RADIATION PROBLEMS OF THE GATCHINA ISOCHRONOUS H^- CYCLOTRON[1]

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Radiation problems of an H^- ion accelerator arise from unremovable H^- losses due to electric dissociation and beam-gas scattering. The H^0 particle beam formed as a result of H^- ions decomposition travel outward tangent to their orbits in median-plane and strike construction elements of an accelerator. The H^0 bombardment causes activation of the accelerator and radiation damage of the materials of vacuum seals, electrical isolation, etc.

For Gatchina Isochronous Cyclotron (GIC) the losses are supposed to be 1.5% due to electric dissociation and 15 or <5% due to beam-gas scattering in dependence on internal or external ion sources being used. For beam current inside the cyclotron 100μA and for beam energy up to 80 MeV such beam losses cause the problems with induced radioactivity and irradiation and it should be taken into account when designing a cyclotron. The main problems are as follows: decreasing the activation of a vacuum chamber to avoid using a remote handling at maintenance period, reduction of radiation doses on a chamber equipment and optimal choice of materials from point of view of its radiation hardness. As far as H^0 beam irradiation takes place in median plane the displacement of the metalwork out of the median plane can give reduction of the induced radioactivity. This approach was realized for dee and dee-stem design and the vacuum seals and locks of the probes were located out of the median plane. Aluminum alloys (Al) and stainless steel (SS) were investigated as a material of the vacuum chamber. The results of calculation the radioactivity induced in Al and SS chamber walls are shown in Table 1. According to the results of Table 1 Al chamber is activated one-third as many as stainless steel one.

The well known method of effective reduction of chamber activation uses baffles. The baffles are plates of low-activated material which are installed at the median-plane to keep all the chamber walls from H^0 beam. The shielding effect of the baffles can be explained by low production of the secondary radiation for such materials as carbon or beryllium, bombarded by H^0 beam and by low level of residual γ-emission in general. The beryllium was rejected for the reason of toxity. The influence of baffles is demonstrated on the second line of Table 1.

Table 1

Dose rates of induced-radioactivity gammas at distance 1 m from chamber *

Presence of baffles inside	Material of walls	Dose rate, cGy·h^{-1}
Without bafflers	Al	0.2
	SS	0.6
With bafflers	Al	0.1
	SS	0.1

* 1h after shut-down.

When we use the baffles we can use stainless steel for the chamber. It is more convenient from the technological point of view.The baffles for GIC are graphite bars 50×50 mm

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attached to easy removable Al panels fixed to the chamber. The cross-section of the panel is sufficient for the heat transmission from graphite to the iron of the magnet under temperature drop no more than 2–6°C. The baffles installed along the whole perimeter of the chamber provide the effective interception of H^0 beam of all energies up to maximum value 80 MeV.

The radiation doses of the elements of chamber and magnet coil are shown in Table 2 for the case of a baffles usage and without it.

Table 2

Radiation doses on materials

Irradiation object	Absorbed dose, 10^6 cGy·yr^{-1}	
	Chamber without baffles	Chamber with baffles
Isolation of valley coils	2.1	1.0
Electrical isolation and vacuum gaskets	25	12
Magnet coil	15	8

The radiation doses in Tables 1 and 2 are calculated for the beam losses 10μA under assumption of the uniform azimuthal loss distribution and exponential loss rising with increasing the radius.

For the radiation doses shown in Table 2 it is necessary to use fiberglass as electrical isolation of the coils and polyuretan rubbers as vacuum gaskets to guarantee the long-duration cyclotron running.

The cardinal method of decreasing the radiation problems is connected with using the external ion source. Even in this case it is necessary to develop a rather complicated axial injection system. The cyclotron with external injection can become a practically "clean" accelerator.