Status of vacuum pumping systems in accelerator facilities

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Vacuum pumping systems in accelerator facilities have the following two problems: vacuum leakage and update issue. The vacuum leakage is a malfunction of old accelerator facilities caused by age-related deterioration. The update issue is that almost all old vacuum pumps and accessories cannot be replaced with new units owing to a budget limitation. In this paper, we discuss the current status of vacuum pumping systems.[1,2)]

A vacuum pumping system in an accelerator facility[1)] comprises cryopump systems, turbomolecular pump (TMP) systems, rough pumping systems, additional chamber (AC) pumping systems, and subpumping systems (subvacuum of a resonator). Table 1 lists the number of vacuum pumping systems in accelerator facilities. Each ring cyclotron contains more than 80 sets of cryopump systems,[2)] more than 120 sets of TMP systems, and 2–8 sets of rough pumping, AC pumping, or sub-pumping systems. In addition, more than 160 module-type vacuum gauges (total pressure gauge controller) combined with Pirani and cold cathode gauges are used to monitor vacuum pressure and interlocking vacuum process control in accelerator facilities. Table 2 lists the number of malfunctions in the pumps and gauges from 2018 to 2020. In a year, three to nine malfunctions occur in each unit. The number of malfunctions may have been lower before 2017 because of the shutdown of the RILAC due to the SRILAC installation in 2017–2019 and the closure of the RIBF due to the COVID-19 pandemic in 2020.

Vacuum pumping systems have been in operation for 14–42 years.[2)] In particular, RRC cryopumps, large RILAC TMPs (5000 L/s), and large RRC TMPs (5000 L/s) were manufactured in 1985, 1978–1987, and 1985, respectively. In addition, the doses in the SRC, IRC, and AVF room are extremely high during beam irradiation. Therefore, the number of malfunctions caused by age-related deterioration and environmental radiation will increase further in the future. New spare units of vacuum pumping systems were purchased gradually, but these spare units are still not sufficient. The following requirements remain.

(1) All the existing RRC cryopump compressors have been discontinued by the manufacturer; therefore, at least six cryopump compressors must be replaced with new ones within a few years. Based on such measures, one cryopump system set of the IRC-NE valley cavity was relocated to the RRC-VS valley cavity in 2019, and two cryopump systems operate in the IRC-NE valley cavity. Six SRC cryopump compressors should be also replaced with new ones in the future.

(2) In the case of large TMPs, although one 5000 L/s TMP of the RRC was replaced with a new one in 2017 and one of the RILAC is scheduled to be updated, the other 5000 L/s TMPs are not yet scheduled for replacement. In addition, a few malfunctions of large rotary pumps (RPs) have been occurring in the rough pumping system of ring cyclotrons and have not been repaired. Therefore, these large RPs must be replaced with new units in the future, although their operating times are lower.

Table 2. Number of malfunctions from 2018 to 2020.

	2018	2019	2020
Cryopump[a]	4	6	7
Turbomolecular pump[b]	3	8	4
Rotary pump	5	3	7
Vacuum gauge[c]	4	6	9

[a] Includes a compressor. [b] Includes an attached power supply. [c] Includes a controller, Pirani gauge, and cold cathode gauge.

However, small TMPs and RPs as well as vacuum gauges have been repaired or updated, and these have been relatively stable. Oil leaks in small RPs were mainly repaired by replacing new O-rings and seals, and vacuum gauges were repaired by replacing some boards and parts.

Consequently, if more cryopumps or TMPs malfunction in a year, it will be difficult to operate accelerator facilities depending on the number of spare units. Therefore, the priority would be to purchase a sufficient number of spare units.

References
1) S. Yokouchi *et al.*, RIKEN Accel. Prog. Rep. **41**, 101 (2008).
2) Y. Watanabe *et al.*, RIKEN Accel. Prog. Rep. **50**, 154 (2016).

Table 1. Number of vacuum pumping systems in accelerator facilities.

	RILAC[a]	RILAC2[a]	AVF[a]	RRC	fRC	IRC	SRC	BT[a]
Cryopump system	11	8	2	14	6	14[b]	22	3[c]
TMP system (TMP + RP)	14	11	1	4	2	4[d]	4[d]	78
Rough pumping system (MDP[e] + RP)	–	–	–	2[d]	2	2	2	–
AC pumping system (TMP + RP)	–	–	–	4	–	4	–	–
Sub-pumping system (TMP + RP)	–	–	–	–	–	4	8	–
Module-type vacuum gauge	16	9	1	14	3	14	10	78

[a] Excludes ion sources, SRILAC, or charge strippers. [b] One set was relocated to RRC. [c] Includes a re-buncher and D6-BEA.
[d] One is out of order or offline. [e] Mechanical booster pump.

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