4.1 OPERATION OF THE RCNP CYCLOTRON

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Summary of the performance of the AVF cyclotron and the Ring cyclotron in the ficalyear 2000 is given in Table.1. The WN beam line, which was involved in the previous annual report[1] was removed and a new beam line (WS) was constructed in the spring in 2000[2]. About 99 % of beam time was carried out by using the Ring cyclotron. We had ~130 hours of unscheduled shutdown in 2000, which is mainly due to the following severe machine troubles:

1) burnout of the resister in the power supply for the screen grid for the flat-topping cavity in the Ring cyclotron. A similar trouble was carried out in the fisicalyear of 1999.
2) breakdown of the vacuum of the main chamber in the Ring cyclotoron due to breakdown of the thin foil in the ES course.
3) trouble of voltage-adjusting system in the main cavity #3 of the Ring cyclotron.

We succeeded to repair the cyclotron complex within 30 hours in each trouble in 2000.

Table 1: A summary of operational statistics

Beam time	Beam time for experiments	I	30h10min
		WS	2416h10min
		N0	77h10min
		EN	68h00min
		ES	289h10min
		total	2880h40min
	Tuning of beam for experiments		505h10min
	Preparation for Acceleration and Developments		1829h40min
	Total		5215h30min
Maintenance			1625h10min
Shutdown	Scheduled shutdown and holidays		1791h30min
	Unscheduled shutdown		128h20min
Total			8760h00min

The beam usage of the cyclotrons is summarized in Table 2. Mainly, high–quality light-ion beams, such as proton, deutron and helium beams, have been required. In 2000, more than 90 % of the beam time was carried out for the light ions. High-quality beams in momentum spread have been strongly required in the RCNP and were obtained for some ions. For example, 55 keV and 62 keV of the energy resolutions were obtained for 300 MeV and 392 MeV proton beams, respectively. The ratio of the Rf voltage of the flat-topping cavity to those of the main cavities was empilically found out as one of the key parameters. Until 2000, the Rf voltage of the flat-topping cavity was operated as a settled parameter for simplicity. However, careful search of the Rf voltage of the flat-topping cavity by 1 kV is found out to be necessary to obtain extremely high-quality beams. The voltage ratio of the flat-topping cavity to the main ones adopted before seems a little bit higher in comparison to that obtained in 2000. This discrepancy may come from ambiguity of pick-up ratio of a probe to the real voltage of the cavity.

In addition, we would like to stress an importance of an operation of the AVF cyclotron for extremely high-quality beams. It was found that when quasi single-turn structure of beams was observed in the AVF cyclotron, quality of beams from the Ring cyclotron was quite well. Empirical method to obtain quasi single-turn structure of beams was found out for some ions. It should be noted that the time needed to adjust the operational parameter of the AVF cyclotron becomes longer than before for extremely high-quality beams because of lack of beam-diagnostic probe in the cyclotron.

The new WS beam line can accomplish both lateral and angular dispersion matching between the beam line and the Grand Raiden spectrometer. In this dispersive mode, the energy resolution of ~13.3 keV in FWHM for 295 MeV proton was already reported[2]. Even in dispersive mode, an energy resolution of the beam itself is much important practically[3].

Table 2: A summary of the beam usage of the RCNP cyclotrons

Particles	
Proton	$989^{h}00^{min}$
Pol. Proton	$2038^{h}00^{min}$
Pol. Deutron	$573^{h}10^{min}$
^{3}He	$611^{h}40^{min}$
Alpha	$698^{h}40^{min}$
^{7}Li	$152^{h}00^{min}$
^{14}N	$118^{h}00^{min}$
^{16}O	$35^{h}00^{min}$
Total	$5215^{h}30^{min}$

It was found that the magnetic field strongly correlate with quality of beams reported elsewhere[3]. The magnetic field for a cyclotron can be controlled by adjusting cooling water temperature. In the RCNP, since many kinds of ions with various energies are accelerated, water-cooling system for the coils should have some degree of freedom. In addition, such system should be effectively isolated from outer circumstance for the stable cyclotron operation day and night for all seasons.

A cooling system of the AVF cyclotron was improved in 2000. Main purposes are 1) to control the water temperature for the main coil independently and 2) to stabilize the water temperature both for the main coil and the trim coils by the order of 0.1 degree independently of outer circumstance. For the former, an additional water pump and heat exchanger was installed for the main coil. For the latter, a three-way valve was newly installed nearby the cooling tower in order to cancel out influence on outer disturbance. A new buffer tank for chilling water was also installed.

Effective feedback from measuring magnetic field with an NMR probe is also necessary for the RCNP cyclotron complex. In 2000, a one-turn coil called fine tuning coil (FT coil) was installed to the AVF cyclotron. Typical current is » 10 A. Current control of a few tens mA leads to control the magnetic field on the order of 10^{-7}. By improvement of the cooling system for the AVF cyclotron and installation of the FT coil to the AVF cyclotron, to obtain high-quality beams in a long term becomes easier than before.

The operation statistics from 1977 are shown in fig. 1. The scheduled shutdown decreased and the beam time increased a little bit as compared with the last fiscal year, respectively.

References

[1] e.g. S. Ninomiya et. al., RCNP Annual Report 1999 p.107.

[2] T. Wakasa et. al., RCNP Annual Report 1999 p.95

[3] S. Ninomiya et. al., elsewhere in this report.

Fig.1 Operating Statistics