VACUUM CHAMBER FOR PROTON-HEAVY ION SYNCHROTRON

Goldin L.L., Zudinov Ju.B., Ivanov N.E., Kruglov B.I., Nikolaev V.I., Onosovsky K.K.

Institute for Theoretical and Experimental Physics

Moscow, USSR

Introduction

Three years ago it was decided to reconstruct the 10 GeV ITEP proton synchrotron which has been active since 1961 and to create on its basis an accelerator complex for ions of broad mass range (from H to U). It was decided to accelerate in the synchrotron ions with several or even many electrons. This option has many advantages. We can employ various ion sources which generate ions with different i to A ratios; we can have a comparatively simple injector and the possibility of ion extraction by their recharging inthe inner target [1].

Complex Layout

To construct the accelerator complex it was necessary to develope an injector of multicharged ions, to reconstruct the high frequency and vacuum systems of the synchrotron itself and to build an additional magnet ring.

On completion of all these jobs the complex will be as follows. In the existing ring tunnel of the synchrotron we place an additional magnet ring which is 230 m long. The ajacent rooms house the present proton injector - the 25 MeV linac - and a new pulsed accelerator, which can accelerate ions with the i/A ratio from 1/20 to 1/3 and will be used as an injector [2]. The complex layout is shown in Fig. 1.

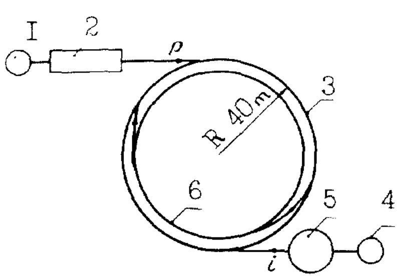

Fig. 1. The principal layout of the proton-heavy ion complex: 1 - proton sourse; 2- linac; 3 - synchrotron; 4 - heavy ion sourse; 5 - injector; 6 - additional ring.

The accelerator complex will operate with the frequency of 15-20 cycles per minute. Ions produced in an ion source will be preliminary accelerated in the injector, recharged on a foil and injected into the synchrotron. After acceleration in the synchrotron, light ions with the maximum energy of 3.5 GeV/a.m.u. will be transported to experimental halls, and heavy ions are to be recharged and put into the additional ring. They will remain there as long as it is necessary to readjust the synchrotron magnetic field for new charge values. After this the ions will be reinjected into the synchrotron, accelerated up to the energy of 2.5-3.0 GeV/a.m.u. and extracted.

Vacuum Requirements

The decision to accelerate ions with a considerable number of electrons leads to severe requirements to the residual gas pressure in the accelerator vacuum chamber. According to estimations the mean value of the residual gas pressure must not exceed $5 \cdot 10^{-8}$ Pa if ion losses due to recombination are to be less than 50 %. It should be noted that to accelerate protons it is enough to have $3 \cdot 10^{-4}$ Pa. To meen the drastically increased requirements to vacuum it was necessary to construct a new vacuum chamber and a new pumping system.

Chamber Design

The new vacuum chamber of the ITEP synchrotron is manufactered of stainless steel and, in accordance with the magnet ring structure, consists of 8 similar periods. Each chamber period contains 6 sections. The design of one of the sections is shown in Fig. 2. Each section consists of 2 curved chambers installed in the gaps of the magnetic blocks and a straight part between them. Depending on the site of the the section installation the demensions of the pumping devices and the chamber cross sections vary a little.

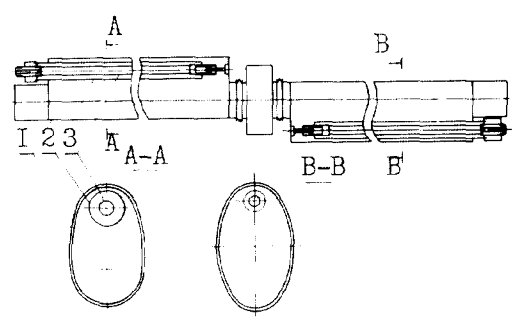

Fig. 2. The vacuum chamber section: 1 - chamber; 2 - heater; 3 - current conducting rod.

The chamber wall profile is shown in Fig.3. Chambers of such a design posses a number of advantages. They are mechanically rigid, have high electrical resistance and minimal inner surface which can be easily

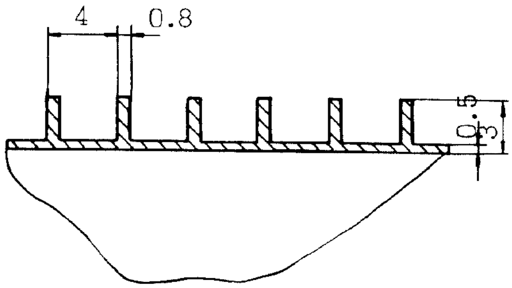

Fig. 3. The vacuum chamber wall profile.

treated and cleaned. A thin-walled stainless tube covered with a layer of non-evaporable getter (porous titanium) is placed in each curved chamber. The tube houses a current conducting rod.

Evacuation System

In order to reach ultra high vacuum in each of the eight periods of the ring vacuum chamber there are installed 4 pumping stations. Each station comprises a sputter ion pump NMD-0.4 (or NMD-0.16) and a getter pump with porous titanium. The latter has a form of a stainless cylinder 100 mm in diameter and 500 mm long. Its outer surface is covered with porous titanium. The cylinder can be filled with liquid nitrogen to increase the ultimate vacuum and to provide the possibility of tracing leaks at ultra high vacuum.

From the atmosphere pressure to 10^{-2}-10^{-3} Pa the system is evacuated by a preliminary pumping station comprising a forvacuum pump NVZ-20, a turbomolecular pump TMN-200 and a preliminary sputter ion pump NMDO-0.25 (NORD-250) with additional water cooling.

Surface Treatment. Degassation. Getter Activation

After mechanical treatment all vacuum chamber parts are carefully washed, electropolished and cleaned in Freon-113 by ultra sound.

After preliminary pumping and leak testing the assembled chamber is installed in the gaps of the magnetic blocks and after evacuation, baked out for 48 hours at 400°C. Baking is carried out by an outer belt heater ENGLU-400. The sputter ion pump NMD-0.4 is baked out simultaneously, and evacuation is echieved by the preliminary pump NORD-0.4.

On cooling down the pump NMD-0.4 is switched on. If vacuum is worse than $1 \cdot 10^{-6}$ Pa another leak testing is performed by a leak detector PTI-10.

After $1 \cdot 10^{-7}$ Pa is reached the getter is activated, that is it is baked out for 30 min at 600 °C. At the same time the chamber is being evacuated by the pump NMD-0.4. When the getter is cooled down (in 4-5 hours) vacuum in the chamber reaches $1 \cdot 10^{-8}$ Pa and tends to improve.

Experiments with Titanium Getter

In the first runs with the porous titanium we reached $2 \cdot 10^{-8}$ Pa in a limited volume. After thorough preparation of the vacuum surfaces and long (48 hours) baking at 400 °C we reached $5 \cdot 10^{-10}$ Pa after several days of pumping. Nitrogen pumping speed by the porous titanium surface is found to be 0.02 $l \cdot cm^{-2} \cdot s^{-1}$. The argon pumping speed is too low to be measured. The measurements were carried out at 10^{-6} -10^{-8} Pa. If vacuum is worse than 10^{-5} Pa the pumping speed drops drastically. If the titanium surface is cooled to nitrogen temperature the pumping speed of the getter increases by 1.5-2.0 orders of magnitude. However inert gasses are not evacuated. This feature of titanium getter is used in leak tracing at 10^{-8} Pa. It is done in the following way. When the porous titanium is cooled down to the liquid nitrogen temperature the sputter ion pump is switched off and the supposed leak is blown with a helium jet. If helium gets into the vacuum system the vacuum meter immediately indicates increase of pressure. When the sputter ion pump is switched on vacuum is quicky restored. The sensitivity of such a technique is not worse than that of a conventional helium leak detector.

Conclusion

Acceleration of not completely stripped ions increases drastically the vacuum requirements. In our case vacuum must be not worse than $5 \cdot 10^{-8}$ Pa.

By now the development of the vacuum chamber and the evacuation system is completed. The first chamber sections are being tested. The chamber manufacturing is in full progress. In accordance with the synchrotron magnet structure the chamber consists of 8 periods. One chamber period is already installed in the ring. 2 other periods are manufactured and will be installed in the near future. By the next summer the synchrotron vacuum chamber and evacuation system are expected to be completely installed.

References

1. N.N. Alexeev et al. ITEP Complex for Proton and Heavy Ion Acceleration. IEEE Trans. on nucl. sc. Vol. 32, N 5, p. 1693-94.
2. N.N. Alexeev et al. Preprint ITEP - 110, 1985.