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PROPOSAL FOR EXPEDITING THE ACHIEVEMENT OF A STRONG (10^{14}-10^{15} NEUTRON) THERMONUCLEAR DD REACTION BY EXPLOSIVE COMPRESSION

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PROPOSAL FOR EXPEDITING THE ACHIEVEMENT OF A STRONG (10^{14}-10^{15} NEUTRON) THERMONUCLEAR DD REACTION BY EXPLOSIVE COMPRESSION

by

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Based on what Messrs. Fowler et al of GMX-6 have already done, and building up from what we already know about electromagnetic compression and heating in Sherwood, I think it is virtually certain that HE compression can be applied very directly and quickly to raise the level of thermonuclear reactions currently achieved in Sherwood (about 10^9 neutrons per compression) to 10^{14} and foreseeably without too much strain to 10^{16}. The HE compression adds the equivalent of about 10 MJ of condensers to an electromagnetic compression. Where one goes after 10^{16} depends, I would think, on what one sees from that vantage point. But I see no reason why still higher levels could not ultimately be reached via, for example, spherical implosions of closed electromagnetic systems. All kinds of nice (and nasty) developments might follow. I think we at Los Alamos could very properly be criticized if we do not go into this thing with a will. And I am absolutely sure that the competition would jump at it, if they only had the wits to see how. The GMX-6 is a terribly small outfit - and to do this experiment, they should literally live with it and resolutely drop everything else. We in Sherwood could conceivably be of some help (apart from the advice and equipment we have provided hitherto) - by for example designing and constructing an end-fed coil and checking its performance. But this would mean a partnership with GMX-6 and all that that implies. And we would have to stop doing something we are doing now - which is hard.

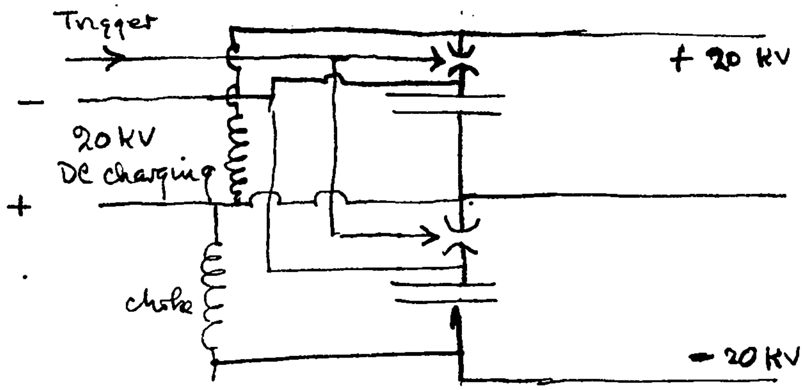
As a matter of fact, GMX-6 have already come within a hair's breadth of seeing an amplification of the neutrons from an electromagnetic implosion - and the only reasons that they have not already achieved large increases are (1) the use of a condenser-coil system of too low a voltage, (2) an undue tendency to stay with electromagnetic systems having a high degree of asymmetry, (3) having too small a condenser bank, which obliged them to use their magnetic energy so economically that their choice of coil lengths, diameters and feeder conductors was restricted, and (4) side-tracking into other applications of HE magnetic compression.

From the GMX-6 work, it seems clear that the output from an explosive compression can be expected to have two characteristic thresholds, (1) that produced by compression of a glass-walled system. The glass debris fills up the available space after compression, limiting the maximum field to about 10^6 gauss - which in turn computes to a yield of perhaps 10^{14} neutrons from DD. (2) More complicated systems which eliminate the glass, placing the compression conductor in contact with the plasma. In this case, the maximum field it is believed can be upwards of 10^7 gauss. From this, we might expect 10^{16} neutrons from DD.

The question has been asked: What value has such an exercise? After some reflection, my opinion is that this experiment does not need to have some piece of plasma physics information - e.g. cyclotron radiation from a hot plasma - to justify it. A 10^{16} neutron laboratory thermonuclear reaction is a worthwhile technical objective in its own right. The Frascati Laboratory under the direction of Linhart with the connivance of many quite distinguished physicists of Euratom has been working for years on just this aim.

The Proposals:

1. Double the effective operating voltage - from 20 keV to 40 keV.



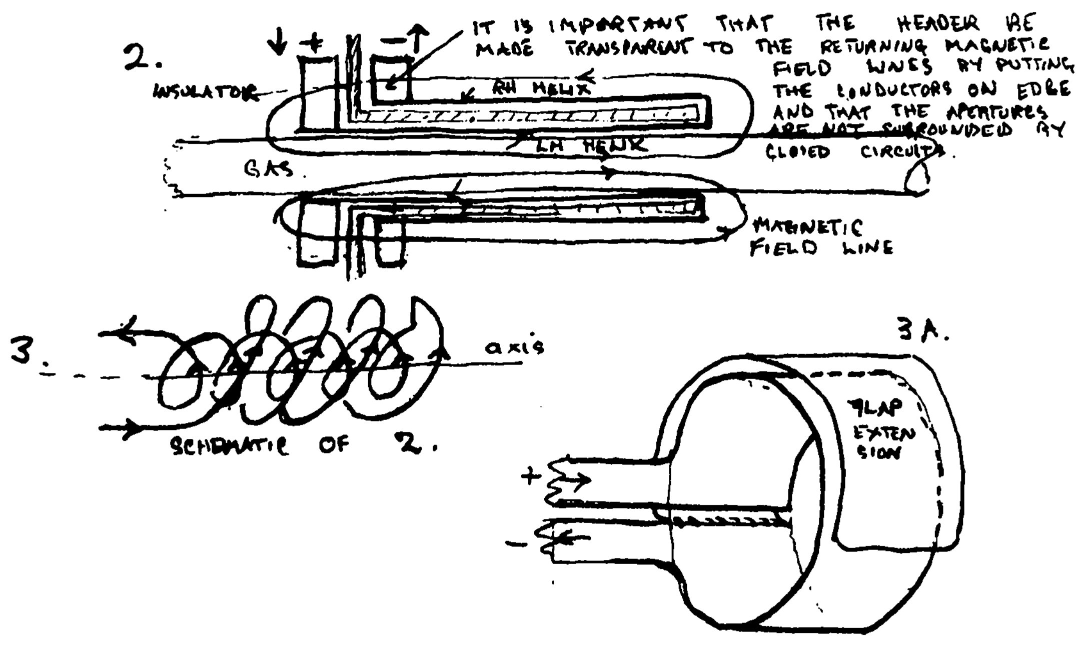
1.

The circuit of Fig. 1 allows one to do this in a nice way without requiring or producing more than 20 kV with respect to ground using the present Sherwood condensers. In effect, the condensers are charged in parallel, but discharge in series + and - with respect to ground.

The increase of voltage is the most important proposal I have to make. There are many (perhaps thirty) θ-pinches in operation around the world. Most of these were built as a consequence of the obvious success of our Scylla. The high voltage θ-pinches produce high temperatures and the low voltage θ-pinches tend not to. A discussion of the reason for the dependence of temperature on electric field is complicated by the presence or absence of a reversed magnetic field which shares in the heating process. However the probable explanation for the higher temperatures at higher electric fields is that the initial ionizing shock strength p/p_o is proportional to the initial electric field, E_θ and that the initial ion temperature is more than linearly related to the shock strength. This conclusion is supported by a recent computation by Oliphant and Ribe - see Sherwood Semiannual Report, November 1964.

We have produced good neutron yields from a 20 kV θ-pinch - namely that of Mather. But in this exceptional case, the parasitic inductance had been made extremely low - to a value hard to approach for an HE system where the condensers must be protected from the blast. Increasing the effective coil voltage is much less work and more flexible.

2. For the coil: Use one of the numerous possible end-fed conductor arrangements (i.e., of the kind Fowler calls T-M coils). Figs. 2 and 3. There is a possibility of correcting the grave asymmetry of the present GMX-6 coils - which would work almost equally well. Fig. 3-a.



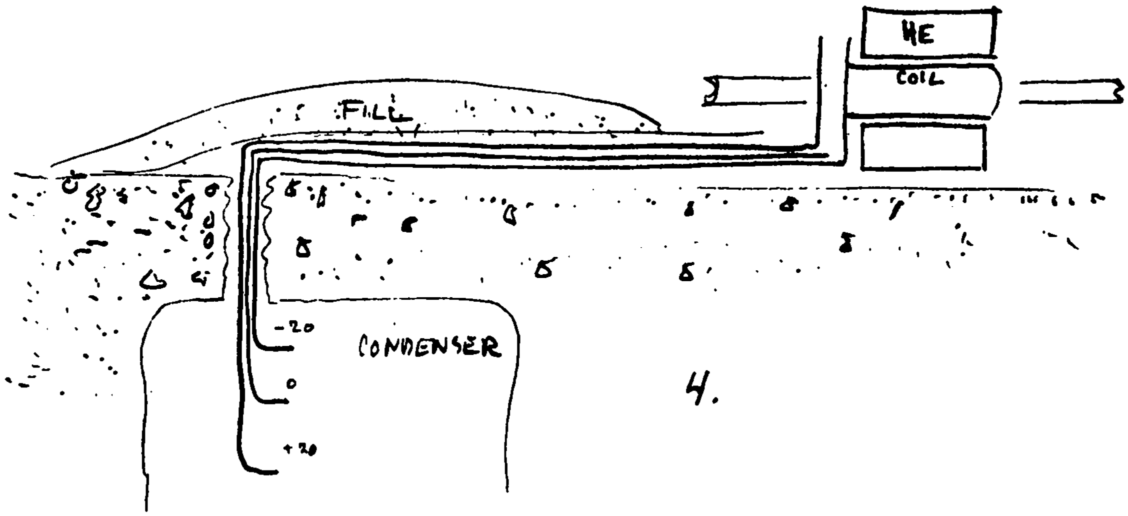
This will effectively give electromagnetic symmetry, and also makes it possible if needed, to slip the HE over the coil at the last minute.

3. The problem of whether or not to use magnetic mirrors on the compression coil is many sided - probably one should try both. The absolutely most reliable way of making sure that the explosive compression is a success, would be to use a very long coil without mirrors. This in turn implies a large condenser bank - say 200 kJ in order to be able to fill it with magnetic field, and large HE charge to be able to implode it, which in turn complicates the blast protection. On the other hand, if the coil is made short, magnetic mirrors are needed to keep the plasma from leaking away during the relatively slow HE compressions. The magnetic mirrors increase the risk of plasma loss radially across the magnetic field by flute instability. Our experience suggests that the risk is not large if the temperature can be made high - 1 keV or more, which in turn emphasizes the importance of high voltage for the condenser bank. The use of magnetic mirrors on the coil requires that the HE be managed in such a way that the magnetic mirrors be maintained during the HE implosions. This looks rather straightforward to me, and it may even suffice to initiate a plain HE cylinder simultaneously from its ends.

4. Condenser bank details: Ignitrons at full 20 kV voltage suffer from prefires. The thin end-fed coils are probably destroyed by the electromagnetic forces so they only serve for one shot. Hence, and for explosive safety reasons, ignitrons at 20 kV, though fine for Sherwood, are not good for Fowler.

The Mather vacuum spark gaps provide an ideal solution. They are reliable, and work over a great voltage range (better than ignitrons). This allows the coil to be cautiously tested in position before the HE firing. But the technique must be lifted in its entirety - order them off the existing drawings and make no changes whatever. People have made inconsequential-looking changes in this technique with disastrous results.

5. I think that the Sherwood technique of many coaxial cables from condenser to coil as currently used by GMX-6 is not the best for them - since there is so much detail work replacing all the cables and connections which are destroyed after a shot. I think a parallel plate line made of thin copper sheet, taken straight off the roll, and interleaved by the appropriate number of Mylar sheets similarly taken off the roll, would be much less labor. The line would be covered over with Mylar and held down by weights or even by earth (dirt fill) heaped on it. The line would shift under the electromagnetic forces but by then, the shot is over. It should be noted that such a design can readily give inductances comparable with multiple cables, and connects very naturally to the end-fed coil. The insulation between the inner and outer layer of the end-fed coil is plastic welded to a flange which interleaves with the Mylar insulation of the parallel plate transmission line. Fig. 4.



6. The preheating should be done with a modest (20,000 A) Z pinch, in the presence of a low B_z bias field as is done on the G.E θ-pinch. The Z pinch electrodes should be placed in long extensions, about one meter away from the ends of the coil. This keeps the electrodes clear of the implosion region, increases the range of pressures at which the discharge can be started, and is most simple in circuitry.