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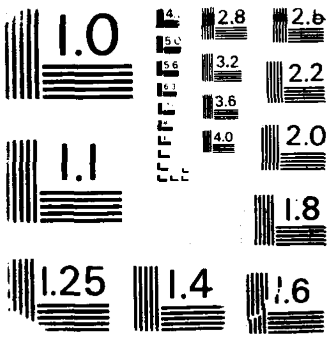
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FOREIGN TECHNOLOGY DIVISION

ELECTRIFICATION AND ELECTRIC GUNS

by

A.A. Korol'kov

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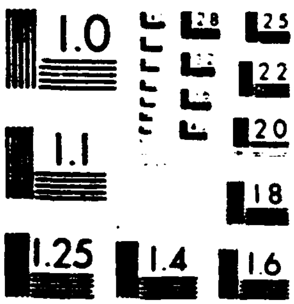
1 OF 1



MICROCOPY RESOLUTION TEST CHART

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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ELECTRIFICATION AND ELECTRIC GUNS

A. A. Korol'kov, Prof.

The USSR is presently in the stage of electrification in which powerful 50-, 100- and 200-thousand kilowatt plants are being built in it. They derive their energy from the fall of water of powerful rivers, from using coal wastes at its mining sites, and from the combustion of peat at its mining sites.

The inexpensiveness of these power sources and the lack of expenditures for transporting them makes the electrical power obtained much less expensive. Expenditures on building powerful electric power plants do not increase in proportion to the increase in power, but rather more slowly; therefore, the expenditures on the entire installation of a large power plant (dam, sluice, building, machines) comprise a smaller part of each kilowatt than those of small plants. Supplying the electric power over wires to the utilization site involves a certain power loss on its transformation, on heat-up of the wires, and on leakage, but nevertheless, electrical power is several times cheaper to use at the consumption point when it is obtained from large central power plants than when it is obtained from local plants.

Of course, these economic advantages will generate an ever increasing number of powerful central power plants. All of these plants will be built to serve the economic interests of the regions in which they are located. Volkhovstroy, Syas'stroy and Kondostroy service the North-Western Oblast'; the Shaturskaya and Kashirskaya Plants service the Moscow Region; the Shterovka-Don, Balakhinskaya Peat Plant services the Nizhegorodskiy Region; the Kizilovskaya Plant services the Urals; etc.

But here we have the question of whether considerations related to State defense are taken into account when building regional stations.

The problems of supply and transportation for military requirements are probably not overlooked by competent establishments. In this report I would only like to consider whether it would be possible to have regional power plants for the direct purposes of defense, namely, for launching missiles using electric guns.

Description of Electric Guns

All of the proposed designs of electric guns are essentially plans for an electric motor which imparts the missile with a high velocity on the axis of the gun. The design principles of the electric gun are the same as those for designing an electric motor, i.e., primarily, calculating the magnetic circuit, the electrical circuit, and the ratio between the electric and the mechanical power.

Therefore, an electric gun can be designed for direct current, based on the interaction between the magnetic field of the gun and that of the missile, through which the current passes (French design); a magnetic field can be created in the gun, moving rapidly to the mouth and carrying the steel missile with it (Swedish design for direct current); one can use an alternating current and obtain an interaction between the magnetic field and the induced field in the missile (E. Thompson's principle); one can use a multiphase alternating current and obtain a rapidly moving magnetic field which carries along the steel missile (magnetic-explosive gun). There are as many methods of designing an electric gun as there are types of electric motors.

The difference between electric guns and electric motors lies in their dimensions: to be fired, the gun requires hundreds of thousands of kilowatts, and it must be nearly a hundred meters long.

The main fundamental difference between an electric gun and an electric motor is that the electric motor is designed for the steady state of the current, while the gun operates only in the initial state of the current, when it increases from zero to a certain value in a short period of time (firing duration). For an electric motor, this initial period of current build-up when it is shorted is insignificant, and it is not usually taken into consideration; the conditions when the current reaches the steady state are considered.

When the current in an electric gun is shorted, the current power is expended on creating the magnetic field in the gun and the magnetic field around the missile; only a small percentage of the power is expended on moving the missile. This effect appears as if there were a reverse electromotive force, called the electromotive self-induction. Since the magnetized masses are very large, the time required to magnetize them is great, and the current strength in the conductors and the magnetic field increases rather slowly. Because of this, the missile can fly out of the gun at that moment when the current strength in the circuit and the value of the magnetic field reach the greatest value. Secondly, the mean value of the magnetic fields is equal to approximately half of their highest voltage.

The existing methods of decreasing self-induction and speeding up magnetization and the current build-up are very complex and cumbersome. It would be possible to combine large capacitances (capacitors) to do this, but the construction of capacitors to compensate for high self-induction involves practical problems which are hard to solve.

The second peculiarity of electric guns, involving the need for vast amounts of electric power, was dealt with in the existing designs of these guns so that a low relative power was expended over a large period of time on increasing the kinetic energy of the flywheels; then, at the time of firing, this kinetic energy was transformed into electric power. This approach was hampered by the problem of being unable to convert the energy of the flywheels into electric power during the brief firing time. As I will show below, the firing time should be equal to several hundredths of a second, and during this time, the flywheel must be braked by the resistance provided by the dynamo, generating a current. Up to now, no other methods of accumulating energy during a long period of time in order to liberate it later during the brief firing time have been proposed. The accumulation of energy by the existing electric batteries requires periods of time measured in hours, like for discharging them.

As for hydraulic power, it would seem that by closing all of the sluices, it would be possible to raise the water level, thus accumulating energy, and then, by opening the sluices to the turbines, obtain a large amount of stored power in a short time. But no matter how wide the escape sluices are opened, water does not flow out of them in a very short time. And even if there were no resistance, the run-out time would nevertheless not be shorter than the time taken to fall from the height of a dam; at a height of 5 m, the time would be one second. The counteraction of the turbine and dynamo blades would slow down the time taken to expend the stored energy even more.

It might have been possible to accumulate large amounts of steam in steam boilers, repersenting a large amount of potential energy, and then suddenly release the steam into turbogenerators. But again, this release requires a large amount of time compared to the length of the firing time. The stored energy cannot be expended during the brief firing time.

In any case, the storage of the energy needed for firing requires time, and thus, firing can only take place at widely-spaced intervals.

Electric guns can only be rapid-firing when they expend energy which is available in the generators, and not stored in some sort of power stores (electric, hydraulic, steam, etc.).

Simplest Relationships Between the Weight of the Missile, Its Muzzle Velocity, the Length of the Gun, the Firing Time, and the Required Power

In order to have a numerical reference point for further conclusions, we will obtain some simplified relationships between the values listed in the heading. We will designate:

weight of missile .... P
muzzle velocity V
length of gun L
time of movement into
  channel of gun .... T
required power .... W

Assuming that the velocity of the missile increases in the gun channel uniformly from 0 to V, we will obtain a mean rate of movement equal to V/2. Then the dependence between the length of the channel, the time of movement into the channel, and the mean velocity is expressed by the formula:

$$L = \frac{V}{2} T \qquad (1)$$

The energy of the missile at the muzzle is expressed by the formula:

$$W = \frac{P}{g} \cdot \frac{V^2}{2} \qquad (2)$$

Here g is the acceleration of gravity (9.82 m/s^2), which we will express by the number 10 for approximate calculations.

In order to obtain this muzzle energy, the current generators must expend the large quantity of energy W_1, whereupon the ratio $W/_1W$ [sic], which represents the efficiency of the electric gun, can hardly be considered to be greater than 0.5. For ordinary electric motors, it is equal to 0.8-0.9, and even higher, since the energy is only expended on parasite resistance in them; in the steady state, expenditures are not needed to create the magnetic field. In an electric gun, at the moment of firing, energy is expended on creating the magnetic field in the gun and the missile. Therefore, a much smaller part of the generator's energy is left to move the missile. Thus, in future calculations we will assume that the power of the generator W_1 must be twice the power of the missile at the muzzle of the gun.

Velocity of Missile at Muzzle of Gun

In ordinary guns with explosive substances, the muzzle velocity depends on the size of the charge. The base pressure of the gun, the longitudinal breaking force, and the transverse braking force increase with the size of the charge. There is a limit to increasing the wall thickness of the gun beyond which a further increase in the thickenss does not increase the strength of the gun. Therefore, the muzzle velocity of the gun also has a limit, which approaches 1000 m/s in the latest guns.

In electric guns, there is no base pressure on the gun and radial pressures on the wall. Therefore, it is only necessary to consider the longitudinal breaking force, which is smaller, and which is overcome by the entire cross section of the gun. Thus, one can obtain higher velocities in electric guns than in powder guns without worrying about breaking the gun. An electric gun can be open on both ends; it is unnecessary to close and reinforce the breech section. Therefore, a new missile can be inserted immediately after one missile departs. The firing speed of an electric gun can be very great, if the power of the generator is great enough for firing and it is not necessary to accumualte energy by one of the above methods.

Length of an electric gun. The length of an electric gun is essentially determined by the same conditions as for firearms; it must be strong enough to keep from breaking, and it must not be too heavy, so that it is easy to handle.

The housing of an electric gun is not made of a solid iron mass, but rather from sheets of iron covered by insulation. Therefore, the strength of an electric gun must be created by a well-designed cellular frame made of steel trusses. The external appearance of an electric gun is much different from that of a firearm.

But the length of an electric gun is primarily determined by the requirement that the missile must remain in the channel of the gun long enough to use the electric power of the generator. Therefore, the length of electric guns is generally much greater than that of firearms. For example, at a generator power of 100,000 kilowatts, the work expended in the gun in one second will be equal to 100,000 kilojoules (almost 10,000 kilogram-meters, since one kilogram-meter is equal to 9.82 joules). If the missile is under the action of the current for 1/5 second, one-fifth as much work is expended on moving it than as in one second, i.e., 2000 kilojoules. If the muzzle velocity of the missile is 500 m/s, its mean velocity will be equal to nearly 250 m/s, and it will cover 50 m in 1/5 second. And this is the length of the electric gun. If one wished to use all 100,000 kilojoules, it would be necessary to subject the missile to the effect of the magnetic field for a whole second, which would make it necessary for the gun to be 250 m long.

This unavoidable need for very long electric guns if one wishes to use the energy of the generator without storing it in any energy stores is a very unfavorable feature of electric guns. And this characteristic cannot be eliminated, for it is the result of the very nature of the gun.

This unfavorable side of electric guns is not offset by its advantages. The absence of smoke and noise during firing is one of the advantages of electric guns. The range of flight of the missile can be changed not only by changing the elevation angle, but also by changing the strength of the current fed to the gun winding. By combining changing the elevation angle and the current strength, it is possible to obtain different terminal velocities and angles of incidence with the same range.

To What Battery is a 100,000 Kilowatt Electric Power Plant Equivalent?

As an example, I will calculate how many guns a 100,000 kilowatt electric power plant is equivalent to with the condition that only the available energy of the generators is expended, without storing it by any energy stores.

As the unit of comparison, we will use the 145-155 mm French gun of the 1916 model, for which: length of gun - 42 caliber (6.3 m), initial velocity - 785 m/s, weight of missile - 36.5 kg, range of flight - 18 km, firing velocity - 1 shot per minute.

We will calculate the work of an electric gun needed to fire a missile weighing 36.5 kg with an initial velocity of 800 m/s using the formula $W = \frac{P}{g}\frac{V^2}{2}$; $W = \frac{36.5}{10}\frac{640\,000}{2} =$ 1,170,000 kgm.

Since one kgm is equal to 9.82 joules (10), W = 1,170,000 joules = 11,700 kilojoules.

Considering that the efficiency of an electric gun is equal to 0.5, we find that the generator must expend twice the energy W_1 on firing, i.e., W = 23,400 kilojoules.

The work of the electric power plant, as we stipulated, is 100,000 kilowatts, or 100,000 kilojoules per second. Therefore, the generator produces the work W_1 in almost 1/4 s (0.234 s).

Whence we find the length of the electric gun, in which the missile, moving at a mean velocity of $\frac{0+800}{2} = 400$ m/s, covers 100 m in 1/4 s. And this is the length of the gun (100 m).

We will calculate the muzzle velocity that a missile would have in a shorter gun, e.g., 6.3 m, 10 m, and 50 m, with the same current strength, which means with the same force acting on the missile, which we will consider to be constant over the entire length of the gun. Then the movement of the missile will have uniform acceleration with acceleration of $a = \frac{v}{t} = \frac{800}{1/4} = 3200$ m/s^2.

The velocity v acquired on the path L will be equal to $\sqrt{2aL}$

With a gun 50 m long, we obtain $v_{50} = \sqrt{2.3200.50} = 560$ m/s.

With a length of 10 m, we obtain $v_{10} = \sqrt{6400.10} = 252$ m/s.

With a length of 6.3 m (the length of a 150 mm gun),
$v_{6.3} = 200$ m/s.

Thus, in one second, a 100,000 kilowatt plant can fire four missiles weighing 36.5 kg each at a velocity of 800 m/s, and it can fire 240 missiles of this weight in a minute. All 240 of these missiles can be fired in one minute from one gun, or 24 missiles each from 10 guns per minute.

A 150-mm firearm can fire once per minute. Therefore, with a 100,000 kilowatt generator, a 150 mm electric gun of the same caliber is equivalent to the firing power of 240 firearms of the same caliber and the same initial velocity.

In the above example, the power of the electric gun was 240 times that of the firearm, while the electric gun was approximately 15 times (100:6.3) longer than the firearm, i.e., the power of the electric gun increased almost in proportion to the square of its length.

If one wanted to have an electric gun for a caliber larger than 150 mm (6") or for a higher initial velocity than 800 m/s at a generator power of 100,000 kilowatts, it would be necessary to build a gun longer than 100 m. Considering this to be the maximum length, it is necessary to limit oneself to a caliber of 150 mm.

* * *

Based on the above information, one ~~should~~ conclude that:

1. Electric guns with generators with insufficient power for firing, designed for storing the energy necessary for firing in a

short period of time, hardly make sense in practice because of the difficulty of using the stored energy during the short firing time and because of the low efficiency of power stores for rapid output.

2. Generators with power on the order of a hundred thousand kilowatts can service electric guns with a weight of the missile of around forty kilograms and an initial velocity of around 900 m s.

3. A 100,000 kilowatt generator can fire around 200 missiles per minute, each weighing around 40 kg.

4. Electric guns which continuously expend the power of the generator must generally be much longer than firearms.

5. An electric gun can be hundreds of km away from the generator, being connected with it by wires and transformers.

6. With the current state of electrification in Russia, it would be timely to build one experimental electric gun with a caliber close to 150 mm (6") with an initial velocity of 500-800 m/s.

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