ON SEPARATION OF VACUUM VOLUMES ON THE PATH OF AN ELECTRON BEAM

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The problem of separation by a thin foil of vacuum volumes located on the path of an electron beam is considered. It is shown that in the case of the 300 MeV electron LINAC being under reconstruction, the vacuum separation of physical installations is possible using the titanium foil with the thickness 0.5...1.0 μm. Strength of such a foil is sufficient for the role of a safety barrier in the case of an atmosphere breakthrough into one of separated volumes.

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One of the problems of passing the electron beam over more than one experimental installation consists in difference of the requirements to vacuum conditions in each of these installations as well as in the accelerator. The simplest solution to this problem is the separation of vacuum volumes by a thin foil located on the path of an electron beam. In principle, the foil with a molecular thickness would fit to this problem. Such a foil would definitely have no significant influence on the electron beam passing through. However, fabrication and using as a construction element of such a thin foil is not a simple technical problem. Therefore, let us consider the question of thickness of the separating foil (SF) from the point of view of permissible distortion by this foil of electron beam parameters.

Effects which occur during passing of electron beam through the SF are the following:

(a) Generation of γ-radiation in the beam direction.

(b) Distortion of energy spectrum.

(c) Increase on the angular beam divergence.

As for effects (a) and (b), their influence is fully eliminated if SF is located before the region where the beam is turned by the parallel translation magnet. For the estimation of the effect (c), one can use the formula for multiple scattering of electrons which overestimates the mean-square angular divergence (see [1] p.235)

$$\langle\theta^2\rangle = (E_S/E)^2 \cdot t\,, \qquad (1)$$

where $\langle\theta^2\rangle^{\frac{1}{2}}$ is in radians, $E_S = 21.2\,MeV$, E is the electron energy in MeV, and t is the SF thickness in radiation length (RL) units.

Let us consider an application of SF for vacuum volumes of 300 MeV electron LINAC being under reconstruction (see Fig.1). In this case, there exists an incompatibility of the requirements to vacuum conditions in the 300 MeV electron LINAC and electron storage ring "NESTOR" with such requirements in the installations $SP-95$ and "ELECTRON". Last two installations are located after the parallel translation system (RM-1, RM-2 in Figure), whose monochromator controls the energy broadening width of the passing beam to be in the range between 0.1% and 1%. Such an energy broadening width corresponds to the angular divergence of the beam after the magnet RM-1 (0.7...7.0) $\times 10^{-3}\,rad$ (the angular dispersion of RM-1: $D = 7.0 \times 10^{-3}$ rad/%). In the parallel translation system the beam divergence which occurs during passing of electron beam through the SF is not related to its energy dispersion. Thus, SF restricts the beam monochromatization as

$$\delta E_{min} = \langle\theta^2\rangle^{1/2}/D\%\,. \qquad (2)$$

Let us chose such a foil thickness that beam divergence caused by the foil is $\langle\theta^2\rangle^{\frac{1}{2}} \approx 10^{-3}\,rad$. In accordance with formula (2), it correspond to $\delta E_{min} \approx 0.14...0.07\%$ at $E = 100...200\,MeV$. According to the formula (1), thickness of the foil causing the above mentioned divergence at $E = 100\,MeV$ must be about $2.2 \times 10^{-5}\,RL$. We assume the SF thickness equal to $2.8 \times 10^{-5}\,RL$. This thickness corresponds to 10^{-4} cm in case of titanium and is acceptable from the technological point of view.

Let us consider the question of ability of such a foil to withstand the pressure. For this purpose we use the formula from [2][1], which connects the thickness of the self-formed round foil with the permissible pressure

$$P = 4\frac{t}{r}\eta; \qquad \eta = \frac{\sigma_T X_0}{\rho}\sqrt{\frac{\varepsilon}{1-\varepsilon}}\,, \qquad (3)$$

where r is foil radius; X_0 is the radiation length of the material; σ_T is the specific strain of plastic de-

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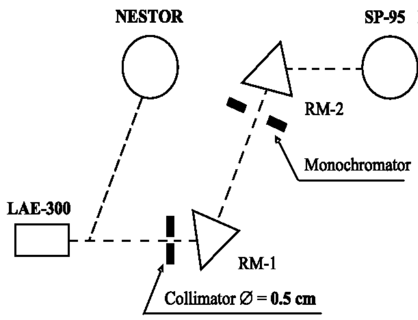
[1] This formula was written with misprint in [2]. Here it is represented in the correct form (3), as in [3] p.34-37.

formation; ε is the elongation of plastic deformation; ρ is a specific density. The cross section of an electron beam is limited by the aperture diameter of the hole collimator (see Fig.1), whose operation value is limited by $0.5\,cm$. Therefore, one should place SF near the hole collimator and adopt $r = 0.3\,cm$. Term η is connected with the material properties. As follows from formula (3), the larger is the value of η, the higher is the pressure which can be withstood by the foil with given thickness t (in RL units). According to the parameter η, one of the most convenient foil materials (see [3]) is the titanium VT3 which includes besides the main element also 4...6% Al and 2...3% Cr. For this alloy, the limit value of σ_T is $\sigma_{T,max}$ = (8.67...10.71) $\times 10^3\,kg/cm^2$, the fracture stress is σ_S = (9.69...19.73) $\times 10^3\,kg/cm^2$ (p.50 [4]) and $\varepsilon \geq 0.12$ (p.39 [3]).

Substituting this data in formula (3), we obtain that for a micron-thick VT3 SF the limit operation pressure is $P \geq 4.3\,atm$ and the fracture pressure is $P_S \geq 4.8\,atm$. For the confirmation of this calculation result, which is not obvious, let us give an example of use of the foils out of titanium VT3 with $r = 1\,cm$ and thickness equal to $150 \times 10^{-4}\,cm$ in gaseous targets where the operation pressure is equal to $100\,atm$ [2, 3]. Since the pressure on the foil is $\propto t/r$, the re-calculation according to this scaling law with the assumption that the load on SF is the same as in gaseous targets shows that $P = 2.2\,atm$ in our case. Note that calculation of gaseous targets contains the double safety factor and, therefore, the actual load on foils in these targets is $\sigma_T = 4.6 \times 10^3\,kg/cm^2$.

Thus, SF out of the titanium with thickness values starting from $0.5 \times 10^{-4}\,cm$, can be used for the separation of vacuum volumes of physical installations of $300\,MeV$ electron LINAC. At the same time, the strength of the foil is sufficient for the role of a safety barrier in the case of an atmosphere breakthrough into one of separated volumes. As regards to the maximum thickness of SF, it is determined by the requirements of the energy homogeneity of the electron beam. If you reduce these requirements to $\delta E \approx 0.3\%$, then $t_{max} = 2 \times 10^{-4}\,cm$ for titanium or $t_{max} = 5 \times 10^{-4}\,cm$ for aluminum.



Scheme of $300\,MeV$ electron LINAC (LAE-300) main units and location of experimental installations. Dashed lines show electron beams, the rest of notation is explained in the text

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О РАЗДЕЛЕНИИ ВАКУУМНЫХ ОБЪЁМОВ НА ПУТИ ПУЧКА ЭЛЕКТРОНОВ

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Рассмотрена задача разделения тонкой фольгой вакуумных объёмов, расположенных на пути пучка электронов. Показано, что в случае реконструируемого ускорителя ЛУЭ-300 возможно разделение по вакууму физических установок фольгой из титанового сплава толщиной $0,5...1,0$ мкм. Прочность такой фольги достаточна для выполнения роли предохранителя на случай прорыва атмосферы в один из разделяемых объёмов.

ПРО РОЗДІЛЕННЯ ВАКУУМНИХ ОБ'ЄМІВ НА ШЛЯХУ ПУЧКА ЕЛЕКТРОНІВ

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Розглянуто можливість розділення тонкою фольгою вакуумних об'ємів, що розташовані на шляху пучка електронів. Показано, що у разі реконструюємого прискорювача ЛПЕ-300 можливо розділити по вакууму фізичні установки фольгою з титанового сплаву товщиною $0,5...1,0$ мкм. Міцність такої фольги достатня для виконання ролі запобіжника на випадок прориву атмосфери в один з об'ємів, що розділяються.