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HUNTING ENERGY IN SPACE

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Hunting energy in space

§1. Suppose that an electron gun and an ion gun are connected through a resistor $R$ according to Fig 1. $C$ is the cathode, $F$ the focusing and accelerating electrode of the electron gun, which shoots a beam to the anode $A$. $C'$ is the anode, $F'$ the focusing and accelerating electrode, and $A'$ the receiving cathode of the ion gun. Both guns emit the same current $I$ which is supplied by a battery $V$. If the guns are appropriately constructed the currents $I_1$ and $I_1'$ to the accelerating electrodes (fed from batteries $V_1$ and $V_1'$) need only be a small fraction of $I$.

We assume that the regions between $F$ and $A$, and between $F'$ and $A'$ are field-free. This means that the space charge of the beams is neutralized by particles at rest of opposite sign, and that

$$ V = V_1 + V_1' + RI $$  \hspace{1cm} (1)

Consider an imaginary cylinder $a a'$ with radius $r$ and length $l$, enclosing the guns and the resistor. Its axis coincides with the (coinciding) axes of the guns. The battery $V$ feeds the power

$$ P = VI $$  \hspace{1cm} (2)

into this cylinder. Of this

$$ P_1 = (V_1 + V_1')I $$  \hspace{1cm} (3)

is used for accelerating the electrons and ions, and the rest

$$ P_R = P - P_1 = RI^2 $$  \hspace{1cm} (4)

is dissipated in the resistor. Further the batteries $V_1$ and $V_1'$ deliver the power
P_2 = V_1 I_1 + V_1' I_1' \tag{5}

to the accelerating electrodes. Finally, a certain power \( P_3 \) is necessary for heating the cathode \( C \) and producing the ions in \( C'F' \). The total loss power is

\[ P_L = P_2 + P_3 \tag{6} \]

It is possible to make \( P_L \) much smaller than \( P_R \).

§2. We make our imaginary cylinder a real one, connecting its conducting end plates to the electrodes \( F \) and \( F' \). The cylindrical surface is made of insulating material. We place our device in interplanetary space and remove \( A \) and \( A' \) to large distances from the cylinder. Further we replace the battery \( V \) by the polarisation field

\[ V = \int_{A'}^{A} (v \times B) \, ds \tag{7} \]

in the solar wind. The electrodes \( A \) and \( A' \) are replaced by "mixing regions" where the particles of the beams mix with the solar wind so that electric contact with the plasma is achieved. The regions \( FA \) and \( F'A' \) cannot be perfectly field free in the solar wind. Essential for the following is that space charge in these regions do not turn back the emitted particles to the space craft (see 4).

§3. We see that the spacecraft (consisting of the cylinder with guns and resistor inside) receives the energy \( P \) from space. A fraction \( P_L + P_L \) of this is used for shooting out the beams but the rest \( P_R - P_L > 0 \) can be used in any desired way. Hence we have proved the apparent paradox that

a spacecraft can gain energy from space by shooting out electron and ion beams.

We can check this conclusion by computing the energy
flux over the cylindrical surface. We have $H=2I/r$ and $E=V/1$ and the Poynting vector is $\mathbf{T} = \frac{1}{\mu_0} (\mathbf{E} \times \mathbf{H})$ which should be integrated over $2\pi r l$. This gives $P=V I$ as in (2).

§4. Hence if we construct a spacecraft according to Fig.2 this can extract energy from space. However there is an important condition which has to be satisfied; space must accept the emitted particles and not turn them back to the spacecraft. In fact, if $F$ and $F'$ (or the end plates connected with them) receive a current - either consisting of turned back particles or of particles collected from space - this will cause a power drain of the batteries $V_1$ and $V_1'$ which may exceed the energy gain.

Hence the real problem is how to get rid of the emitted particles.

As the voltage difference between $C$ and $C'$ is $RI$ we must deposit the ions in a region with a voltage which differs by at least $RI$ from the region where the electrons are deposited. This holds if the electric potentials are static, but if there are oscillations or waves the conditions become more complicated.

The conclusion is that a spacecraft may tap any plasma energy stored in a region of space which can be reached by an electron or ion beam shot out from the spacecraft. The art of hunting energy will consist in hitting the game in spite of opposing space charge, in part produced by the beams themselves.

References

Alfvén, H., 1972  Spacecraft Propulsion: New Methods, Science, 176, 4031


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Fig. 1. An electron gun CF shoots electrons to the anode A and an ion gun C\textsuperscript{F} shoots ions to the cathode A'. The result is that energy from the battery V is transferred to the resistor R. Hence a spacecraft can extract energy from space by emitting electrons and ions.
Fig. 2. A spacecraft shooting electrons to a region of positive potential and ions to a region of negative potential extracts energy from space which can be transferred to a plasma gun accelerating the spacecraft.
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It is shown that a spacecraft can extract energy from space simply by shooting out electrons in one direction and ions in another. The energy can be used for example for propulsion of the spacecraft.

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