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CZ9726707

TEST OF EMG-720 EXPLOSIVE MAGNETO-CUMULATIVE GENERATOR

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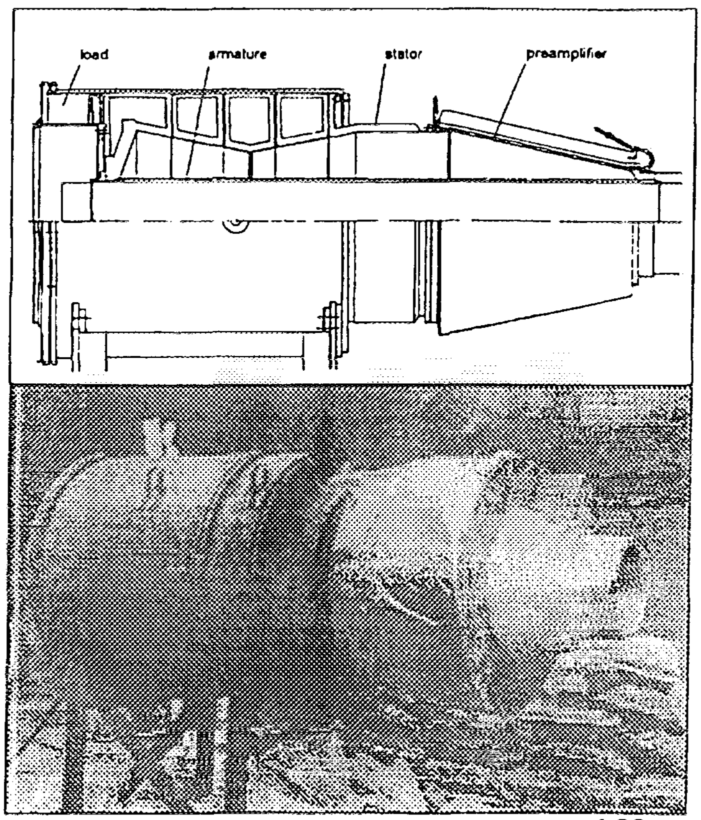
The test results of 30 megajoule EMG-720 explosive magneto-cumulative generator are given here. The generator was powered from the capacitor bank.

Our purpose was to develop a comparatively simple and not expensive generator having the energy storage of several dozens of megajoules, which could be used as the energy source energizing the stationary electro-physical facility placed in a special explosion-protected bunker. Helical magneto-cumulative generators, C-320 [1] and MARK-IX [2], have a long operational period (100 ms), as to fast-operating coaxial [3] and disk [4] generators, they employ very low loads (1 nH) and, moreover, require quite a powerful powering source to get the initial energy. So, neither of the generators known could meet our requirements.



Generator's dimensions:	
length	2500 mm
diameter	1000 mm
HE weight	186 kg
Electric parameters:	
powering current	95 kA
powering energy	250 kJ
operation time	25 μs
final inductance	22 nH
load current	48 MA
generated energy	25-30 MJ

Fig.1. EMG-720 lay-out and generator's view.

To implement the project, the authors proposed the design including a slow-operating helical-cone preamplifier and fast-operating cone generator as well (Fig.1). Such a lay-out provides that the generator preserves the best properties of both helical and cone generators, high current amplification coefficient (500) and small characteristic current rise time (25 ms) and storage of up to 25 MJ of the electro-magnetic energy at a relatively high inductance of 22 nH.

EMG-720 magneto-cumulative generator is comprised by the following: input cable collector with the explosive closing switch and explosive opening switch of the powering circuit; multi-turn helical-cone preamplifier; cone generator; high-voltage multi-slot disk collector; coaxial energy transmission line with film insulation; oil-filled high-voltage cable collector; aluminium liner with HE charge and two-sided initiation system and regulated delay lines.

The distinctive feature of EMG-720 is that it is intended to operation with high magnetic fluxes. As is known, the magnetic energy is directly proportional to the magnetic flux square number and reversly proportional to the load inductance. The most simple way to increase the energy output is to reduce the load inductance. This is the way the most of developers go. Though, if you want not only to obtain the energy of dozens of megajoules, but also feed this energy into a real load, it is necessary to employ a higher magnetic flux. So, some complicated problems are to be solved in connection with the magnetic flux increase proportionally to that of the electric voltages. Besides, to provide for a little current rise time, the starter surface should precisely repeat the liner's shape at the end of the generator operation. In its turn, that required to run several experiments on the liner gas-dynamics working-through. To reduce the requirements to the shape of the surface, the starter's current conductor was divided into three cone sections. The use of the said sections ensures the magnetic flux outlet through four disk gaps and highly reliable insulation, avoiding formation of "traps" where the magnetic flux could be cut off.

In Fig.2. there are shown the views of the liner's surface obtained, using the fast-operating photo registrator. The time interval between the photo is 4,75 ms. The grid size is 48 mm.

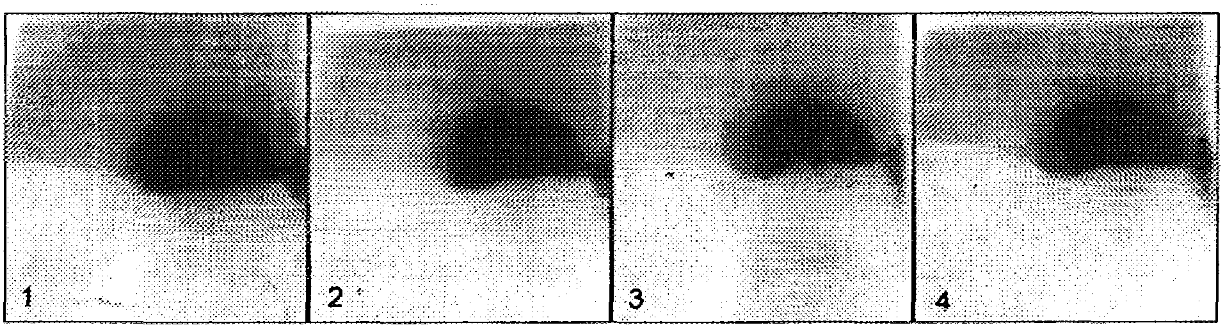


Fig.2. Liner's surface photographs.

EMG-720 testing was conducted at the explosive field of a special bunker. The generator was mounted 4 meters away from the bunker's armor shielding. At the 3d μs the starting pulse is fed to the explosive device initiating the detonators of the capacitor bank closing switch, generator powering cable line opening switch and those of the two lines of the generator's delayed operation. The explosive closing switch commutates the capacitor bank to the generator at the 39th μs. The 1st delayed operation line ensures the firing of the main generator's HE charge at the 260th μs; the 2nd one - at the 380th μs. Correspondingly, the generator powering begins at the 39th μs and finishes (the moment of the liner's connections to the turns) at the 310th μs. The full current rise time in the load from zero to the maximum makes 225 μs.

The equivalent experimental electric circuit is shown in Fig.3.

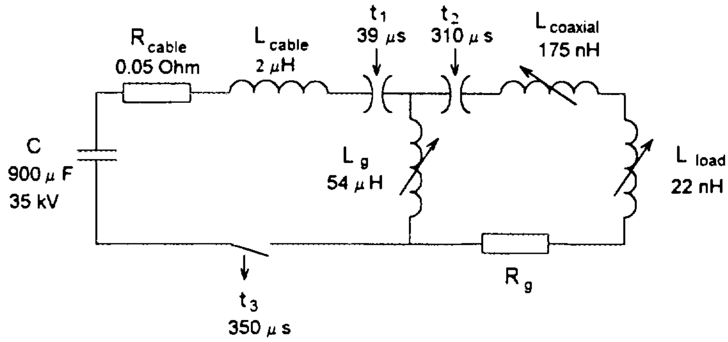


Fig.3. The equivalent experimental electric circuit.

Here: t_1=39 μs is the moment of the explosive closing switch operation and capacitor bank discharge starting;

t_2=310 μs is the moment of the liner's connection to the helix;

t_3=350 μs is the moment of the operation of the powering circuit explosive opening switch; R_g is the ohmic resistance of the generator circuit;

L_{load} is the variable residual inductance of the generator depending on the liner's flight geometry, starter displacement and current conductors' manufacturing technology capabilities.

The currents measured in the powering circuit and load are represented in Fig.4.

The generator powering starts at the 39th μs. While the liner is moving, the flux is pushed from the generator to the powering circuit. The current in the bank's circuit begins to differ from that of the generator powering circuit by the moment of explosive opening switch operation, cutting off powering cable line at the 350th μs. The helical preamplifier starts to operate on to two parallel circuits after the magnetic flux capture between the liner and the turns at the 315th μs, namely: the powering circuit and that of the load.

By this moment the powering circuit current reaches 180 kA, which is higher than the computated number. That may be explained for, on the one hand, by the radial divergence of the helix turns caused by the self-produced magnetic field effect and, on the other hand, by the lower velocity of the liner flight at the edge leading to a later magnetic flux capture. This phenomenon leads to the partial pushing away of the flux from the generator to the bank circuit by the moment of the capture.

The current derivative of the helical preamplifier is rising comparatively rapidly for 50-60 μs, then its rise is slowed down. The presence of high voltages inside the generator compels to take special measures to protect it from breakdowns, resulting in a more complicated generator design. Though, this is compensated by reaching a higher coefficient of the current increase in the helical preamplifier, i. e. ~200, at the helix length of 0,65 m. The generator powering current makes approximately 95 kA by the moment of the liner's movement beginning. The initial powering energy is respectively 250 kJ.

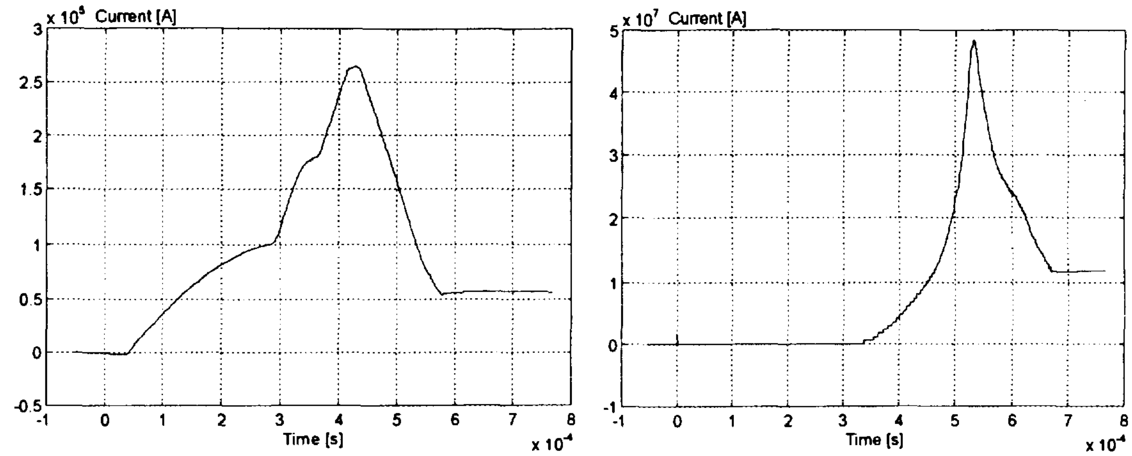


Fig.4. The current in the powering circuit and the current in the load .

By the end of the helical preamplifier operation at the 490 μs the remaining computated circuit inductance makes 100 nH at the current of 16 MA. This corresponds to 13 MJ of magnetic energy.

The cone generator increases the helical generator operation current from 16 MA to 48 MA for a full time of 40 μs.

The complete load inductance including the torroidal collector, line and oil collector makes 20-22 nH by the end of the generator operation. The magnetic energy storage is 25-30 MJ and magnetic flux is respectively is 1.1 Wb.

In some cases we purposefully enhanced the generator reliability, preventing reaching its ultimate parameters. Basically, it is reduced to the greater thickness of the helix conductors' electric insulation which leads to some degradation of the galvanic contact with the liner. Though, it prevents from the breakdowns inside of the generator and space between the helix turns.

The generator developed has the current increase coefficient of nearly 500 and the energy increase factor of 120. The full time of the generator operation is 225 μs. The generator works at the inner voltages higher than 100kV.

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