An Analysis Of The Resultant Magnetizing Field Generated By Superimposing An Alternating Current and An Exponentially Increasing Direct Current In A Coil With Two Windings.

General Considerations.

The coil consists of two windings. Winding 1 carrying the dc-current and winding 2 carrying the ac-current. see fig. 1.

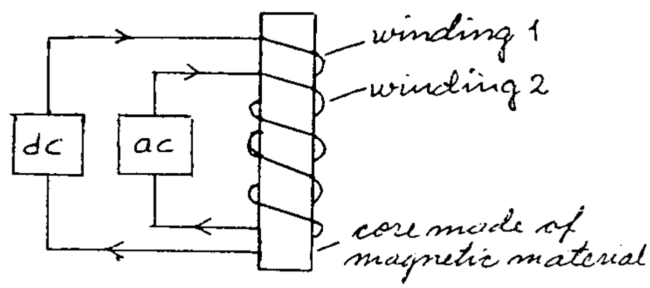


Fig. 1

N_1 = Number of turns in winding 1 (t)
N_2 = Number of turns in winding 2 (t)
R_1 = Resistance in winding 1 (ohms) (Ω)
R_2 = Resistance in winding 2 (ohms) (Ω)
L_1 = Inductance in winding 1 (Henrys) (H)
L_2 = Inductance in winding 2 (Henrys) (H)
U_{dc} = DC-voltage (Volts) (Potential difference) (V)
U_{ac} = AC-voltage (Volts) (Potential difference) (V)
i_{dc} = Instantaneous value of dc-current (Amperes) (A)
i_{ac} = Instantaneous value of ac-current (Amperes) (A)
t = time (Seconds) (s)
f = Frequency of the AC-voltage (Hertz) (Hz or C/s)
T = Periodic time (Seconds) (s)
ω = Angular velocity (Radians/second) (Rad/s)
$\mathcal{H}$ = Magnetizing field (Amperes/meter) (A/m)
$\mathcal{B}$ = Magnetic induction (Weber/meter²) (Wb/m²)
μ = Magnetic permeability (Henrys/metre) (H/m)
IN = Magnetomotive force (ampereturns) (At)

We neglect the mutual inductance M and the capacitance of the windings.

The equation describing the resultant magnetizing Field $H_{res.}$ is found by first solving the differential equations governing the currents in the coil.

The DC-circuit, (Fig. 2).

At the time $t = t_{ON}$ a voltage U_{dc} = constant, see fig. 2, is supplied to winding 1 and the instantaneous current i_{dc} is governed by the differential equation

$$\frac{di_{dc}}{dt} + \frac{R_1}{L_1} i_{dc} = \frac{U_{dc}}{L_1} \dots\dots\dots\dots (1)$$

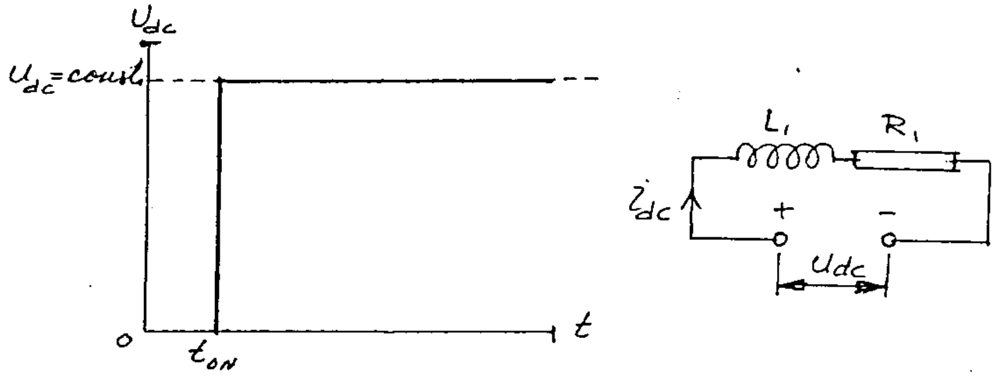


Fig. 2

The solution of the diff. equation 1 is the well known exponential increase of the current i_{dc} from the time $t = t_{ON}$, see fig. 3, and equation 2.

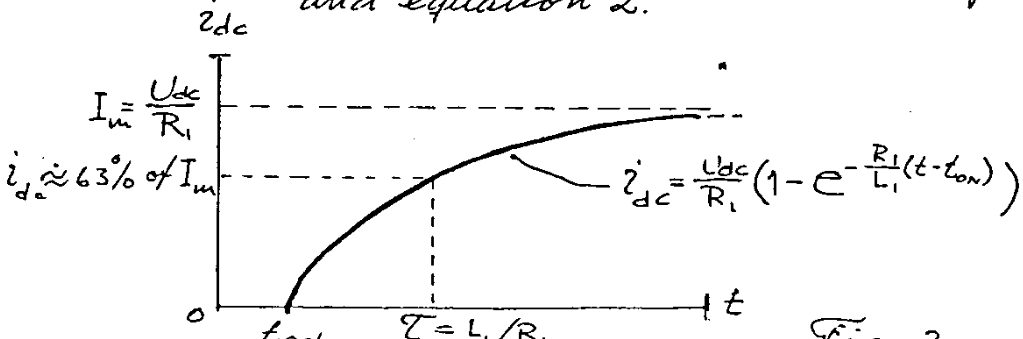


Fig. 3

$$i_{dc} = \frac{U_{dc}}{R_1}\left(1 - e^{-\frac{R_1}{L_1}(t - t_{ON})}\right) \ldots\ldots\ldots (2)$$

The ac-circuit.

At the time $t = t_{ON}$ a voltage $u_{ac} = \hat{U}\sin\omega t$ is applied to winding 2, see fig. 4. In this case the instantaneous current i_{ac} is governed by the differential equation

$$\frac{di_{ac}}{dt} + \frac{R_2}{L_2} i_{ac} = \frac{\hat{U}}{L_2}\sin\omega t \ldots\ldots\ldots (3)$$

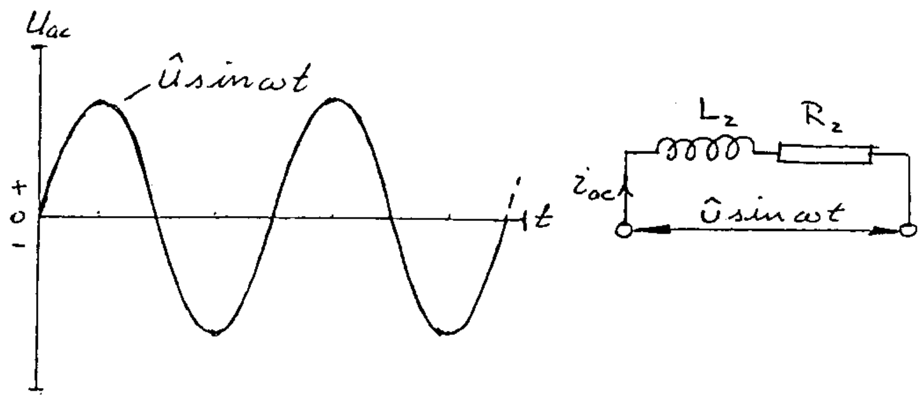


Fig. 4

The solution of differential equation (3) is a sum of a transient current, here

$$-\frac{\hat{U}}{\sqrt{R_2^2 + \omega^2 L_2^2}}\, e^{-\frac{R_2}{L_2}(t - t_{ON})} \sin\left(\omega t_{ON} - \arctan\frac{\omega L_2}{R_2}\right) \ldots (4)$$

see fig. 5, and a steady state current

$$\frac{\hat{U}}{\sqrt{R_2^2 + \omega^2 L_2^2}} \sin\left(\omega t - \arctan\frac{\omega L_2}{R_2}\right) \ldots\ldots\ldots (4a)$$

see fig. 6

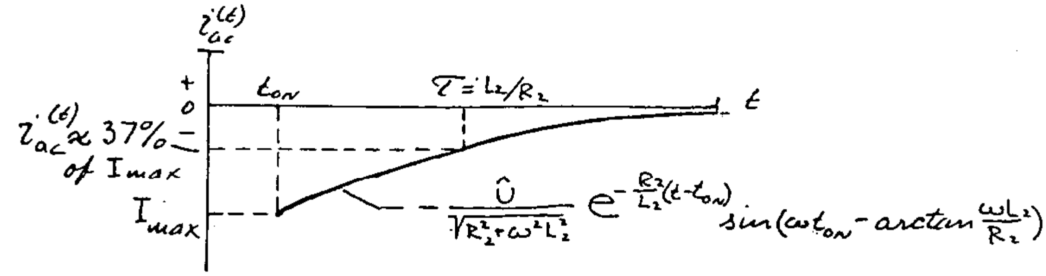


Fig. 5

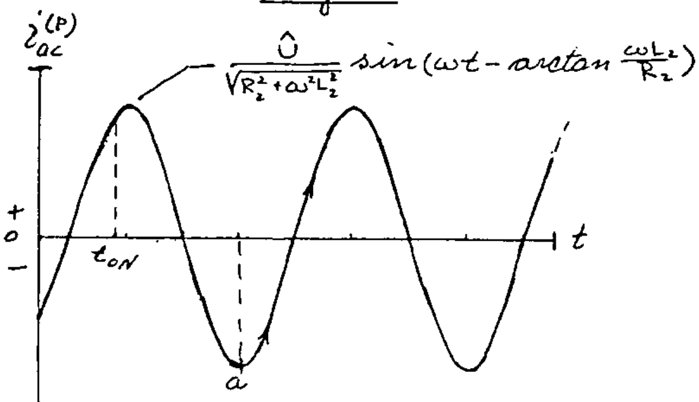


Fig. 6

The sum $i_{ac}^{(t)} + i_{ac}^{(P)}$ which is the true ac-current in the coil* is shown in fig. 7.

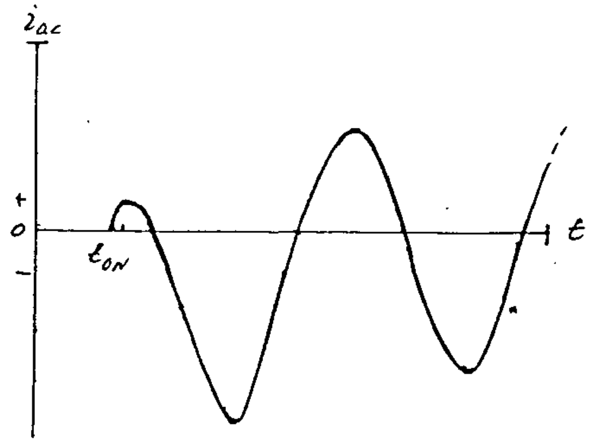


Fig. 7

* Should be winding 2.

The Magnetizing Field.

The total number of ampereturns $IN = i_{dc}N_1 + i_{ac}N_2$ will produce a resultant magnetizing field $H_{res.}$ of the form shown in fig. 8

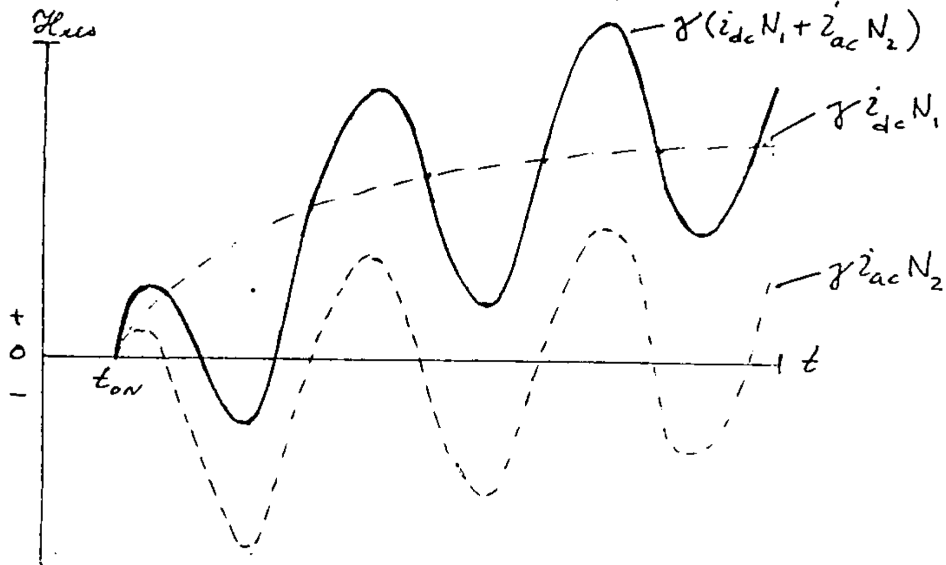


Fig. 8

Thus $\quad H_{res} = H_{ac} + H_{dc} = \gamma\,(i_{dc}N_1 + i_{ac}N_2) \ldots\ldots (5)$

Here, γ is a proportionality factor depending on the geometry of the magnetic circuitry. The curve form in fig. 8 represents the case when the time constant $\tau_1 = L_1/R_1$ of winding 1 is of the same order of magnitude as the periodic time $T = 1/f$ of the alternating current and when the number of ampereturns $i_{dc}N_1$ in winding 1 is of the same order of magnitude as the number of ampereturns $i_{ac}N_2$ in winding 2, i.e.

$$\frac{L_1}{R_2} \sim \frac{1}{f} \quad \text{and} \quad i_{dc}N_1 \sim i_{ac}N_2$$

This case illustrates most clearly the general details of the grows of the magnetizing field.

During the magnetization process the field $H_{res.}$ creates a magnetic induction $B = \mu H_{res.}$ in the magnetic material with a number of minor hysteresis loops superimposed on the virgin curve, see fig. 9

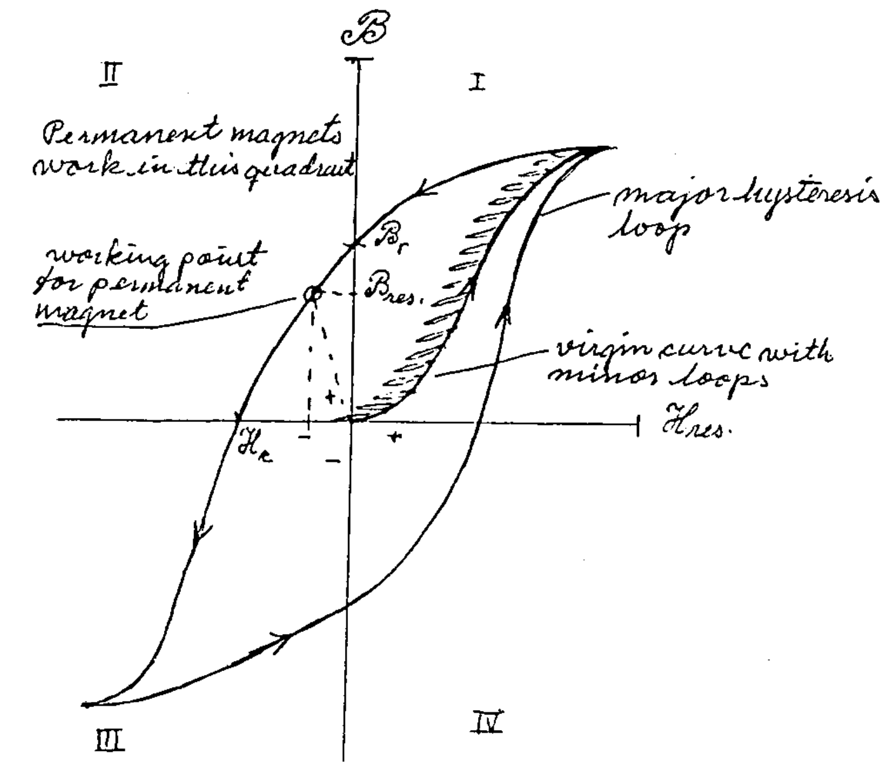


Fig. 9

Fig. 10 shows a more detailed picture of how the first few minor loops are generated.
To gain an understanding of the mechanism responsible for the Searl-Effect we must investigate what happen to the minor loops when the magnetizing field $H_{res.}$ is switched off, i.e. $H_{res.} = 0$ and the major hysteresis loop moves into the second quadrant creating a permanent magnetic induction $B_{residual}$, see fig. 9.

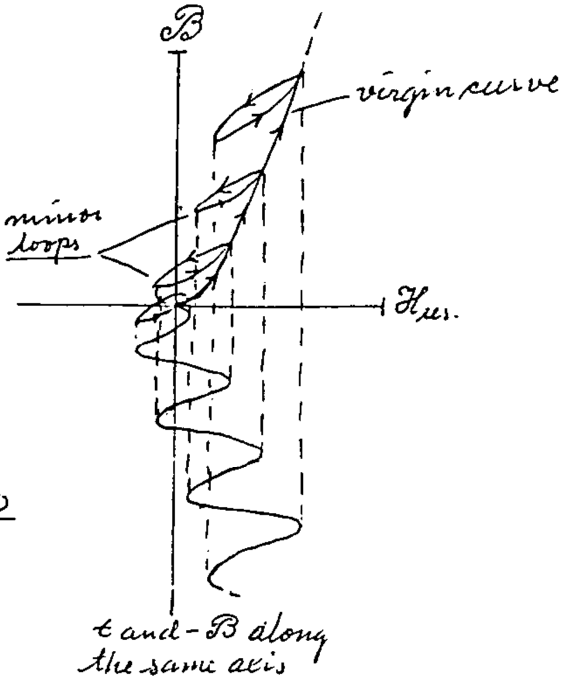


Fig. 10

According to your experience the conditions imposed on the switch should be such that the dc-current i_{dc} and the ac-current i_{ac} are switched on simultaneously at such a time $t = t_{ON}$ that their total magnetomotive force $i_{dc}N_1 + i_{ac}N_2$ is increasing in the positive direction and never allowed to become negative see fig. 11a.

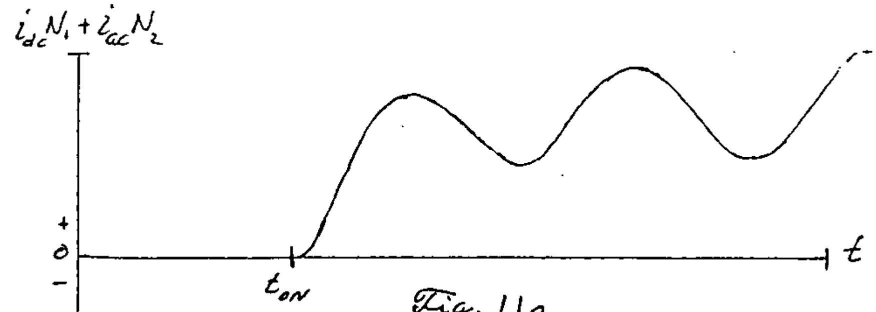


Fig. 11a.

or expressed in mathematical terms

$$i_{dc}N_1 + i_{ac}N_2 \geq 0 \quad \ldots\ldots\ldots (6)$$

this can be achived by switching on the voltage sources when the steady state..... cont'd

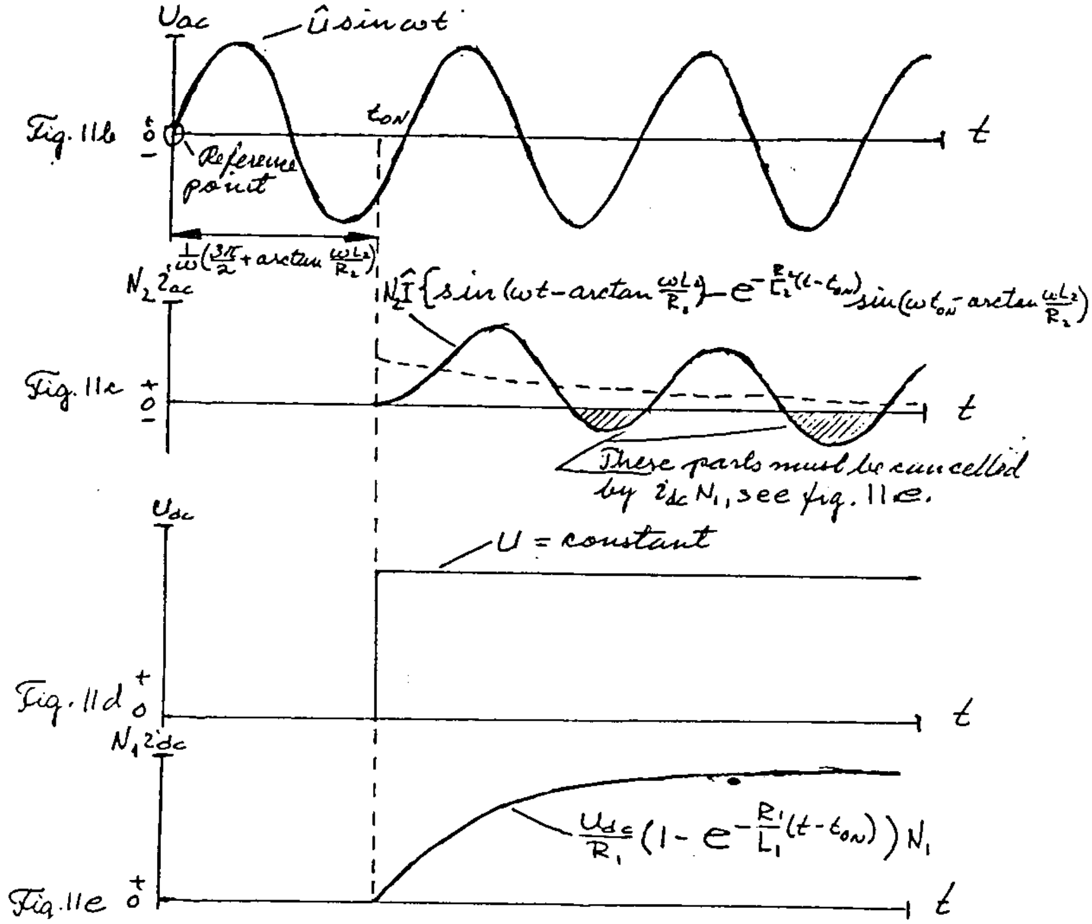


Fig. 11b, Fig. 11c, Fig. 11d, Fig. 11e

current $i_{ac}^{(p)}$ is beginning to grow in the positive direction, see point a in fig. 6. Let us choose as a reference point the zero-crossing of the ac-voltage, $\hat{u}\sin\omega t$, when the voltage is increasing in the positive direction from a negative to a positive value, e.g. the origin of the co-ordinate system in fig. 11b. t_{ON} can then be expressed in terms of L_2, R_2 and f.

thus $$t_{ON} = \frac{1}{2\pi f}\left(\frac{3\pi}{2} + \arctan\frac{2\pi f L_2}{R_2}\right) \quad \ldots(7)$$

The equation (7) is a necessary but not a sufficient condition to satisfy the inequality (6). Another, additional requirement is that the magnetomotive force, $i_{dc}N_1$ is growing fast enough to cancel the negative parts of $i_{ac}N_2$, see 11c and 11e.

The Magnetizing Coils Used For Production Of "High Energy Density" Magnets.

Based upon the information you gave me I have designed a set of magnetizing coils for the runners and the plate with the following specifications.

1. General Design Data.

The coils each consists of two identical windings. Each winding contains N turns of insulated metal strips of rectangular cross-section, $t \times w$, see fig. 12 Insulation thickness is denoted by t_i.

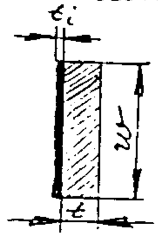


Fig. 12

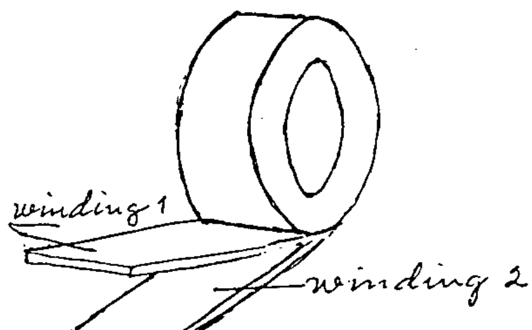


Fig. 13

The two metal strips are wound together around a cylindrical or annular body in a similar fashion as a paper insulated aluminium foil capacitor is made, see fig. 13.

Assume N turns are needed. We can then calculate the dc-resistance in each winding by using the well-known formula

$$R_{dc} = \frac{\rho \times l}{A} \quad \ldots\ldots\ldots\ldots \quad (8)$$

However, we must remember that this value of R is strictly valid only for direct current. Alternating current produces skin-effect that can increase the dc-resistance many times at higher frequencies.
When appropriate strip dimensions, $t \times w$ have been selected, the length l of each metal strip can be found by first calculating the average diameter D_{avg} of the coil. see fig. 14.

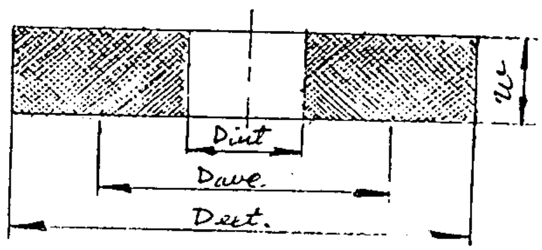


Fig. 14

D_{int} = internal diameter,
D_{ave} = average diameter.
D_{ext} = external diameter,
t = thickness of metal strip,
t_i = insulation thickness,
w = width of metal strip,
N = number of turns per winding,
l = length of metal strip in each winding.

$$D_{ave} = \frac{D_{int} + D_{ext}}{2} = 2N(t+t_i) + D_{int}$$

thus $l = N\pi D_{ave} = N\pi \{2N(t+t_i) + D_{int}\}$

and $R = \frac{\rho N \pi}{t w} \{2N(t+t_i) + D_{int}\}$ . . . . . (9)

here, ρ = resistivity of the metal used.

These dimensions of the "one-ring" generator in fig. 16 are in agreement with your specifications of the 15th of August, 1982.

Two coils (A and B), each with two identical windings, are needed to magnetize the runners see fig. 17:

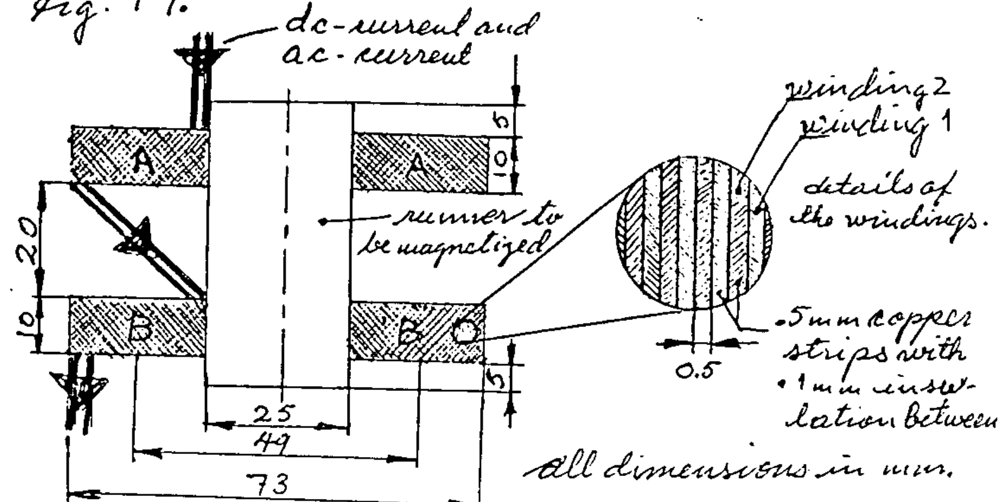


Fig. 17

$D_{int} = 25$ mm	$l = 3079$ mm in each winding.
$D_{ave} = 49$ mm	$R_{dc} = 0.011$ ohms if copper strips are used
$D_{ext} = 73$ mm	$L = 50\,\mu H$
$t = 0.5$ mm	$I_{dc} = 30$ A
$t_i = 0.1$ mm	$\hat{I}_{ac} = 50$ mA
$w = 10$ mm	$X_L \approx 314\,\Omega$
$N = 20$ turns in each winding	

The inductance of each winding is 19.3 μH according to the formula for a single air loop. However, the magnetic material in the core will increase the value of L, let us say 50 μH.

If we use frequencies between 1 MHz and 3 MHz the inductive reactance $X_L = \omega L = 2\pi f L$ will be considerably greater than the resistance, i.e. $\omega L \gg R_{dc}$ even if we take the skin effect into account.

At 1 MHz we have

$$X_L = 2\pi \times 10^6 \times 50 \times 10^{-6} \approx 314 \text{ ohms.}$$

Due to the assumption that the dc-winding is identical to the ac-winding we have

$N_1 = N_2 = N$
$R_1 = R_2 = R$
$L_1 = L_2 = L$

To simplify the calculations we neglect the skin effect since it does not contribute any new knowledge regarding the magnetization process.

Equation (5) for the resultant magnetizing field $H_{res.}$ generated by the currents in the coil can now be written in the following, simplified form

$$H_{res} = \gamma\left\{\frac{U_{dc}}{R}(1-e^{-\frac{R}{L}t}) + \frac{\hat{U}}{\omega L}(e^{-\frac{R}{L}t} - \cos\omega t)\right\}N \ldots\ldots (13)$$

together with the condition (6)

$$\left\{\frac{U_{dc}}{R}(1-e^{-\frac{R}{L}t}) + \frac{\hat{U}}{\omega L}(e^{-\frac{R}{L}t} - \cos\omega t)\right\}N \geq 0 \ldots\ldots 13a$$

For the coil in fig. 17 we have the following data:

$R_1 = R_2 = 0.012$ ohms
$L_1 = L_2 = 50\mu H$ (micro henrys)
$N_1 = N_2 = 20$ turns
$\frac{U_{dc}}{R} = I_{dc} = 30A$
$\frac{\hat{U}}{\omega L} = \hat{I}_{ac} = 50mA$

f is between 1 and 3 MHz.

Thus

$$H_{res} = \gamma\left\{30(1-e^{-240t}) + 0.05(e^{-240t} - \cos(2\pi f t))\right\} \times 20$$

Let us look at the details of the magnetomotive force IN for a 1MHz ac-current a few micro seconds after switching on:

$$\mathcal{H}_{res} = \gamma [I] N = \gamma \{30(1-e^{-220t}) + 0.05(e^{-220t} - \cos(2\pi \times 10^6)t)\} \times 20$$

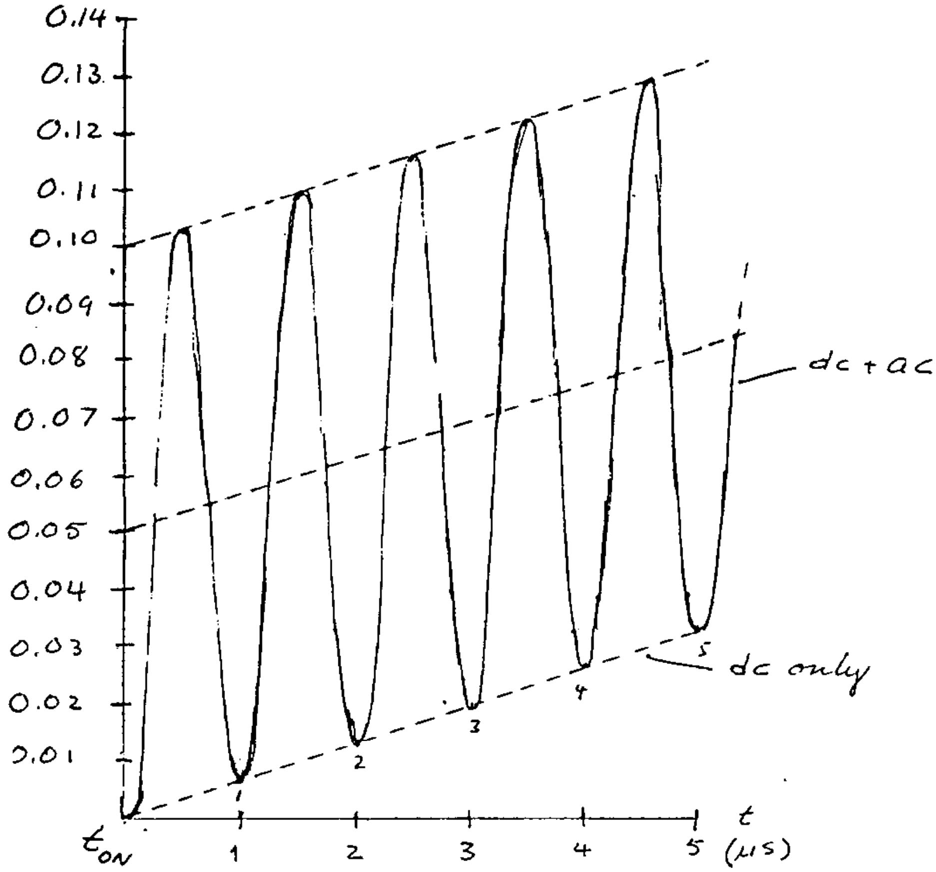
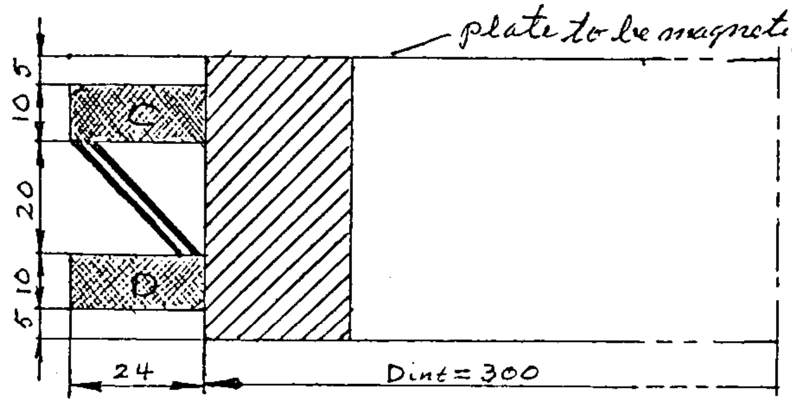


Fig. 19

Fig. 19 shows the first five periods of the ac-current and the exponential increase of the dc-current for the condition that $\hat{u} \sin \omega t$ is switched on at $t_{ON} = 0$.

The Magnetizing Coils For The Plate.

These coils are used for magnetizing the plate to the generator in fig. 16.
Two identical coils, each with two identical windings are needed to magnetize the plate see fig. 20.



* This is valid if we use the same DC-power supply for runners and plate.

Fig. 20

Dint = 300 mm	ℓ = 20.36 m in each winding
Dave = 324 mm	R = 0.073 ohms if copper strips are used
Deit = 348 mm	L = ~~2~~330 μH
t = 0.5 mm	I_{dc} = ~~30~~A (5A)?*
t_ξ = 0.1 mm	$\hat{I}_{ac}$ = 7.5 mA
w = 10 mm	
N = 20 turns in each winding	

* This is a very uncertain figure due to lack of information about the powersupply (DC). The current is probably much higher.

The inductance of each winding is 128 μH according to the formula for a single air loop.
Due to the magnetic material in the plate the value of L will increase, let us say 200 μH. to 330 μH.
If we use the same dc powersupply and the same signal generator, set at the same frequency and the same output voltage the current. ...

cont'd

$\hat{I}_{ac}$ in the ac-winding will drop to a lower value due to the increase in the inductive reactance X_L,

thus $$\hat{I}_{ac} = \frac{\hat{U}_{ac}}{X_L} = \frac{\hat{U}_{ac}}{\omega L} = 7.5\ mA,$$

if we use the same ac-voltage for the plate-coils as we did for the runners-coils, and keep the frequency constant. Due to the lower ac-current the minor loops in the magnetization diagram (fig. 9 and 10) will be correspondingly smaller.

Summary.

Two sets of coils have been designed, one set for magnetizing the runners and another set for magnetizing the plate, see fig. 21

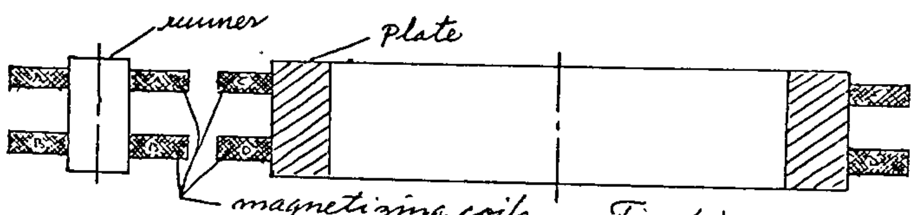


Fig. 21.

Each coil consists of two identical windings, one winding carrying the dc-current and the other winding carrying the ac-current. The coils are made of 10 mm × 0.5 mm copper strips and all windings contain the same number of turns. In this particular case the number of turns N = 20.*

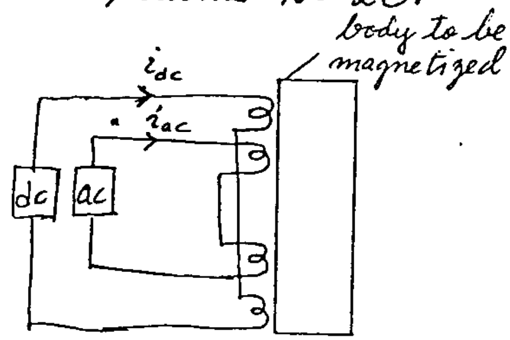
$U_{dc} = 0.7V\ (0.7V)$

$I_{dc} = 30A\ (5A?)$

$\hat{U}_{ac} = 16V\ (16V)$

$\hat{I}_{ac} = 50mA\ (7.5mA)$

Figures within brackets valid for the plate

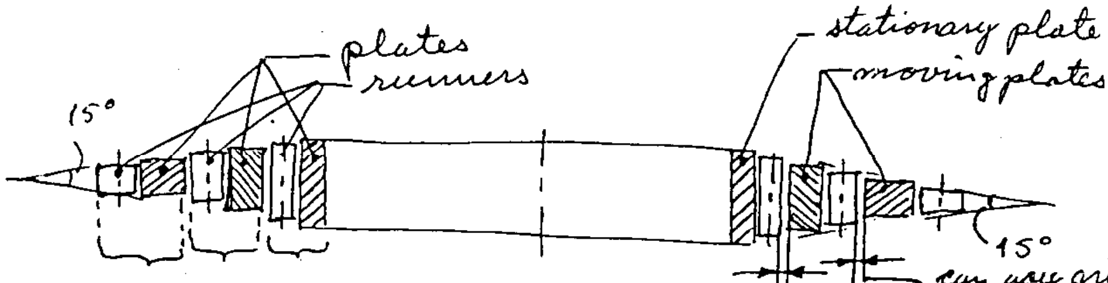


* Each coil contains 2 × 20 = 40 turns. Do you think this is enough? Is the current high enough. Please, can you comment on these and other points.

The dc-current $I_{dc}^{(P)} = 5A$, is the theoretical value of the current in the plate-coils, if we use the same dc-voltage across both plate-coils and runner-coils, when the current in the runner-coils is adjusted to 30A and we neglect the internal resistance of the power supply. In practice, however, we must consider the internal resistance of the power source, which means that the dc-voltages across the coils will be different for the runner-coils and the plate-coils even if we use the same power-supply in both cases. This implies that the dc-current $I_{dc}^{(P)}$ in the plate-coils, could be anywhere between 5A and 30A depending on the internal resistance of the power-source, unless the current was regulated by a rheostat. Do you ~~rember~~ remember whether or not you controlled the dc-current $I_{dc}^{(P)}$ in the plate-coils, to be set to the same value as the dc-current $I_{dc}^{(R)}$ in the runner-coils.

If you consider the coils to be of proper design, I will go ahead with the construction of the electronic switch and the coils for a "one-plate" generator. I am also planning to write a paper on the "3-plate generator" used in the Searl-Disc and analize the problem of finding the optimal size of the generator, based on the conditions you have stipulated.

When I have all the facts right I will make proper drawings of the magnetizing coils with power supply and electronic switch. I have also started to make drawings of the craft, but there are still many details to be discussed. I enclose a sketch of the "3-plate generator" according to your description

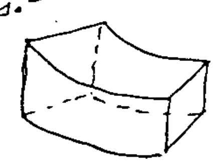


Diametral cross-section of 3-plate generator.

can you give som idea of the distance between each section? pleas.

The weight of each ball-race section should be the same, i.e. the weight of each section is one third of the weight of the generator. The generator weight is 70 % of the total weight of the craft. Each section contain the same number of runners. — NO

Could you give me some information regarding the plates. I assume each plate is made of a number of circle segments, is this correct? How many segments compared to the number of runners. How are the segments fixed to each other, are there any spacers between the segments?



ring-segment

You may find this information, concerning the magnetizing coils, a bit confusing. I will ~~rewrite it~~ reformulate the content and make it more comprehensible when I have all the details right. I will send you a ~~copy~~ type written copy later.