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THE MAIN POINTS OF THE METHOD OF CALCULATION OF PULSE GENERATORS FOR ELECTRIC FISHING

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Creation of new fishing methods and new fishing gear including the method of electric fishing was considerably facilitated by invention of new technique of underwater control of fish behavior. That is why the research work, especially that which concerns electric trawl has considerably livened up recently in a number of countries. In this connection one of the most urgent problems is projecting and calculating pulse generators of big capacity which create surge electric field in the water. There are many various schemes of pulse generators which can be used for this purpose. Capacity accumulators of electric energy are usually utilized in these schemes. Commutation of mordern pulse generators is effected with powerful thyristors, while the energy is transmitted to the space between the electrodes by the line containing a board rising pulse transformer, an underwater reducing pulse transformer and a high-voltage cable.

Picture 1 shows the charging and discharging electric circuits of pulse generator which forms unipolar electric impulses or series of bipolar impulses in case the thyristor is shunted by diode (dotted line).

The similar scheme of charging - discharging electric circuit with loaded accumulator circuit is shown in Picture 2.

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It should be emphasized that the scheme with a diode and a shunting thyristor allows to obtain a series of impulses in a discharging circuit which consist of semi-sinusoids n (depending on the length of impulse which switches on the thyristor). The other peculiarity is that it allows to reduce the weight of charging throttle by several times and to increase the coefficient of performance of the scheme.

By solving a classic differential equation for a charging and a discharging contours in case of ascillatory discharge, i.e. $d < 2$ and using recharging voltage as a coupling parameter U_{Π} - residual voltage of the condensem when the charging began, one can calculate the dependence between the instantaneous values of discharging current and condensers' voltage.

These two equations will be the basis of our calculations $i = \frac{U_c}{\omega L} e^{-\delta t} \sin \omega t$ (1)

$$U_c = U\left\{1-\left[1-(-1)^n \frac{1+K_p}{1+(-1)^n K_p K^n} \cdot K^n\right] e^{-\delta_p t} \frac{\omega_{0p}}{\omega_p} \cos(\omega_p t - \beta_p)\right\} \ldots \quad (2)$$

where U_c is the voltage of the condenser battery at the end of charging. $\omega = \frac{\pi}{T_a} = \sqrt{\omega_0^2 - \delta^2}$,

$T_a = \frac{2T_0}{\sqrt{4-d^2}}$, $T_0 = \pi\sqrt{LC}$, $d = \frac{R}{\sqrt{\frac{L}{C}}}$, $\omega_0 = \frac{1}{\sqrt{LC}}$, $\delta = \frac{R}{2L}$,

$K = e^{-\pi m}$, $\beta = \operatorname{arctg} m$, $m = \frac{\delta}{\omega} = \frac{d}{\sqrt{4-d^2}}$,

U - feeding voltage

C - capacity of the condenser battery

L, R - inductance and active resistance of discharge circuit in the circuit of energy accumulator.

The values marked with 'p' refer to the charging circuit, those which are not marked refer to the discharging circuit.

Having equated $t = \frac{\pi}{2w} - \frac{\beta}{w}$, we obtain the amplitude value of the discharging current.

$$J = \frac{U_c}{\sqrt{\frac{L}{C}}} \cdot K_i \tag{3}$$

$$K_i = e^{-m\left(\frac{\pi}{2} - \mathrm{arctg}\, m\right)} \tag{4}$$

and with $t = \frac{\pi}{w_p}$ we get the maximum voltage value of the condenser battery.

$$U_c = U \frac{1+K_p}{1+(-1)^n K_p K^n} \tag{5}$$

with $t = \frac{\pi}{w}$ we calculate recharge voltage

$$U_{\Pi} = U_c K^n (-1)^n \tag{6}$$

If $n = 1$, i.e. discharging impulse of the current consists of one semisinusoid, then the condenser voltage can be expressed like:

$$U_c = U \frac{1 + K_p}{1 - K_p K} \tag{7}$$

As the equation (7) shows, condenser voltage depends on reliability of both charging and discharging contours, so that in fact it can surpass by several times the feeding voltage.

Working value of discharging current can be obtained from:

$$J_{ef} = \sqrt{\frac{1}{T}\int_0^{nT_a} i^2 dt} = U_c \sqrt{\frac{Cf}{2R}\left(1-K^{2n}\right)} \qquad (8)$$

where $f = \frac{1}{T}$ is the frequency of impulses

T – the period.

The average value of discharging current is:

$$J_v = \frac{1}{T}\int_0^{nT_a} i\,dt = U_c C f\left[1-(-1)^n \cdot K^n\right] \qquad (9)$$

In case of aperiodic discharge d 2, the needed dependences obtained the same way will be expressed like:

$$J = \frac{U_c}{\sqrt{\frac{L}{C}}} \cdot K_i \qquad (10)$$

$$K_i = \left[\frac{2}{d\left(1+\frac{1}{j^m}\right)}\right]^{jm} \qquad (11)$$

$$J_{ef} = U_c \sqrt{\frac{Cf}{2R}} \qquad (12)$$

$$J_v = U_c C f$$

$$j = \sqrt{-1} \qquad (13)$$

Calculation of concrete scheme can be made in different consecutive order depending on which parameters are initial and which values are desired ones.

As a rule, calculation of pulse generator is usually begun when the electric scheme is already known, i.e. when the place of various elements of the electric circuit of the trawl is determined and geometric characteristics of the circuit are known, including the length of secondary cables, the form and the place of electrodes in space, the characteristics of high-voltage coaxial cable.

Thus, the values L_H, R_H, L_k and R_k are not hard to find since we know that the inductance L_H is concentrated mainly in the poupling cables and the active resistance of the discharging circuit R_H is practically equal to electrode spreading resistance and to active resistance of the coupling cables.

By the length of coupling cables l can be determined:

$$L_H = l \cdot L' ,$$

where $1,5 < L' < 2,0 \mu H/m$

R_H is calculated according to the methods of calculation for grounding, while active resistance of high-voltage circuit R_k and L_k are taken from the technical description of the cable.

Depending on the reaction of fish which is the basis of electric fishing, like electro-narcosis is for pelagic electric trawling and anode reaction is for fishing without nets, the most advantageous impulse frequency in respect of power f is chosen with the help of diagrams made of the results of volume characteristics of fish reaction on electric current (see picture 4). The voltage of the condenser battery U_c is limited by the permissible voltage of the thyristor.

The voltage of the high-voltage cable U_k is chosen so that it does not exceed the permissible producer's technical conditions.

In fact one can achieve that $R_v \ll R$ and $L_v \ll L$, where R_v and L_v are active resistance and inductance of discharging contour in the accumulator circuit. That is why the coefficient of transformation of board pulse transformer can be calculated with sufficient precision for practical use.

$$n_1 \cong \frac{U_c}{U_k} \qquad (14)$$

Using oceanological tables we can determine specific resistance of the water ρ in case of crest saltness value and temperature. R_v and L_v can be taken within the limits:

$$4 \leqslant R_v \leqslant 8\ m\Omega; \quad 4 \leqslant L_v \leqslant 8\,\mu H$$

Thus, taking into account the above we have found the following values:

f, U_c, L_H, R_H, U_k, ρ, R_v, L_v, R_k, L_k, n_1.

Now we have to choose the transformation coefficient for underwater pulse transformer n_2 and the length of impulse T_a.

It is known from physiology that steep front of growing current causes bigger effect on a live organism. Owing to this fact the length of impulse should be reduced by deminishing transformation coefficient of underwater pulse transformer n_2, which in our case is equal to the increase of steepness of the fore front of the impulse. Yet by overreduction of n_2 and consequantly of T_a the steepness of the fore front of the current may reach the critical point for the thyristor. Therefore n_2 should be chosen when permissible speed of current growth for the type of thyristor is taken into account, Then the general inductance of the discharging circuit in the accumulator circuit may be described like

$$L = \frac{U_c}{\frac{di}{dt}} \qquad (15)$$

On the other hand,

$$L = L_V + L_K n_1^2 + L_H n_1^2 \cdot n_2^2 \qquad (16)$$

From (15) and (16) we can find n_2 and after that the general active resistance of the discharging circuit.

$$R = R_V + R_K n_1^2 + R_H n^2 \qquad (17)$$

where $n = n_1 \cdot n_2$ - the general coefficient of transfornation.

For preliminary determination of the length of impulse T_a we shall put the decay coefficient within the limits:

$$05 \leqslant d \leqslant 07$$

where the lower limit is taken for $U_c > 2000$ V, and the upper limit for $U_c < 1000$ V. Then we find:

$$T_a = \frac{2 \pi Lm}{R} \qquad (18)$$

Further calculation depends on the reaction of the fish to the electric field. The hardest case from the energetic point of view is that of electro-narcosis which we are going to study.

It should be noted that the current parameters and energy characteristics of the scheme depend on time T_H which is needed to cause electro-narcosis. The value T_H is taken depending on the mechanism of interaction between the electric field and the fish,which has become the basis of electric fishing. One should remember that if T_H is too short it will cause drastic increase of the used energy and of the dimentions of the installation.

Further on, having found T_H and $Q = \frac{T}{T_a}$ from a corresponding diagram drawn on the basis of aquarium experiments, we shall determine specific capacity P' spent on 1 m^3 of water, which is needed to cause the threshhold of the reaction. Picture 5 shows as an example diagram: $P' = \varphi (T_H)$ for $Q = 10_H$ $\rho' = 1 \Omega m$.

After that we can find the threshhold value of the field tension.

$$E = \frac{1}{\lambda} \sqrt{\frac{2 \rho' P'}{Ta\, f}} \qquad (19)$$

where ρ' - specific water resistance for aquarium experiments (see picture 5), ·

$$\lambda = \frac{1}{K_i}\sqrt{\frac{1-K^2}{2\pi m}} \tag{20}$$

λ - see picture 3.

In order to find the current amplitude we can use the following dependence:

$$\frac{J_H}{S} = \frac{E}{\rho} \tag{21}$$

and

$$J = \frac{J_H}{n} \tag{22}$$

where S - the surface with similar firld gradient equal to E.

For spherical space $S = 4\pi r^2$, where r - the radius of the electric field.

From picture 3 we can find K_i and using formula (3) calculate C, then find

$$d = \frac{R}{\sqrt{\frac{L}{C}}}$$

If the found value of d differs much from the desired one, T_a, J and C should be recalculated according to formulas (18), (22) and (3).

Then we calculate J_{ef}, J_v by formulas (8), (9) and having put K_p within the limits $0{,}7 \leqslant K_p \leqslant 0{,}85$ fin the feeding voltage U by (5).

The found values permit to start choosing power elements of the scheme and projecting the charging throttle, the pulse transformers and the control scheme for pulse generator.

Special attention should be paid to the place where different elements of the circuit are situated ih order to reduce the most possible the inductivity and the active resistance of the charging circuit, for this reduction will benefit weight, size and power characteristics of the pulse generator.

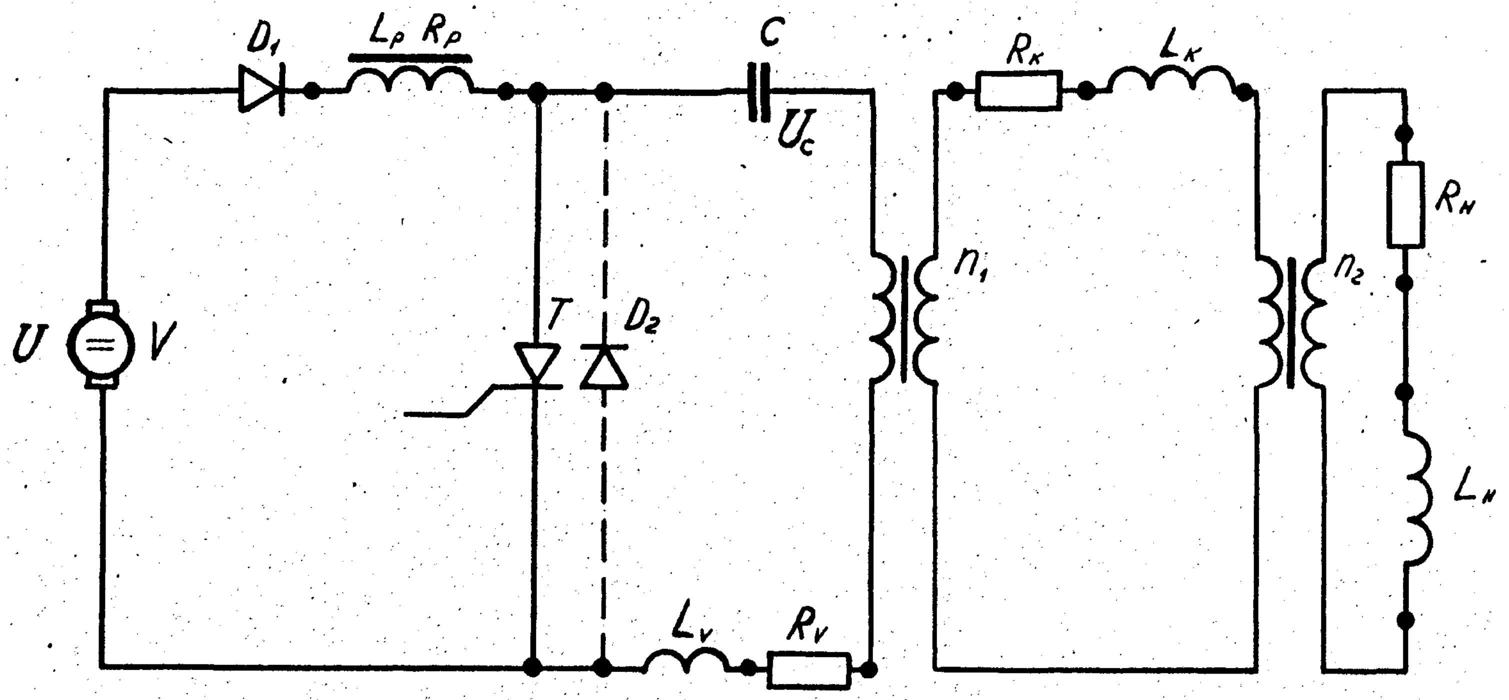


Fig. 1

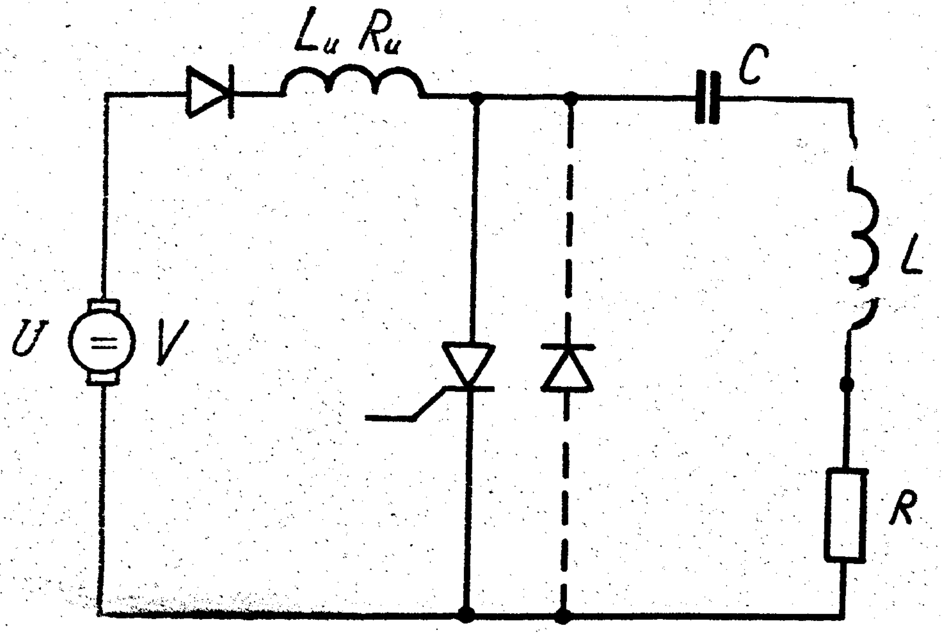


Fig. 2

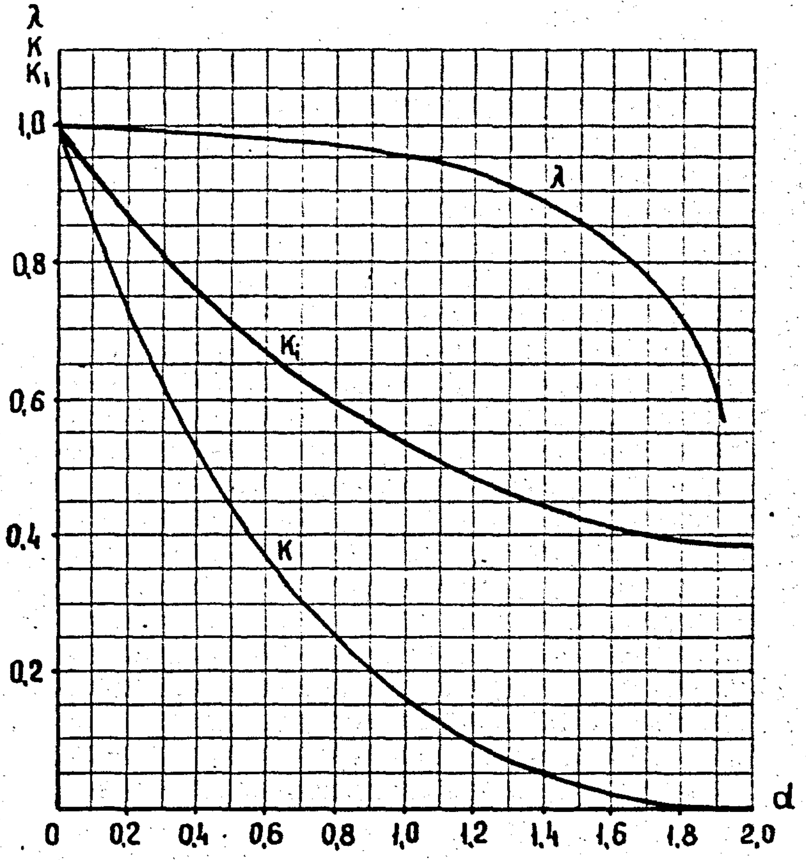
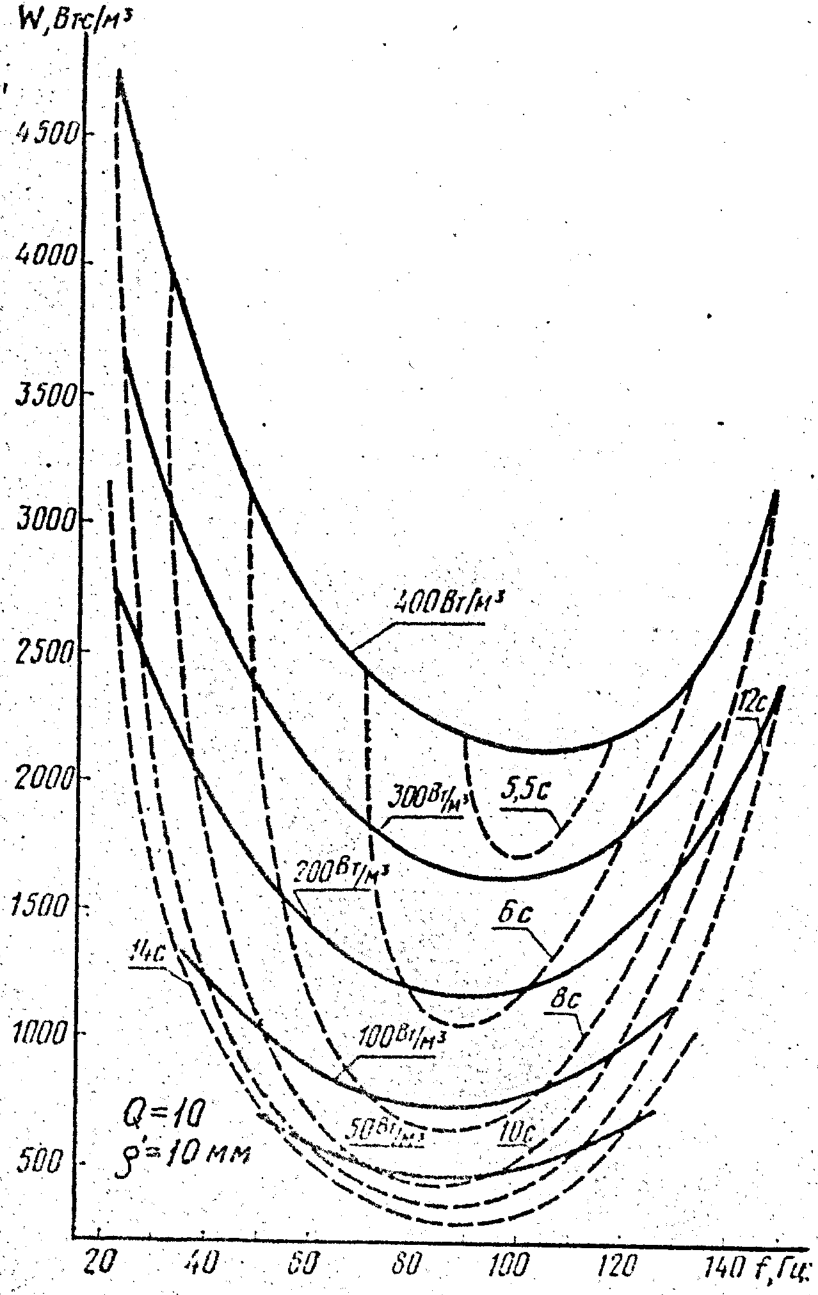
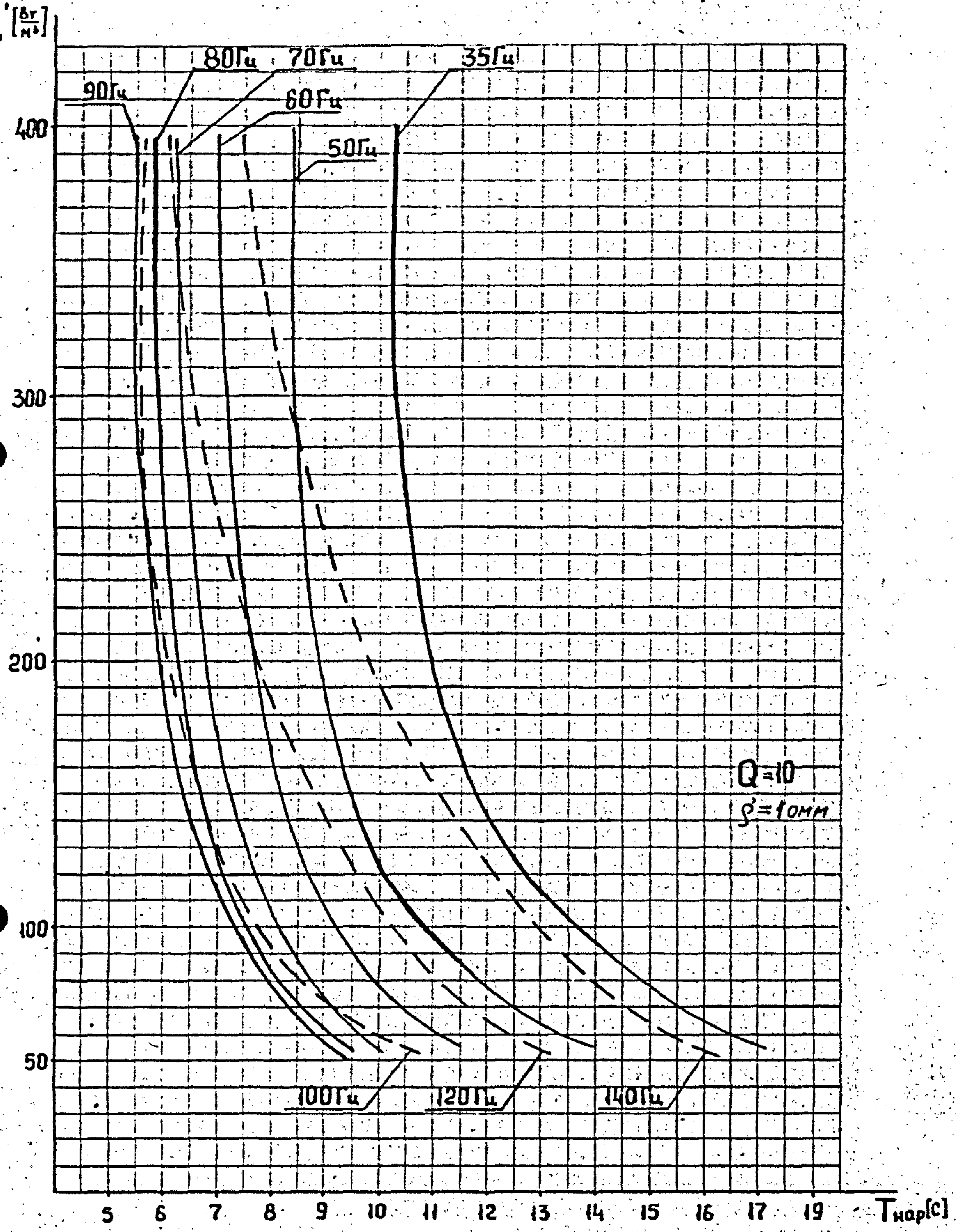


Fig. 3



W, Втс/м³
4500
4000
3500
3000
2500
2000
1500
1000
500
20
40
60
80
100
120
140 f, Гц
400 Вт/м³
300 Вт/м³
200 Вт/м³
100 Вт/м³
50 Вт/м³
5,5с
6с
8с
10с
12с
14с
Q=10
ρ'=10 мм

Fig. 4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70Гц
60Гц
50Гц
35Гц
100Гц
120Гц
140Гц
Q=10
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17
19
Тнар[с]

Fig. 5

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