THE SYSTEMS TO EXTRACT THE LINEAR, RING AND CONCENTRATED ELECTRON BEAM INTO THE ATMOSPHERE

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The system of beam extraction into atmosphere is one of the main devices for an industrial accelerator. Such technological parameters as the irradiation zone size, non-uniformity of linear dose distribution, maximum electron beam current density are determined by this system. Two versions of the device for beam extraction into atmosphere are developed for ELV-type accelerators [1,2] : "linear scanning" (with the beam being extracted through titanium foil) and "concentrated beam" (with the beam being extracted through the system of diaphragms with holes). The intensive electron beam extraction through the foil puts in the forefront such problems as uniformity of beam density on the foil surface to avoid local overheating. Of special importance are also operational parameters as: the foil life time, personnel qualification, etc.

The system forming the raster of electron beam on the foil in ELV-type accelerators is performed in a way presented in Fig. 1. By a saw-shape triangular current applied to the electromagnet coils the beam is scanned in two perpendicular directions: along and transverse the extraction window. Every electromagnet has the correction coil supplied with D.C. current. This coils are needed for centering electron beam raster on the foil. An electromagnet scanning the beam in transverse direction is combined with the quadrupole lens. To ensure the uniformity heating load of the foil, the frequences of scanning along and across the extraction window is made by dividing the general generator frequency by integer numbers M and N. The ratio $\frac{f_x}{f_y} = \frac{M}{N}$ is always constant and independent of the stability of frequency f_0 . The beam trajectory on the foil forms the net, which is closed itself in the time period $\tau = M \cdot N \cdot T_{gen}$. This time must be less than the foil cooling time constant. The extraction device of ELV-type accelerators consists of the scanning magnets placed outside the vacuum chumber. The screening effect of the walls does not allow to make the frequences arbitrarily large. Usually we use: M = 251, N = 15 and $f_x \approx 50 \div 60$ Hz.

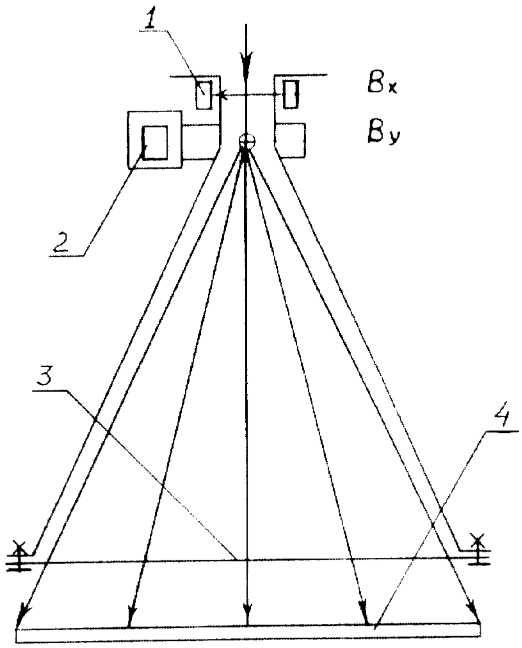

Fig. 1.

For a 50 micron titanium foil and air cooling jet velosity above 40 m/s we have the maximum electron beam density $\approx$ 220 mkA/cm^2. For providing the long-term operation without the foil failure the beam density is about of 100 mkA/cm^2. Corresponding to extracted beam 100 mA per meter of the foil with the window width of 10 cm.

The size of the foil raster and its centre-of-gravity location with respect to the window are controlled by mini-computer simplifying substantially its exploatation.The mini--computer calculates the current value of scanning magnets and quadrupole lens with respect to the energy of electrons. Mini-computer controls parameters of all system of accelerator during its operation. This data are used for testing the extraction device and for programmable protection. The accelerator is switched off if one of these parameters is out of admissible level. The same will be in the case, if functional relation scanning currents and energy of electrons is violated.

There is independent protection switching off the accelerator if currents of scanning magnets become lower than the admissible level.

The principle of centering raster consists in picking up the signal corresponding to each of four walls of extraction device, from the total electron current on insulating socket. Therefore, the measurements of current are made in phase with scanning magnets currents. In a standard situation the currents on the opposite walls are the same. If it is not so, the centering system with the help of correction coils displaces the beam so that these currents became equal.

For total irradiation of the cylinder-shape objects an extraction systems are provided with two C-shaped magnets (Fig. 2).

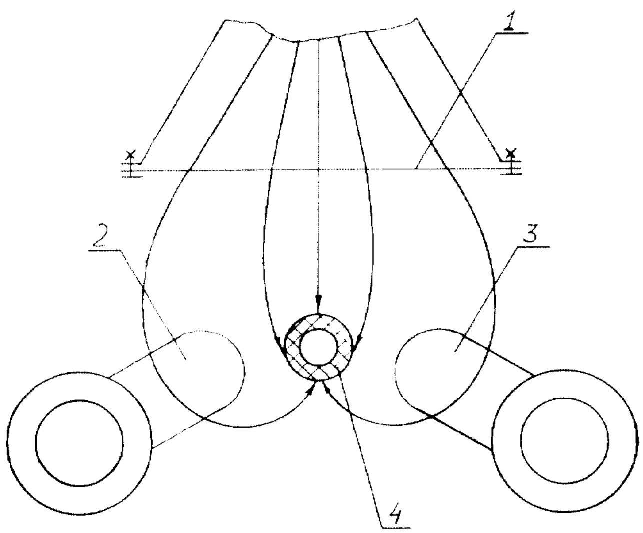

Fig. 2.

The azimuth uniformity of irradiation is determined by the magnetic field and length of raster on the foil. An incomplete use of foil length and reflective electrons limits the extraction current in this system down to the level of $\simeq$ 30 mA. Because of that, electrons are turned in the air an electron scattering has influence on parameters of device. With a decrease in the beam energy the azimuth uniformity becomes larger but efficiency becomes smaller. At an energy of about 1,5 MeV, diameter of object - 60 mm, nonuniformity $\simeq$ 10%, above 60% of electron beam is used. If the energy of electrons is 0.8 MeV only 30% of electron beam is used.

The design diagram of the device for extraction of the beam into atmosphere through the hole is shown in Fig. 3.

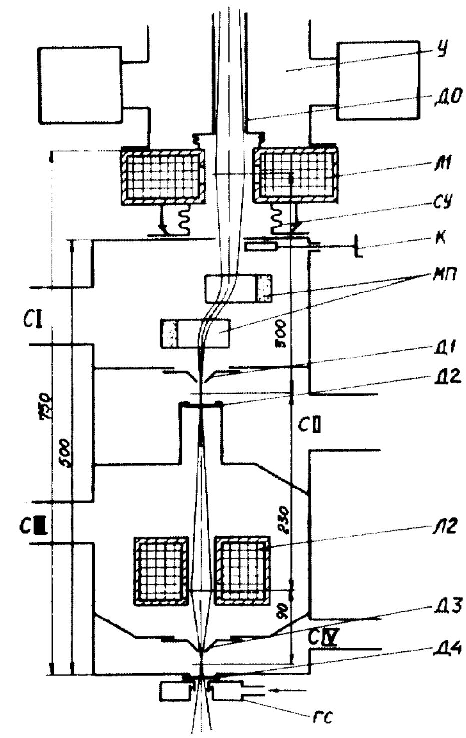

Fig. 3.

After passing the accelerating tube an electron beam comes to cylindrical electromagnet lens L_1. The current of such a lens is selected in a way that the beam crossower is placed between diaphragms D_1 and D_2. The lens L_2 focuses the beam and beam crossower is placed on D_4 diaphragm. For normal operation the accelerating tube vacuum lower than 10^{-5} torr is necessary. The difference in pressure with respect to that of atmosphere up to 10^{-5} torr is produced by the system of differential pum ping. This system includes diaphragms, vacuum pumps and vacuum shutter. The shutter allows having vacuum in the tube when the system of differential pumping is out of operation. In the process of melting metal near the output diaphragm and beam power higher than 15-20 kW break-downs of accelerating tube were observed. The parallel beam transfer at 15-20 mm excluding straight wiev between channels of extraction device and accelerating tube eliminates this effect. After long time operation on the diaphragms between channels one can see a microscopic quantity of material irradiated. All diaphragms are cooled by water. The holes in them are melted directly by the beam. The output diaphragm has minimum size of the hole. This size is determined by the beam power: beam power $\leq$ 25 kW - diameter $\leq$ 1 mm; beam power $\leq$ 40 kW - diameter $\leq$ 1.4 mm; beam power $\leq$ 70 kW - diameter $\leq$ 1.6 mm.

Maximum beam power density in the output diaphragm is about $3 \cdot 10^6$ W/cm^2.

References

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