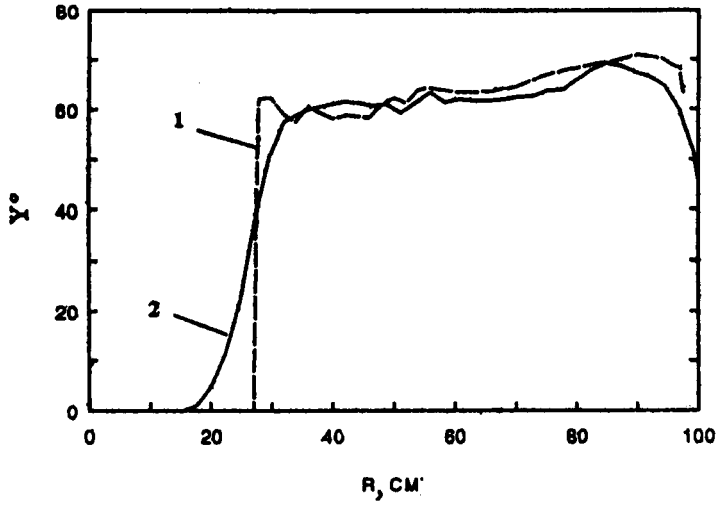

Fig.3. Spirallity angle in dependence on cyclotron radius: *1* — geometry data of k=8 model; *2* — experimental values

difference between effective and geometrical spiralliy angles reach approximately 7^0 that at $65^0 - 70^0$ corresponds to focusing decreasing by 50%.

At the end 1995 all magnet elements with the exeption of pole tips with sectors have been manufactured and assembled. The next–future tasks are the accomplishment of pole tips manufacture and start of the magnetic measurements.

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LOSSES OF H^- IONS DUE TO ELECTRO-MAGNETIC DISSOCIATION AND THEIR EFFECT ON SELECTION OF ISOCHRONOUS CYCLOTRON MAGNETIC STRUCTURE

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The acceleration of H^- ions has advantage in 100% extraction efficiency. But side by side with an obvious asset there is a shortcoming connected with H^- dissociation during acceleration.

The second electron of H^- ion has a very low binding-energy of ϵ_0= 0.755 eV [1] and can be easily detached in a strong electric field E. Such a field is arising in the own coordinate system when ion is moving at velocity $\vec{v}$ in magnetic field $\vec{B}$:

$$E = 0.3\ \beta\ \gamma\ B, \qquad (1)$$

where β - relative velocity of ion, γ - relativistic factor, B - in kGs.

The beam losses I can be calculated from equation:

$$\frac{dI}{I} = -\frac{dt}{\gamma\tau} , \tag{2}$$

where τ - average life-time of the negative ion, determined by probability of the penetrate for external electron through potential barrier at electrical field (1). The value τ can be presented in the form:

$$\tau(E) = \frac{A}{E} exp\left[\frac{D}{E}\right] , \tag{3}$$

where A and D are constants which have been obtained as a result of approximation of the experimental data. The most known in scientific literature the combination of these constants are presented in Table 1.

Table 1

Values of constants A and D used in calculations. The constant A is measured in s·MV/cm, and constant D - in MV/cm

Constant	Number of variant and reference		
	1	2	3
	[2]	[3]	[4]
$A \cdot 10^{-14}$	1.05	7.96	2.47
D	49.25	42.56	44.90

For calculation of losses in cyclotron it is convenient to transform the expression (2) to the form:

$$\frac{I}{I_0} = exp\,(-\int_0^{\theta_k} \alpha(\theta)d\theta), \qquad \alpha(\theta) = \frac{1}{\gamma\omega\tau} , \tag{4}$$

where θ_k - final azimuthal angle on last turn of acceleration, $\omega = 2\pi f$,where f is frequency of revolution, which in isochronous cyclotron is the constant value.

The integral in expression (4) in periodic magnetic field can be presented in form

$$\int_0^{\theta_k} \alpha(\theta)d\theta = N\sum_{i=1}^{M}\int_{\theta_{i-1}}^{\theta_i} \alpha(\theta)d\theta , \tag{5}$$

where N - number of periodicity elements of the magnetic structure (in our case $N = 4$) ;

$\theta_{i-1} = \frac{2\pi}{N}(i-1)$, $\theta_i = \frac{2\pi}{N}i$;

M - number of turns, determined as $M = \frac{W_k}{(\Delta W)_0}$;

W_k - final energy of ion,

$(\Delta W)_0$ - energy gain per turn.

On GIC the magnetic rigidity is equal Br = 13.2 kGs·m on final radius r_k , that corresponds of final energy 80 MeV. Then at $r_k = 0.9m$ should be $< B_k >=$ 14.67 kGs, and B_0 = 13.52 kGs. It was chosen fourth sectors magnetic structure , and energy gain per turn $(\Delta W)_0$ = 200 KeV. Two variants of magnetic structure have been examined. The variants have on extract ion radius the following parameters [5]:
the variant M1 with flatter $F \sim 0.04$, angle of spirallity $\gamma_0 \sim 55^0$, amplitude of main harmonic $A_4 \sim 4.15$ kGs; the variant M2 with flatter $F \sim 0.025$, angle of spirallity $\gamma_0 \sim 65^0$, and amplitude $A_4 \sim 3.28$ kGs.

For calculations of H^- losses at the expense of electrical dissociation a computer program has been developed. The magnetic field B in (1) is presented by

$$B(r,\theta) =< B(r) > \cdot(1 + A_4(r) \cdot cosN\theta), \tag{6}$$

where $< B(r) >$ - average magnetic field in dependence on radius, and $A_4(r)$ - amplitude of main harmonic, measured for variants of magnetic structures M1 and M2 [5].

As a results of calculations it was shown the main losses of H^- ions on the electro-dissociation takes place in hills region, where the life-time $\tau \sim$ in 100 times less, than time live corresponding to average field.

In Table 2 are presented the calculations of H^- ions losses on the electro-dissociation for various magnetic structures.

Table 2

Losses of H^- ions (K,%) on the electro-dissociation on dependence of energy gain $(\Delta W)_0$ per turn for various structures M1, M2 and for parameters A, D (see Tab.1) of variants 1,2,3

$(\Delta W)_0$, MeV/turn		0.05	0.10	0.15	0.20	0.25
M1, K	1	20.0	10.6	7.2	5.5	4.3
	2	44.5	25.6	17.8	13.8	10.9
	3	48.5	28.3	19.8	15.4	12.2
M2, K	1	4.7	2.3	1.6	1.2	0.9
	2	14.3	7.4	5.0	3.8	3.0
	3	15.0	7.7	5.3	4.0	3.2

The analysis of calculation results shows that the parameters A and D of the variant 1 give very underestimated H^- losses on the electro-dissociation in comparison with variants 2 and 3. The references [3,4] contain the most new results and give the coincide beam losses. For that a reason it was decided to consider the parameters from variants 2 and 3 as a most authentic. Besides from table 3 it is visible that the variant of magnetic structure M1 gives too high losses $\sim$ 15% in comparison with structure M2, where the losses of H^- ions do not exceed $\sim$ 5%. It should be noted that main losses of H^- ions take place on radiuses $r \geq 80$ cm, that corresponds the energy $W \geq 65$ MeV.

As a result of calculation it was concluded that for H^- cyclotron it is reasonable to use a magnetic structure with a high spirallity and small value of flatter. The structure with small value of flatter provides a low field at the hill and low beam losses due to electro-magnetic dissociation. The necessary vertical focusing is provided at the expense of high spirallity.

In conclusion it should be recorded that analysis of electro-magnetic beam losses is of fundamental importance for design new generation H^- cyclotron with high beam intensity. Ten percent beam losses give rise the inacceptable radioactivation elements of vacuum chamber. To decrease the beam losses the special magnetic structure to be selected for the isochronous cyclotron.

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THE FIELD MAPPING SYSTEM FOR THE ISOCHRONOUS CYCLOTRON AT GATCHINA

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INTRODUCTION. The magnetic field measuring system must meet followinnng requirements: the range of the measuring field 0-20 kGs, field gradient up to 1.5 kGs/cm, accuracy of measurement at uniform field 1 Gs, accuracy of the probe positioning 0.1 mm , time of measurements all the map 8 hours. To meet the requirements Hall probes were used for magnetic field measurements and mapping should be computer controlled. Mapping system consists of the Hall magnetometer and computer controlled scanning machine. The block diagram of the mapping system is devoted at Fig.

HALL MAGNETOMETR. For increasing a rate of measurements twenty Hall plates are mounted with 5 cm step on a moving carriage. The magnetometr consists of two groups Hall plates of ten plates at every chain and two stubilised current sources. Hall plates the type ПХЭ 1602 118 A with sensitivity of 16μV/Gs at current 160 mA and temperature stability $2{\cdot}10^{-3}\%/$K were developed at Joffe Physical Technical Institite. The temperature coefficient is so low that there is opportunity to use the Hall plates without the temperature stabilisation. The reference voltage elements and current measuring resistances are disposed at the thermostat. The temperature of the thermostat and a current are controled during the measurements. The longtime exciting Hall plate current stability is $\sim 3 \cdot 10^{-5}$. The Hall and another voltages are measured with digital voltmeter (DV) Ш-1516. The Hall plates are calibrated by NMR. The resulting measurement error is added together the error of the