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Licensing and Safety Analysis of the Ion Accelerator for Developing

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1. Introduction

Before using a radiation generator (RG), it should be permitted by Nuclear Safety & Security Commission (NSSC). Whereas, If it comply with the prescribed purposes or capacity defined by NSSC, the process of licensing could be simplified as a used registration, not a used permission. A RG should be manufactured by a manufactured authorization institution through the process of the design approval. If non-profit institution is authorized a used permission with including information related to the manufacture and design, the design approval process also can rule out.

Although the ion accelerators of the Proton Engineering Frontier Project (PEFP) could be classified to a used registration equipment prescribed by NSSC, it will be classified to a used permission one by KINS due to be ruled out the design approval.

Accordingly, all ion accelerators which already manufactured by PEFP are on re-authorizing process as a used permission equipment, not a used registration equipment.

2. Change of the License for the Proton Accelerator Research Center

The authorized location of the gas ion accelerator (120keV, 5mA) and metal ion accelerator (100keV, 2mA) as the used registration equipments of PEFP was in Dongguk University Gyeongju campus. Additionally, the authorized location of the dual-ion accelerator located in the site of the Proton Accelerator Research Center, where is called Gyeongju office.

PEPF is going to integrate the location for using them on the site of the Proton Accelerator Research Center. Before the change, radiation safety has to be clarified again.

3. General Safety Criteria

Concerning radiation, the ALARA principle shall be applied. In other word, the radiation shielding of the accelerator facility should be capable of reducing the radiation levels, by keeping the occupational doses and doses to the members of the public as low as reasonably achievable (ALARA), and preventing a loss or degradation of the equipment performance caused by a radiation environment during normal operation conditions. For the safety design, PEFP must have some dose criteria according to zones classification listed in Table 1. As shown in Table 1, the zones are divided by three classifications according to the workers' access availability and frequency. The design values have been made as a half value of the law in order to ensure the safety margin.

Table 1 Design Criteria (Zones Classification)

Zone Designation	Design Value (uSv/hr)
General Public Area	$DL \le 0.25$
Radiation Worker Area	$0.25 < DL \le 12.5$
High Level Radiation Area	$DL > 12.5$

Shielding must has enough performance such following that the areas in the building where worker's in and out is frequent are not admitted to exceed the amount of 1 mSv per week. Whereas, in the general public area outside the radiation worker area, it is not admitted to exceed the amount of 1mSv per year. [1] These limitations described above are regulated by the nuclear energy law in Korea. An ordinary concrete shield thickness should be based on a density of 140 lb/ft^3 when the radiation shielding calculation is performed. For other concrete with a density differing from it, shield thickness of this concrete should be determined to ensure that the attenuation properties are the same as those of the ordinary concrete shield required in the area of concern. When multiple sources affect the protected area, shield thickness should be adequately determined to ensure that the radiation level from all the significant radiation sources in that area will not exceed the designated dose limits.

4. Radiation Safety Aspects

2.1 Analyses & Calculation for reviewing Ion accelerator Safety

By the nuclear energy law, dose limit to a controlled and non-controlled area for 40 hours per week of a working time is set to 1mSv/week and 0.1mSv/week, respectively. However, shielding design objective was set as 2.5uSv/hr to ensure the safety margin.

Shielding design for the ion accelerators of PEFP is reconsidered. That is performed by simplified equation

(1). [2] The calculated thickness and installed thickness of lead are showed in the table 2. The measurements and the calculations have been carried out at a distance of 1 meter from the device surface.

$$H_M = \frac{D_{I_o} T}{(1.67E-5)\times d^2} \times B_x \qquad (1)$$

Where

H_M is the maximum permissible dose-equivalent or dose-limit rate (mrem hr^{-1})

D_{I0} is the absorbed-dose index rate (rads m^2 min^{-1}) at a standard reference distance of 1 meter from the source.

T is the area-occupancy factor

B_x is the shielding transmission ratio for x rays; the value by which the x-ray absorbed-dose index rate that is incident on the entrance face of the shielding barrier shall be diminished by the barrier thickness to the requisite levels of H_M and dose limit rate at the exit face of the barrier.

d is the distance between x-ray source and reference point (meters).

The constant (1.67E-5) = (1 E-3) rad $mrem^{-1}$ x (1.67E-2) h min^{-1}.

Table 2 Calculated Thickness & Installed Thickness of Lead

Device Name	Calculated Thickness (lead, mm)	Installed Thickness (lead, mm)	Measure (nSv/hr)
Gas Ion Accelerator	2	3	840
Metal Ion Accelerator	1.1	3	380
Dual-Ion Accelerator	3	3^*	160

2.2 Optimization of Shielding

The accelerated ion will not produce a secondary ionizing radiation in the tube but it will make a secondary free electron by hitting at an electrode. The secondary electron produce bremsstrahlung (x-ray) during accelerated in the opposite direction with the ions. It is one of parameters needed to perform the shielding, which is a different value in accordance with each a device design. The design to reduce it as possible should be needed to prevent the unnecessary radiation. The yield assumed 10 % of ion current in the equation (1).

And if the normal electron arrangement around a nucleus is altered through ionization of an inner electron or through excitation of electrons to higher energy levels, the electron begins complex transitions to vacancies in the lower shells. In each electronic transition, the difference in binding energy between the initial and final state is either emitted as a photon, called a characteristic x-ray. Because it has enough low energy to be shielded by the tube component, extra shielding is no need for it.

Energy of the characteristic x-ray can be calculated by Equation (2) to within 4% tolerances. [3] For example, its energy on Cu target is Ek (eV)=5.706 x $(29)^{2.186}$ = 8.977 keV.

$$Ek(eV)=5.706Z^{2.186} \qquad (2)$$

5. Summary

Before using a RG, it should be permitted by NSSC. The ion accelerators of the PEFP will be classified to a used permission device by KINS due to be ruled out the design approval. Therefore, all ion accelerators which already manufactured by PEFP are on re-authorizing process as a used permission device, not a used registration device. Shielding design for the ion accelerators of PEFP is reconsidered. That is performed by simplified equation.

REFERENCES

[1] Enforcement Decree of the Act, Korea

[2] Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities, March 1, 1977. NCRP Report No. 51

[3] Arthur B. Chilton, J. Kenneth Shultis and Richard E.Faw, "Priciples of Radiation Shielding," 1984.