RADIATION SHIELDING IN HISOR PROJECT

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Abstract

Radiation shielding factors were obtained for neutrons and gamma rays emitted from three types of accelerators planned in HiSOR project. There are two types of leakage of radiation, one is direct irradiation from the sources and the other is skyshine effect from the roofs. For the 45 MeV linear accelerator and 1.5 GeV synchrotron, 1.5 m thick concrete is necessary to protect people who work within this area and for those who live outside. For 1.5 GeV storage ring, 30 cm is enough for such purpose.

Introduction

HiSOR project have been proposed to contribute to the scientific activities mainly in the western area of Japan. The design of the accelerator system for this HiSOR project has been reported in earlier articles.(1) In this paper, determination of radiation shielding and concrete thickness or such factors for radiation protection and the basic concept of radiation protection is discussed. In addition we have compared and discussed the radiation shielding in several other accelerator facilities.

Basic concept of radiation shielding

There are three accelerators which should be considered in the shielding design. These are (1) a 45 MeV electron linear accelerator, (2) a 1.5 GeV electron synchrotron and (3) a 1.5 Gev electron storage ring. Radiation shielding was designed for each accelerator independently, since scientific research programs were proposed not only for the synchrotron X-ray experiments but also for the 1.5 GeV electron synchrotron and the electron linear accelerator. The benefit of this concept is that experimental preparation for the synchrotron X-ray users and machine maintenance by HiSOR staffs can be made during the time of the operations of the synchrotron and the linear accelerator.

Domestic law of the radiation protection established three limits for radiation leakage from these accelerators under the basis of the recommendations of the international commission on radiation protection (ICRP).(2) According to this law three corresponding borders in the HiSOR project are considered as,

(1) the border between the campus area and the area of the public,

(2) the border in the area of HiSOR separating general area to that under the supervision of the laboratory for radiation protection, and,

Table 1. Characteristics of the accelerators and operating condition.

	Electron linear accelerator	Electron synchrotron	Storage ring
Energy	45 MeV	1.5 GeV	1.5 GeV
Current	83 mA	50 mA	300 mA
Number of pulses per second	120 pps	0.5 pps	
Time of operation per year	3000 h y^{-1}	3000 h y^{-1}	3000 h y^{-1}
per week	72 h w^{-1}	72 h w^{-1}	72 h w^{-1}
Time to round	-	3 x 10^{-7} s	3 x 10^{-7} s
Pulse width	3 μs	-	-
Life time	-	-	10 h

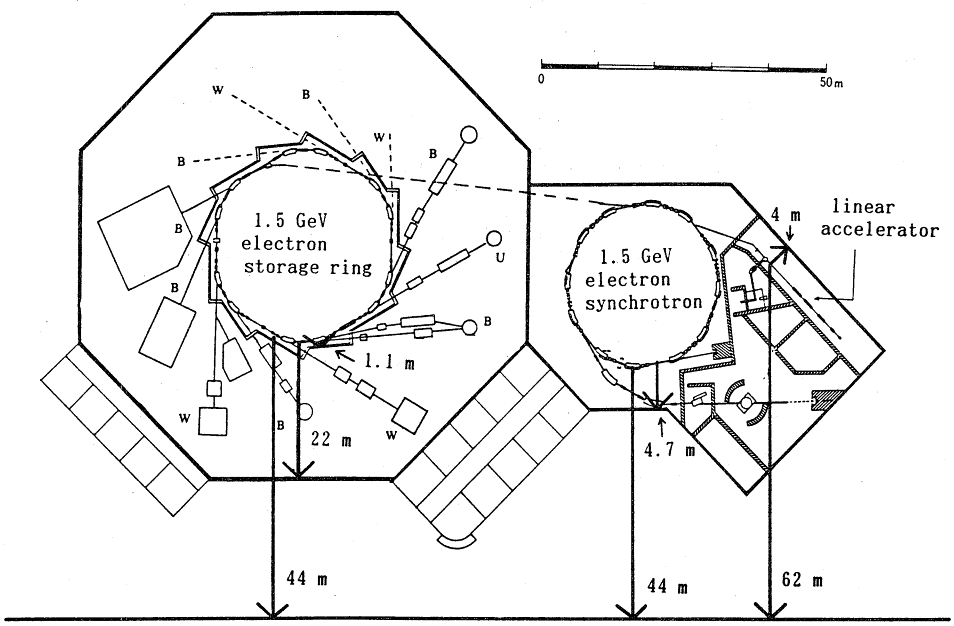

Fig. 1. Points of radiation dose calculation.

(3) the border in the area under the supervision between the entry limited area and that without such limitation, when the machines are in operation.

The limited leakage doses in these three borders were established by law as 100 mrem per year, 30 mrem per week and 5 rem per year, respectively. In the HiSOR project, these limitations were determined as (1) 5 mrem per year, (2) 13 mrem per week and (3) 120 mrem per week, respectively. The limitation in the border of (1) was decreased by 5 % less than that required by law because of safety to the public.

Calculation of the shielding

The parameters of the machines and the operating conditions are shown in Table 1. The factors in Table 1 are used in the calculation of radiation shielding.

Beam loss occurs mainly at the exit of the linear accelerator, at the entrances of the synchrotron and the storage ring, and near bending magnets. For the shielding calculation three points for each accelerator were assumed to loose all of the beam energies as shown in Fig. 1. Maximum leakages were considered in the cal-

Table 2. Results of the leakage doses in HiSOR.

	Linear accelerator	Synchrotron	Storage ring
Ordinary concrete wall thickness (m)	1.5	1.5	0.3
Experimental room (mrem y^{-1})	-	-	1350
Border under the supervision (mrem w^{-1})	126	81	0.080
Border of the campus (mrem y^{-1})	14	45	1.0

Table 3. Guiding principles of radiation shielding in other laboratories.

	KEK*	IMS#	IPCR=	RCNP$	LNS%	HiSOR
Experimental room ($rem\ y^{-1}$)	<18	-	2	-	-	5
Border of supervision ($mrem\ w^{-1}$)	13	-	10	-	-	13
Border of institution ($mrem\ y^{-1}$)	5	5	5	<80	5	5

* National Laboratory for High Energy Physics.
\# Institute for Molecular Sciences.
= The Institute of Physical and Chemical Research.
$ Research Center for Nuclear Physics, Osaka University.
% Laboratory of Nuclear Science, Tohoku University.

culation for safety.

The equations of the leakage calculation were taken from reference.(3) From these equations shielding factors concerning the four types of leakages were obtained: (1) for gamma rays, (2) for giant resonance neutrons, (3) for high energy (100 MeV) neutrons and (4) for skyshine effect of neutrons.

Results

The results of the calculation at the places indicated in Fig. 1 are listed in Table 2. Operating conditions in Table 1 and the four types of leakage for gamma rays and neutrons were included in the calculation. For thickness of the wall 1.5 m ordinary concrete data was used.

Discussion

In Table 3, dose limits adopted in the design of the systems are listed. Basic concept of the radiation shielding in HiSOR project is almost same as those laboratories in Table 3. At the border of the public area and campus area 5 mrem per year are adopted in almost all of other laboratories although as per law it is 20 times higher.

Our values at the border of the area under supervision are 81 mrem w^{-1} and 126 mrem w^{-1} for the electron synchrotron and the linear accelerator, respectively. Corresponding values for campus area are 45 and 14 mrem, respectively. These values are higher than our limits in HiSOR project. However, these can be reduced by (1) installing scrapers at the exit of the linear accelerator and at the entrance of the synchrotron to reduce the size of the beam and shielding the scraper effectively and locally by 10 cm thick iron, and (2) changing the assumption in the calculation from one point beam loss to uniformly distributed beam loss. The case (1), for example, in Photon Factory KEK 80 % of the beam is lost at the scraper. By calculation assuming (1) and (2) leakage dose are reduced to 10 %, additional concrete block shieldings of 50 cm in the accelerator rooms can reduce leakage by about one-half and reduction of operating time of the electron synchrotron can further reduce leakage dose. By these methods leakage dose less than the HiSOR limits can be obtained.

In the calculation of the shielding of the storage ring 90 degree direction was assumed, however, to the direction near 0 degree, dose is about 100 times larger than 90 degree. For this direction additional shielding by paraffin and by lead can decrease leakage dose to appropriate ranges. In the case of Photon Factory such shielding were actually made to reduce leakage.

References

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