SELF - FOCUSING ION LINAC.

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A lot of attempts have been made to use the accelerating field of the linac for focusing. In particular, Ya.B.Fainberg suggested an alternating phase focusing /1/ and V.V.Vladimirski - - a focusing by means of r.f. quadrupoles /2/. The r.f. quadrupole field is formed either with fingers in gaps /2/ or with rectangular aperture tubes /3,4/. Drift tubes for the self-focusing field /ФУП/ are attractive with its constructive simplicity. However, in first works /2-4/ it couldn't obtain enough effective focusing. The essential progress was achieved only after appearing the idea of "double gap" /5/ in H-cavity /6/. A normalized acceptance more than 1 mrad·cm was succeded at specific acceleration rate of $2.7 \cdot 10^{-3}$ and gap efficiency not less than 0.85 /7/ (See table).

A scetch of the double gap is shown in fig.1. The gap has an intermediate electrode. The field has an axially-symmetrical component in one half of the gap and a quadrupole component in the other one. A total length of the double gap is nearly the same as in conventional accelerator, so the gap efficiency /transit-time factor/ is high enough. The amplitude and phases of the accelerating axially-symmetrical components and the focusing quadrupole one must have a definite relation /depending on the gap geometry only/, which provide the best focusing of particles, stable with a longtitudinal movement. Under a limited field strength, a voltage of the gap is determined with a distance between the fingers and it will be proportional to the aperture radius R. The quadrupole component gradient is proportional to 1/R. The double gap permits to increase the gradient and the gap efficiency, keeping an energy gain. The energy gain in the double gap is twice smaller than in the accelerator with the axial symmetrical field (with the same aperture) due to the additional electrode and fingers. The high specific acceleration rate is acheived when increasing the number of the double gaps per unit length (and their corresponding phasing).

It's quite enough to place two double gaps per $\beta\lambda$ and shift their phases by π in the accelerator up to β =0.3. The accelerating systems with such "shunt" connections of the gaps was used earlier. So B.K.Shembel and A.A.Naumov suggested various types of coaxial resonators. The cavities with a non-uniform field along the cavity /8,9/ were also investigated. H-cavity has some advantages from those suggested earlier (fig.2). In fact , it is a turn of a very wide tape placed in a cylindrical shield. The drift tubes (their assembling is shown in fig.) are the capacity load of the turn-cavity. A resonance frequency of the cavity is determined by its diameter and is independent on the length. The voltage in all gaps is equal. Outer diameter of H-cavity is $\sqrt{3}$ - 5 ($D \approx \frac{1}{5}\lambda$) times smaller than a diameter of a vacuum tank of Alvarez cavities. The dependence of the accelerating shunt impedance on β for H-cavity of non-polished copper and Alvarez cavity (the last dependence is computed according to /10/) is compared in fig.3.

The computation of two variants of ion linac (see table) with using ФУП and accelerating system was made. From the table it can be seen that the main "accelerating" characteristics of proton accelerator, namely: current specific acceleration rate, wavelength, normalized acceptance of the channel were chosen so as in CERN injector /11/ or Serpukhov one /12/. But their constructions are very different. The drift tubes are of simple metal constructions. The power supply system of magnet lenses is not necessary now. The cavity diameter is about 4 times less, the number of vacuum sealings decreased too. As a result , the proton accelerator is rather like an electron linac.

TABLE

Parameters	Proton linac		Heavy ion linac	
	First section	basic sect.	First sect.	Basic sect.
Energy Mev/nuclon	0.6-5.0	5.0-49.5	0.15-2.4	2.4-40
Wavelength , m	4	2	6	3
Length , m	4.9	34.3	20	165
Specific accel. rate	$3.14 \cdot 10^{-3}$	$2.7 \cdot 10^{-3}$	$0.2 \cdot 2.7 \cdot 10^{-3}$	
Field strength in gap, kv/cm	78	110	65	90
Synchronouse phase	30°	30°	30°	30°

Table (continuation).

Cavity diameter cm.	79	38	105	50
Aperture, cm.	2.0	2.3-4.8	2.0	2.0-6.0
Focusing length	$\beta\lambda$	$2\beta\lambda$	$\beta\lambda$	$2\beta\lambda$
Gap efficiency	0.83	0.85	0.6-0.93	0.72-0.96
Normalized acceptance mrad·cm	1.33	1.84-2.0	0.38-0.5	0.61-0.1
Power, Mw	0.055	5.0	0.2	20
Accelerating current (average per pulse) ma.	100		20	

The output energy of a heavy ion linac is equal 40 $\frac{\text{Mev}}{\text{nuclon}}$. The power losses in H-cavity are nearly the same as in cylindrical one. The higher the charge-to-mass ratio, the better parameters of accelerator. The linac at $q/M = 0.2\ e/m_p$ can accelerate the ions with any relation $q/M = /0.2 - 1/\ e/m_p$; it is necessary only to decrease the r.f. voltage and injection energy.

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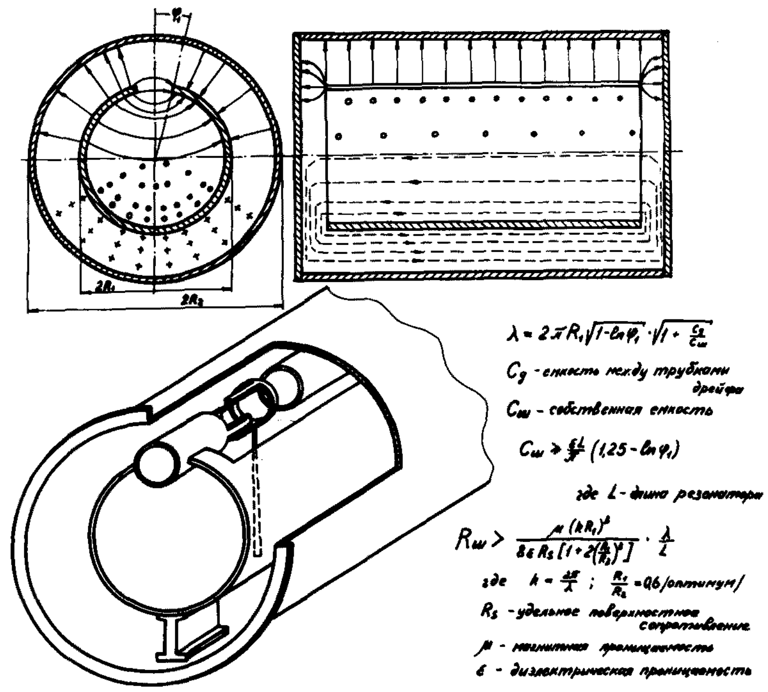


рис. 2

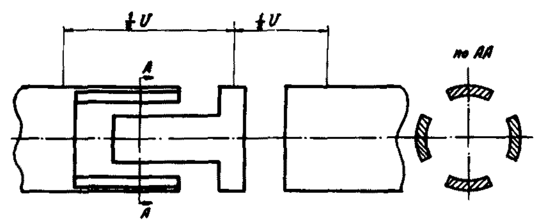
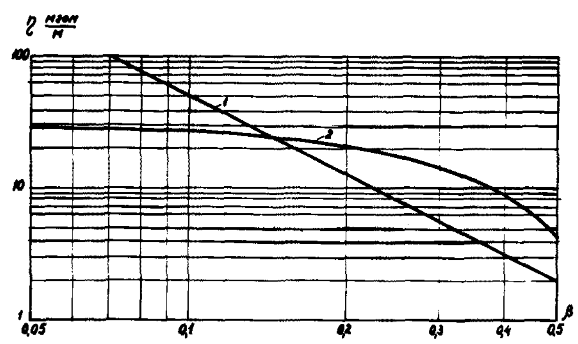


рис. 1



1 – λ = 2 м ; ν = 0,87 для H-резонатора
2 – λ = 2 м ; ν = 0,87 ; α = 0,25 ; d/λ = 0,1

рис. 3