191 / 10-4-79

Hi. 120

LA-8000-C

Conference

MASTER

Proceedings of the Impact Fusion Workshop

National Security and Resources Study Center

Los Alamos Scientific Laboratory

Los Alamos, New Mexico

July 10—12, 1979

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

Post Office Box 1663 Los Alamos, New Mexico 87545

COUNTER-ROTATING DISK HOMOPOLAR GENERATOR ("CRDHG")*

Richard L. Garwin

The following is a brief recap of a proposal of 1950 for a fast-discharge HPG.

1. Mechanical rotation is limited by peripheral speed v such that $1/2\ \rho v^2$ (the kinetic energy density per unit volume) is comparable with the breaking stress S in dyne/cm^2. For a set of <u>rings</u>, we have the well-known criterion $\rho v^2 = S$. Thus, to store a total energy E, we need a mass M such that $1/2\ v^2 M = MS/2\rho = E$, or $M = 2E\rho/S$.
For $S = 150{,}000$ psi $= 10^4$ bar $= 10^{10}$ dyne/cm^2, we need a mass M_1 per megajoule

$$M_1 = 2\rho E/S = 20 \text{ kg/MJ} \quad .$$

2. If the mass is in the form of disks rotating at initial angular velocity ω_o, we are limited by $\omega_o R = v$, so that for no dependence on radial strength (not the only design possibility) and for uniform disk thickness, the kinetic energy stored is

$$\int_{R_1}^{R_o} (1/2)\ 2\pi R\rho H\omega^2 R^2 dR = K = \pi\rho H\omega^2 (R_o^4 - R_1^4)/4 \quad ,$$

and per unit mass $K/M = (v^2/4)(1 + (R_1/R_o)^2)$.

3. Since the mass is already subject to an acceleration $\dot{v}_o = \omega v_o = v_o^2/R$, we can <u>stop</u> the rotation in <u>one radian</u> rotation without adding much to the stress. This is a delivery time $\tau = R/v_o = 1/\omega_o$ and

*To be published as JASON Technical Note, JSN-79-03, SRI International, 1979; done in part under U.S. Department of Energy Contract EY-76-C-03-0115.

may be 60×10^{-6} seconds for $R = 30$ cm and $v_o = 500$ m/sec , corresponding to $S = \rho v^2 = 8 \times (5 \times 10^4)^2 = 2 \times 10^{10} = 2 \times 10^4$ bar .

4. As indicated by the title, we can consider a set of annular disks, N/2 attached to an axis (perhaps loosely) and N/2 interspersed disks attached to the inside of an enclosing cylinder or rotating cage of axial bars at radius R . The N/2 disks extending from the axle and the N/2 disks extending in from the cage are counter-rotated at angular velocity $\mp \omega$. Clearly, each disk produces in the laboratory frame a voltage difference between its inner and outer rim

$$\Delta V = 10^{-8} \int v \times B dR = \omega B \times 10^{-8} \frac{R^2}{2} = \frac{BR}{2} \times 10^{-8} v_o \quad , \quad (\text{if } R_i << R_o) .$$

For $B = 10^5$ gauss , $v_o = 5 \times 10^4$ cm/sec , $R = 30$ cm , $\Delta V = 750$ volts .

A stack of 60 disks therefore gives 45 kv.

5. A cylinder of metal with a 50% packing fraction, 30 cm radius, 60 cm long, with density $\rho = 8$ g/cm^3 and $v_o = 5 \times 10^4$ cm/sec has $E = 1/2\ Mv^2 = 1/4\ Mv_o^2 = 1/4\ \rho \pi R^2 \times R \times (5 \times 10^4)^2 = 4 \times 10^{14}$ ergs = 40 Mj The output power at $\omega = v_o/R = 5 \times 10^4/30 = 1.7 \times 10^3$ rad/sec (or 16000 rpm) is about 40 Gw.

The matched load impedance is order of magnitude Z , such that $V^2/Z = \omega E$ or $Z = N^2(\Delta V)^2/\omega E$. So for $N = 60$, $\Delta V = 750$ volts , $\omega = 1.7 \times 10^3$, $E = 4 \times 10^7$ joule , $Z = 0.03$ ohms . So that $I = 1.5 \times 10^6$ amp .

The circumferential magnetic field near a disk is then $I/10\,R = 1.5 \times 10^6/10 \times 30 = 5000$ gauss , small compared with the 100 kilogauss assumed axial field. Therefore the inductance is <u>low</u> (i.e., the internal magnetic energy is ouly about $E_B = \int H^2 d^3R/8\pi = I^2R/400$ ergs = 20 kj versus some 40 Mj stored kinetic energy.

Although many applications do not need the rapid delivery available from the counter-rotating disk homopolar generator, the potential of such a device should be kept in mind. Naturally, one has the problem of rapidly and synchronously making contact between adjacent rims and center rings of rotating disks, which can be done by coating the disk largely with insulating material where contact is not desired, and striking an arc in an enclosing low pressure gas. The opinions of people more expert than I are sought, and that is the reason for raising this question once again after so many years at this topical conference.