Radiation Protection

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Thanks to efforts by the accelerator group, intensities of polarized beams have been increased close to 1 μA and such intense beam of 400 MeV proton is now used in actual experiments. In addition, beams are sometimes stopped by various kinds of Faraday cups which is not well shielded in many experiments. In spite of such expansion of beam usage, radiation protection at RCNP has still been in fairly good level.

Determination of current limit for each beam line

Facing to such variety of beam usage, we determined the maximum limit of the beam current which may be used in each experimental condition.

In order to decide the limit, a leakage dose to adjacent experimental halls and outside of the experimental building has been measured with a neutron dose meter. The measurement has been performed by using a 400 MeV proton beam stopped at several points on the WN beam line and the T2 beam dump.

The maximum current limit was determined so as to keep the dose lower than about 20% of the lawful limit. The results for 400 MeV proton beam are tabulated below. For other energies and ions, the following rule is applied:

- For 300, 200 and 100 MeV, the values should be multiplied by 2, 4 and 8, respectively.
- For beams other than protons, the beam energy should be replaced by energy per nucleon, and the beam current should be scaled by the nucleon number of the beam ions.
- For the N0 beam dump, the same value as for the WN beam dump is applied.
- For the ES beam dump and the dumps for zero degree measurements with spectrometers Grand Raiden and LAS, the value for 'without shield' is applied temporarily. The value may be modified when it is required.
- In spite of the rescaling above, the maximum current should not exceed 1 particle-μA, which is the limit given in the permit.

Routine monitoring 1: Area monitoring

Continuous monitoring has been done at several points outside the cyclotron building. Background dose of neutrons and γ-rays are around $5 \times 10^{-3} \mu$Sv/hr and 0.05μSv/hr, respectively, and no increase which is correlated with accelerated beams have been observed. Some neutron monitor has recorded sky-shine neutrons from other facilities in the same campus and the total dose of 130 μSv/year, which is more than twice of the background level, was encountered.

Table 1: Upper limit of beam current for 400 MeV protons. See the text for detail.

WN beam dump	T2 beam dump	beam stopper without shield
1 μA	100 nA	10 nA

In the building, dose rate due to activated materials are routinely surveyed in addition to continuous monitoring by area monitors. According to high intensity beams, some parts of beam lines, especially around the quad magnet upstream the WN beam dump and some part in the injection beam line, are significantly activated. The dose occasionally exceeds a several hundred μSv/hr at 50 cm distance from the beam duct. These regions are noticed by caution panels and, fortunately, no serious exposure in these regions has been reported.

Routine monitoring 2: Personal dose

Figure 1 shows a result of personal dose monitoring from the beginning of the AVF Cyclotron operation at RCNP. The exposure values were relatively high in early days, decreased gradually and reached zero, lower than the detection limit, in 1989 and 1990. But operation of the Ring Cyclotron started in 1991 and finite exposure values have been reported again.

Monitoring for users outside of RCNP has been made by using pocket chambers with solid state detectors. Two of those users were exposed to about 0.1 mSv in a replacement work of the WN beam dump and their annual doses, at RCNP, were 0.3 and 0.2 mSv/year respectively. For all of other people, reported values were less than 0.1 mSv/year.

Even though the above levels are much lower than the lawful limit for radiation workers, 50 mSv/year, or even than that for general people, 1 mSv/year, effort to reduce the exposure should be continued according to the concept of ALARA (as low as reasonably achievable).

Non-routine works and change of rules

- Waterproof membrane inside the waste-water reservoirs and a diluting tank was renewed.
- A dedicated drain was prepared at a position where underground water leaks into the building. As a result, amount of radiation-controlled waste-water are reduced drastically.
- A web service was started. Forms for user and radiation-worker registration are now available through the Internet.
- Rules for use of checking sources and issuing the ID card for temporary visitors are modified.

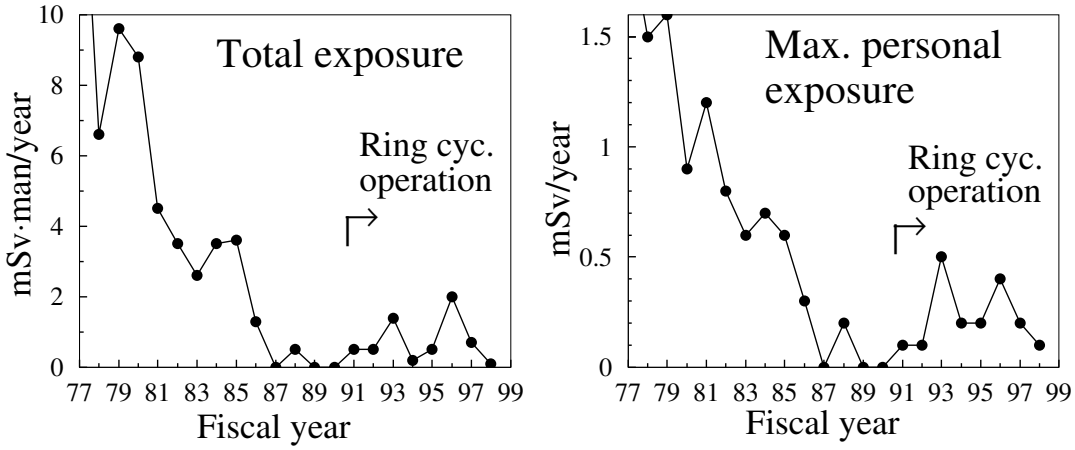

Figure 1: Annual radiation exposure for RCNP and SAS (Sumijuu Accelerator Service Ltd.) people. Left: sum for all of people. Right: dose for a person who suffered the maximum exposure in each year.