VACUUM SYSTEM OF HIRFL'S CYCLOTRONS

X.T. Yang#, J.H.Zhang, Z.M.You, J.Meng and Vacuum group of IMP
Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, P.R.China

Abstract

HIRFL has 2 cyclotrons: a sector focus cyclotron (SFC) and a separate sector cyclotron (SSC). SFC was built in 1957. In the past 50 years, the vacuum system of SFC has been upgraded for three times. The vacuum chamber was redesigned to double-deck at the third upgrade. The working pressure in beam chamber was improved from 10^{-6}mbar to 10^{-8}mbar. SFC has delivered Pb, Bi and U beams in the past few years since the last upgrading of its vacuum chamber. SSC began to operate in 1987. The vacuum chamber of SSC has a volume of 100m^3. 8 cryopumps keep the pressure from 5×10^{-7}mbar to 8×10^{-8}mbar depending on the used pump numbers (2~8). In the past 20 years, because of the contamination of oil vapour and leaks occurred in some components inside the SSC vacuum chamber, the vacuum condition has worsened than the beginning. It is a big problem to accelerate the heavier ions. The upgrade for the SSC vacuum system will be an urgent task for us. The rough pumping systems of both SFC and SSC have been rebuilt recently. As a result, the oil vapour in two cyclotrons will be eliminated and the vacuum condition of them will be improved.

A new small cyclotron will be built in HIRFL as an injector of the Heavy Ion Therapy Facility in Lanzhou (HITFiL). The brief introduction of the vacuum system design is given in the paper.

VACUUM SYSTEM OF SFC

SFC with the energy constant of 69 is the injector of SSC and HIRFL-CSR [1]. It was built in 1957. In the past 50 years, the vacuum system of SFC has been upgraded for three times. The working pressure was improved from 10^{-6}mbar to 10^{-8}mbar. At the third time, the vacuum chamber was redesigned to double-deck [2] (Fig.1). All components with large gas load such as magnet cores, coils and hundreds of electric wires were put into the insulation chamber where the pressure is 10^{-1}mbar pumped by a mechanical pump. Consequently, a pressure of 10^{-8}mbar can be obtained in the beam chamber by 2 cryopumps with a total pumping speed of 40000 l/s. Because the beam chamber was made of thin copper with a thickness of 4mm, the safety valves both in mechanical mode and electrical mode were installed between the two chambers, which are interlocked with the pressure sensors to protect the copper chamber from the damage.

After this upgrade of the vacuum system, 1.1 MeV/u $^{208}Pb^{27+}$ beam was accelerated to confirm the vacuum effect, which turned out that the upgrade of the SFC vacuum chamber was successful. SFC has delivered $^{208}Pb^{27+}$, $^{209}Bi^{31+}$, $^{238}U^{26+}$ beams in the past few years since the last upgrade of the SFC vacuum chamber. So, the heavy ions from C to U can be accelerated in SFC.

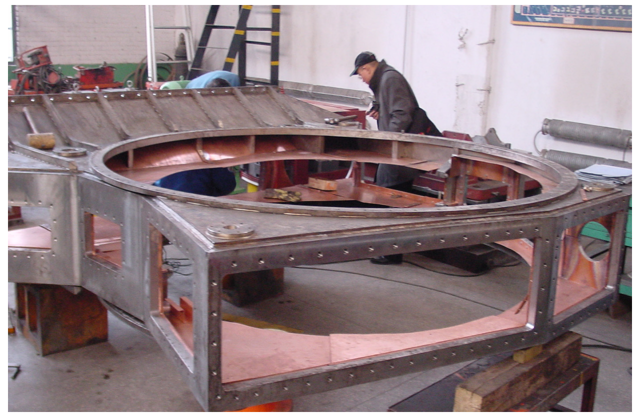

Figure 1: SFC double-deck vacuum chamber

VACUUM SYSTEM OF SSC

SSC with the energy constant of 450 began to operate in 1987. It provides beams to about 10 experimental terminals and is also the injector of the cooling storage ring (HIRFL-CSR). The vacuum chamber of SSC (Fig.2), which was made of 316L stainless steel with a permeability of 1.01, has a volume of 100m^3. The magnet cores, RF cavities, injection and extraction components were inside the vacuum chamber with a large gas load. 8 cryopumps with a pumping speed of 20000 l/s for each were installed in the chamber. Depending on the accelerated heavy ion species, 2~8 pumps were used to keep the pressure from 5×10^{-7}mbar to 8×10^{-8}mbar.

SSC has operated for more than 20 years. Because of the contamination of oil vapour and leaks occurred in some components inside the SSC vacuum chamber, which were very difficult to eliminate, at present the pressures in four vacuum gauges which were installed in different positions were $2\sim4\times10^{-7}$mbar with 6 cryopumps operating. It was a big problem to accelerate the heavier ions although the $^{209}Bi^{31+}$ beam was delivered recently. The upgrade for the SSC vacuum system will be an urgent task for us. In order to improve the vacuum condition, one measure is to change the old pumps which have exceeded the time limit by new ones; second measure is to try to reduce the system leaks and the third one is to eliminate the oil vapour contamination.

yangxt@impcas.ac.cn

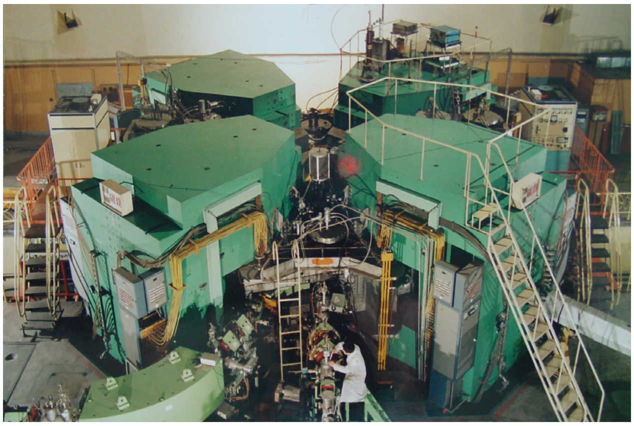

Figure 2: SSC (vacuum chamber is between the magnets)

ROUGH PUMPING SYSTEM UPGRADE

The oil mechanical pumps which cause the serious contamination to the vacuum chambers were used for the rough pumping systems of SFC and SSC for many years. In August, 2010, during the accelerators shutdown period, the rough pumping systems were rebuilt. The oil pump units were changed by large dry mechanical pumps with a pumping speed of 630m^3/h and 250m^3/h for SSC and SFC respectively (Fig.3). As a result, the oil vapour in two cyclotrons will be eliminated and the vacuum condition of them will be improved.

Figure 3: The new rough pumping stations of SSC and SFC

VACUUM SYSTEM OF 7MEV/U CYCLOTRON

The small cyclotron with the energy of 7 MeV/u is the injector of the Heavy Ion Therapy Facility in Lanzhou (HITFiL). The new project is under construction. The vacuum chamber of the cyclotron which is made of stainless steel has a dimension of ϕ1720mm $\times$760mm (D$\times$H). The magnet yokes are used for the cover plates of the chamber. Same as SSC, the RF cavities, magnet cores, injection and extraction elements are designed inside the vacuum chamber. Since rusty surface will induce the significant increase of the gas load, the magnet cores made of DT4 material will be coated with TiN film to avoid getting rusty.

The vacuum equipment layout of the cyclotron is shown in Fig.4. The total gas load of the vacuum system is about 4$\times$10^{-3}mbar.l/s. In order to obtain the working pressure of 5$\times$10^{-7}mbar, the effective pumping speed for center plane of the machine has to be larger than 8000 l/s. Because of the limited room, 4 cryopumps with a pumping speed of 5000 l/s for each can only be installed in the upper and lower planes of the magnet yokes, where there are 4 holes with a diameter of 350mm and a length of 580mm. The pump-down station consists of a turbo molecular pump (TMP) with a pumping speed of 2000 l/s and a dry pump with a pumping speed of 300m^3/h. 5 vacuum gauges are installed in different positions of the chamber to read the pressures and interlock with the valves which fixed to each pump.

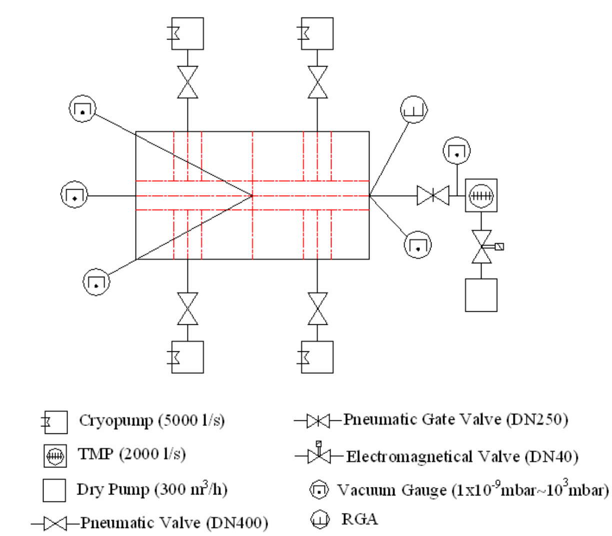

Figure 4: The vacuum equipment layout of the cyclotron

HITFiL project will be completed in 2013. The vacuum system of the new cyclotron will be finished in 2011.

REFERENCES

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[2] D.Z.Wu, Y.F.Wang, X.Q.Zhang, et al., "The upgrade of the vacuum chamber of SFC", Vacuum and Cryogenics, 2005 (1): 40-45 (In Chinese).