of m_s and is called the blocking energy. But thermal energy (kT) can cause oscillations of m_s. So the relaxation time is controlled by the ratio of blocking energy to thermal energy.
>
> Relaxation times vary over many orders of magnitude. SD grains with short relaxation times are referred to as superparamagnetic. A superparamagnetic grain is ferromagnetic with attendant strong magnetization. But remanent magnetization in an assemblage of these grains is unstable; it will decay to zero very soon after removal of the magnetizing field.

For thermal energy k is Boltzman's constant (1.38×10^{-23} J/°K) and T is absolute temperature in °K. Note that at an ambient temperature of 20°C the core material contains $293kAl$ joules of thermal energy where Al is the core volume (area×length). This thermal energy agitation interrupts the alignment of the SD m vectors (stated as *causing oscillations* in the extract above) thus causing M_r to decay with time. Note also that for an exponential decay (1) the rate of decay is also exponential and at any point in time is given by

$$\frac{dM_r}{dt} = -\frac{M_r}{\tau} \quad (3)$$

The SEMP treatment of their Fe cores, a so-called carbonizing process, must have introduced superparamagnetic characteristic into regions of the core, probably the outer surface. For the purpose of this examination of using the fast decay time it will be assumed that the whole core is superparamagnetic, something that may not be achievable in practice. Also resistive losses, eddy-current losses and radiation losses are ignored. It is assumed that the transformer core is a closed magnetic path without air gaps such as a ring core with known dimensions of area *A* and magnetic path length *l*. The core is assumed to have a square-loop characteristic of known remanence B_R and known coercivity H_C, Figure 1 shows the idealized BH loop.

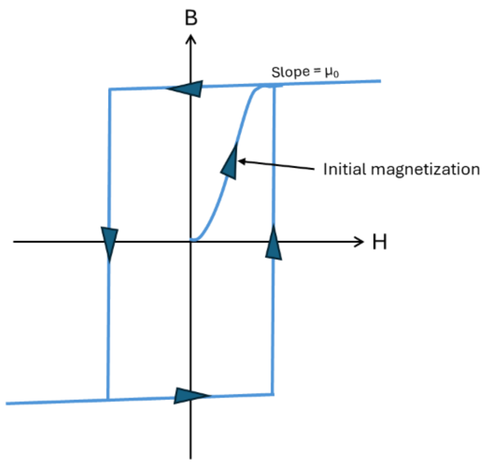

Figure 1 Idealized BH loop

The core is wound with a coil of *N* turns that is connected to a load resistor *R*. For simplicity the coil resistance is assumed to be negligible compared to *R*. Also for simplicity, coil inductance *L* assumes a linear relationship between *B* and *H*. Thus, for initial magnetization of the core from *B*=0 to B=B_R we obtain the linear permeability μ from

$$\mu = \frac{B_R}{H_C} = \mu_0\mu_{R.} \tag{4}$$

The input energy W_{IN} needed to create B_R is given by the triangular area shown in green in figure 2 multiplied by the volume of the core.

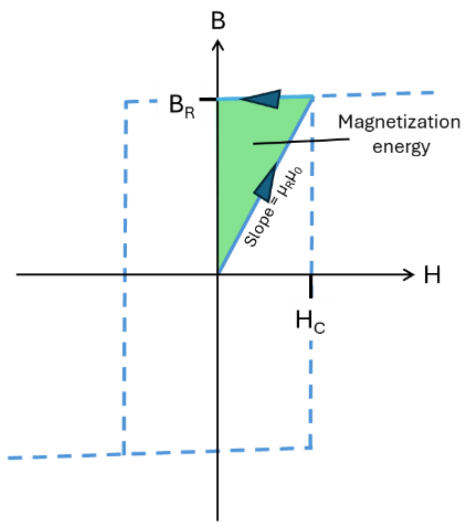

Figure 2. Magnetization energy

W_{IN} is then given by

$$W_{IN} = \frac{1}{2}B_R H_C A l. \tag{5}$$

From the classical formula for inductance L

$$L = \frac{N^2 \mu_R \mu_0 A}{l} \tag{6}$$

and the current i needed to reach H_C is

$$i = \frac{H_C l}{N} \tag{7}$$

we find that W_{IN} as given by the classical formula

$$W_{IN} = \frac{1}{2} L i^2 \tag{8}$$

Is identical to (5)

If, immediately after the magnetizing current through the coil is switched off, we connect the coil to the load resistor R, then the natural decay of magnetization will induce current through R, and by Lenz's Law that current will oppose the natural decay, hence will slow down the decay. If we use τ as the natural exponential decay time constant, and T as the L/R exponential time constant of the output coil, we can deduce the exponential decays for the limit cases where $\tau \ll T$ and $\tau \gg T$. For very small τ (almost instantaneous magnetization decay) current through the coil will quickly rise to a value that holds the field constant, then the decay is governed by the L/R time constant T. For very large τ the opposite is true, the decay is governed by time constant τ. A field decay of time constant $T+\tau$ fits this bill, hence we can expect the B field to follow

$$B = B_R exp\left(\frac{-t}{T+\tau}\right) \tag{9}$$

However, there is a problem with using this because the inductance L is dependent on the starting point for the re-magnetization where B might be above zero, Figure 3, hence T is also dependent thereon.

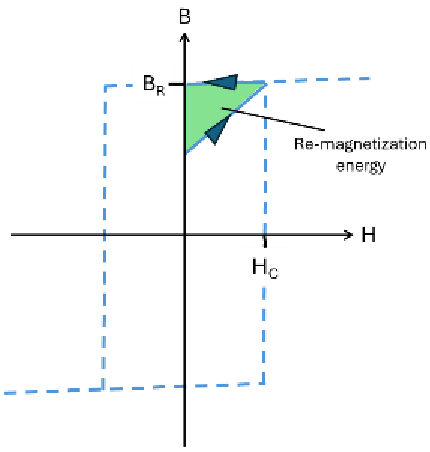

Figure 3. Re-magnetization energy

As a way forward we can use a spreadsheet to calculate the actual decay over small time increments taking account of the change in T. For an exponential decay of time constant $T+\tau$ the decay rate dB/dt at any point B on the curve is given by

$$\frac{dB}{dt} = \frac{-B}{T_{(B)}+\tau} \quad (10)$$

where we show *T* being a function of *B*. Thus we can use small time increments δt in the spreadsheet, then from (9) use

$$\delta B = \left(\frac{-B}{T+\tau}\right)\delta t \quad (11)$$

as the incremental fall in *B* over the time increment δt, with *T* evaluated for that level of *B*. Then increment *B* to a new level by

$$B_{n+1} = B_n + \delta B_n \quad (12)$$

and repeat the process.

3. Results

The spreadsheet was set up for a ring core wound with 100 turns. The core has a magnetic length of 15 cm and an area of $1 cm^2$, a B_R of 0.5T and a H_C of 50A/m. A natural decay of B_R is taken to have τ = 2mS. A typical result is shown in Figure 4 where the 100-turn coil is loaded with a 1Ω resistor; the coil is assumed to have zero resistance.

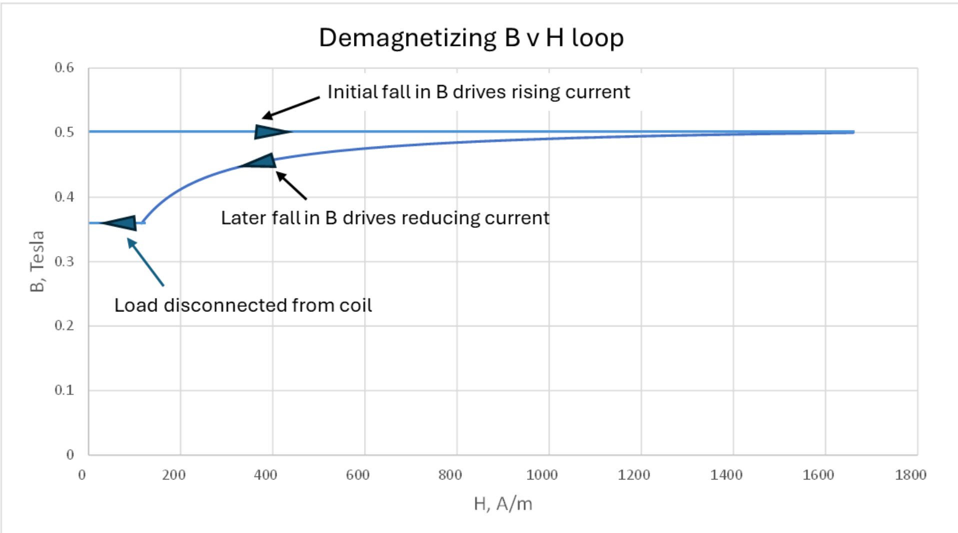

Figure 4. Demagnetizing BH loop

Note the loop is traversed CW indicating energy supplied to the load. Figure 5 shows the energy obtainable compared to the energy required to re-magnetize.

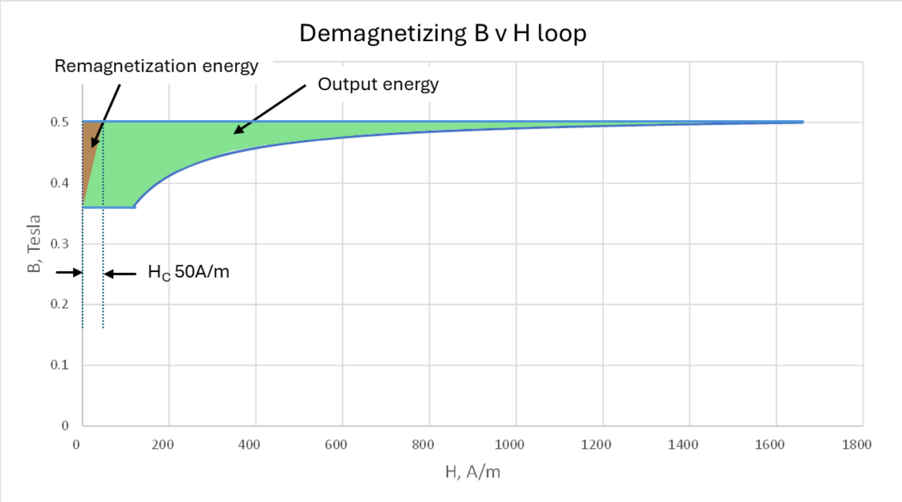

Figure 5. Showing energies

The re-magnetizing energy is 5.25×10^{-5} J while the output energy is 8.14×10^{-4} J, a COP of 15.42. Note the core demagnetization is stopped (coil disconnected from load) at a high value of *B*. Figure 6 shows *B* and *H* against time.

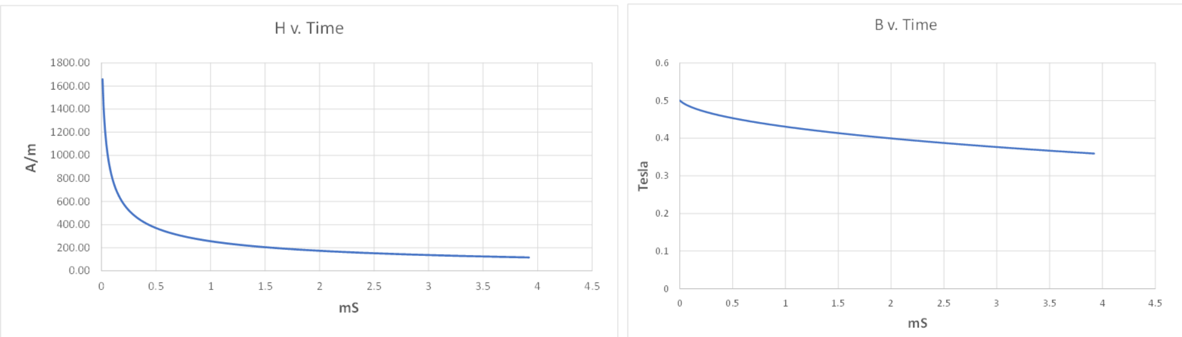

Figure 6. B and H v. time

The pulse sequence can repeat at a rate of 255 Hz yielding an output power of 208 mW. Note the large value of *H* (hence large load-current) that initially occurs due to the low value of *L* at that point (air-cored value at saturation).

4. Where does the excess energy come from?

To examine where the excess energy might come from and knowing that it is thermal agitation that is causing the magnetism decay, the spreadsheet includes a specific heat value for Fe of 451J/Kg°C and a density of 7874Kg/m^3. Then assuming that the output energy is extracted from the heat energy in the Fe core the temperature drop of the core is calculated. With the load kept at 1Ω and the decay time truncated at different values the following results were obtained.

Decay time mS	COP	Frequency Hz	O/P power W	Temp drop °C/S
3.92	15.42	255	0.208	3.9E-3
0.392	31.46	2,550	1.21	2.26E-2
0.0392	52.92	25,500	3.93	7.39E-2

Table 1.

If indeed this system is a means for converting heat energy into electrical energy, then it would require a thermal connection to a large heat source (ground?) with a thermal conductivity sufficient to make good that small temperature drop per second.

Figure 7 shows the B v H demagnetization curves for different load resistance values, with the time span kept at 3.92mS.

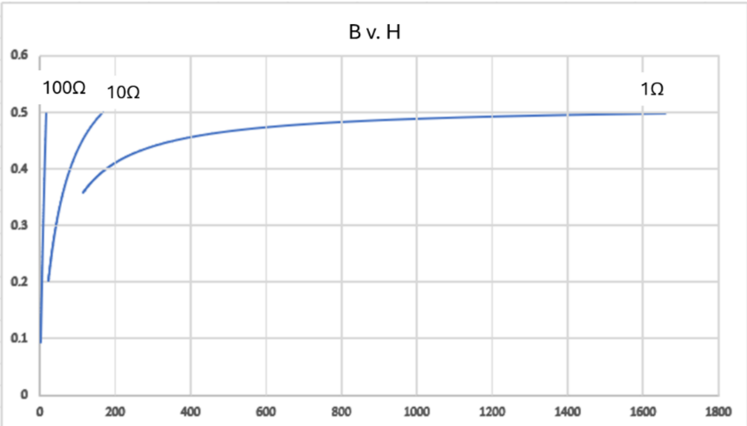

Figure 7. Demagnetization curves

Table 2 shows the COPs for those three demagnetization curves.

Load R Ω	Input energy J	Output energy J	COP
100	1.52E-4	5.50E-5	0.36
10	1.12E-4	3.12E-4	2.78
1	5.28E-5	8.14E-4	15.42

Table 2.

5. Discussion

That considerable excess energy shown in Figure 5 will be challenged by many experts in the field of magnetism, they will claim that you cannot extract magnetic energy from a core in excess of that supplied to magnetize it. Such people will happily accept that in a classical AC transformer energy per cycle transferred from primary coil input to secondary coil output can considerably exceed the core magnetic energy stored and retrieved twice each cycle. The core magnetism is merely an intermediary in the transport of electrical energy from input to output. In this new system the core magnetic energy is an intermediary between thermal energy input converted to electrical energy output.

Perhaps the most startling observation is the huge value of peak H seen in figure 5 that far exceeds the coercive value H_C. Lower values of load resistor yield even higher values, how can this be? If we take the peak value of H which is a turning point on the BH curve we can observe that

$$\frac{dH}{dB} = 0 \tag{13}$$

Then from the well known $B = \mu_0(H + M)$ that leads to $dB = \mu_0(dH + dM)$ which can be arranged as $\frac{dH}{dB} = \frac{1}{\mu_0} - \frac{dM}{dB}$, applying condition (13) and dividing by *dt* yields

$$\frac{dB}{dt} = \mu_0 \frac{dM}{dt} \tag{14}$$

We know that $\frac{dB}{dt}$ leads to a voltage $V = -NA\frac{dB}{dt}$ that drives current $i = \frac{V}{R}$ through a load resistor producing $H = \frac{Ni}{l}$ so that

$$H = -\frac{N^2A}{Rl}\frac{dB}{dt} \tag{15}$$

Note also that inductance L_{SAT} given by

$$L_{SAT} = \frac{\mu_0 N^2 A}{l} \tag{16}$$

Is the saturated inductance of the coil, hence

$$H = -\frac{L_{SAT}}{\mu_0 R}\frac{dB}{dt} \tag{17}$$

Combining (14) and (17) and noting that for temperature driven exponential reduction in magnetization $\frac{dM}{dt} = -\frac{M}{\tau}$ we obtain a value for H_{max} given by

$$H_{max} = \frac{ML_{SAT}}{\tau R} \tag{18}$$

The peak *H* values in Figures 5 and 7 closely meet this criterion. Note that the seemingly excessive (>>H_C) values of H_{max} reached with low values of *R* do not lead to excessive values of magnetization, *M* always shows a reduction from the start value. Put simply, the *H* value (17) from the induced current opposes (but doesn't fully stop) the reduction in *M* and *H* quickly rises to the value (18) before then falling away in slower time. The initial temperature-driven reduction *dM* in time *dt* given by $dM = -\frac{M.dt}{\tau}$ is opposed by the induced *H*. Clearly H_{max} cannot exceed *M* so (19) is only valid if $\frac{L_{SAT}}{R} < \tau$ which is true for the data given in the Figures.

Note the importance of the $\frac{L}{R}$ ratio here. That ratio is normally known as a time-constant applying to the exponential decay of current for an inductor connected to a resistor, or affecting the Q of a LC resonant circuit; (18) shows its significance in other areas.

6. Future work

Attempts should be made to reproduce SEMP's method of creating short demagnetization times. The SEMP patent application [4] [5] [6] shows demagnetization time as a function of the time taken to cool the iron during its heat treatment regime. The iron is heated to between 1000 and 1300°C within burning charcoal, then the charcoal and iron are slowly cooled during which time the iron absorbs a quantity of carbon that gives it the required characteristics. A long cooling period of 10 hours is needed to get the low demagnetization time. Figure 8 is the chart taken from the SEMP patent application showing demagnetization time against cooling time, with the actual times shown there taken from the patent text (the chart in the patent has no scales). It is assumed that the normal process of rapid quenching creates so-called permanent magnetism where the demagnetization time runs into years. The long cooling process of both iron and charcoal together that creates semi-permanent magnetization, reducing natural demagnetization time from years to milliseconds is new to science. For that years-to-milliseconds change to apply to the vertical axis in Figure 8 it must be to logarithmic scale.

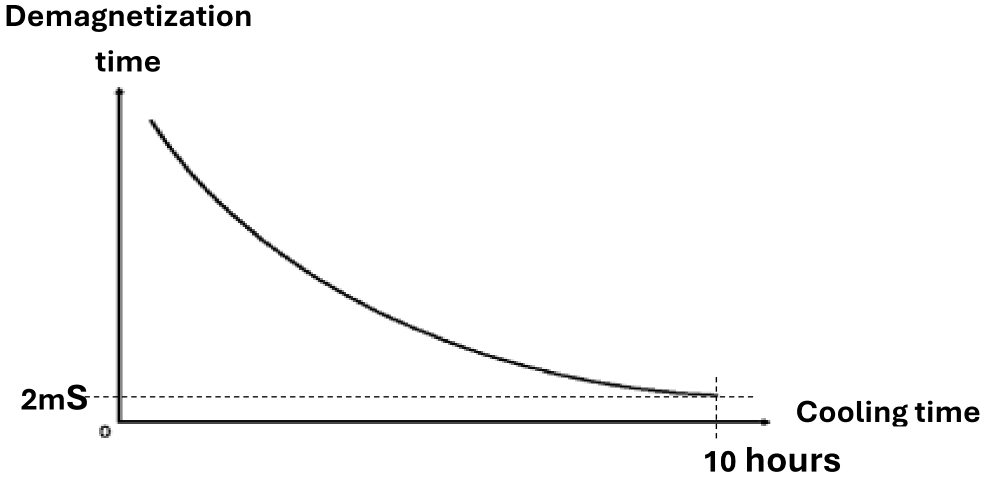

Figure 8. Demagnetization time v. cooling time

The SEMP patent describes Fe tubes onto which are wound a number of coils. It would seem sensible to use similar size tubes for the reproduction attempt, then wind a pair of bifilar coils over the length of the tube. To discover and measure the demagnetization time one coil could be pulsed to magnetize the core while the open-circuit voltage induced into the other coil could be integrated to provide a plot of magnetic field against time. Field change after the magnetizing current is switched off should indicate any natural demagnetization. Also, comparison with results from another assembly where the Fe core has not been carbonized should show a difference.

7. Conclusion

A theoretical approach to the new science of creating and utilising fast decay of remanent magnetism has been provided. This shows that in the sequence of (a) applying a magnetizing pulse followed by (b) using the natural decay to induce current into a load, energy in excess of that used to magnetize might be obtained. If this is found to be true it offers a new means of converting thermal energy directly into electrical energy.

8. References

[1] SEMP web site

https://www.semp.or.kr/en/%EB%B0%9C%EC%A0%84%EA%B8%B0%EC%9D%98-%EC%97%AD%EC%82%AC

[2] Paleomagnetism

https://www.geo.arizona.edu/Paleomag/tocpref.pdf

[3] Origins of Natural Remanent Magnetism

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[4] Korean patent application

https://www.overunityresearch.com/index.php?action=dlattach;topic=4563.0;attach=49839

[5] Korean patent application with English translation

https://www.overunityresearch.com/index.php?action=dlattach;topic=4563.0;attach=49838

[6] European patent application

https://www.overunityresearch.com/index.php?action=dlattach;topic=4563.0;attach=49864