

THE STATUS OF THE ULTRA-HIGH VACUUM SYSTEM OF HIRFL-CSR

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Abstract

HIRFL-CSR, a new ion Cooler-Storage-Ring (CSR) project, is the post-acceleration system of the Heavy Ion Research Facility in Lanzhou (HIRFL). To minimize the beam loss due to charge exchange of very heavy ions with the residual gas molecules, ultra-high vacuum of 3.5×10^{-9} Pa (N_2 equivalent) is required for the HIRFL-CSR facility, which is the lowest pressure in a large vacuum system in China up to now. The total length of the system is about 500 meters and the total inner surface is about 263 square meters. More than 500 standard vacuum components are needed and more than 400 different chambers have to be designed and manufactured in China. A lot of researches have been done and the great success has been achieved. As a result, the required pressure has been obtained both in the prototypes and the subsystems. In this article the following contents are described: the layout of the system; the treatment method to reduce the outgassing rate of the chamber wall surfaces; the test results for the prototypes and the progress of the system.

THE LAYOUT OF THE SYSTEM

The total length of the HIRFL-CSR vacuum system is about 500 m and the total inner surface is about 263 m^2 (not including the equipment inside the vacuum system). The four subsystems (CSRm, CSRe, CSRm-injection beam line and CSR-RIBLL2 beam line) all have different dipole and quadrupole chambers. The Electron Coolers, RF cavities, internal targets, injection and extraction elements such as kickers, bumpers and septa are installed in the straight sections of the two rings. Various beam diagnostic elements are mounted in the appropriate chambers.

The layout of the vacuum system of HIRFL-CSR is shown in Figure 1. Sputter ion pumps and titanium sublimation pumps are selected as the main pumps, which are distributed in about 4 m along the rings according to the calculation. All metal gate valves divide CSRm into 5 sections, CSRe into 4 sections, CSRm-injection beam line into 2 sections and CSR-RIBLL2 beam line into 5 sections. For each section there are one or two pump-down stations where movable turbo pumps can be mounted.

Fast closing valves are installed in the injection and extraction lines to prevent the two rings from possible vacuum breakdown. A pressure measurement device is installed in each vacuum section. Bellows allow for adjustment of the different chambers and avoid damage by the increase of chamber length during the bake-out process.

The rings will be equipped with permanent heater jackets and thermocouples. In the two transfer beam lines there are only bake-out on the last sectors before and after the two rings. Near the rings, there are more pumps installed to reduce the pressure from 10^{-7} Pa to 10^{-9} Pa.

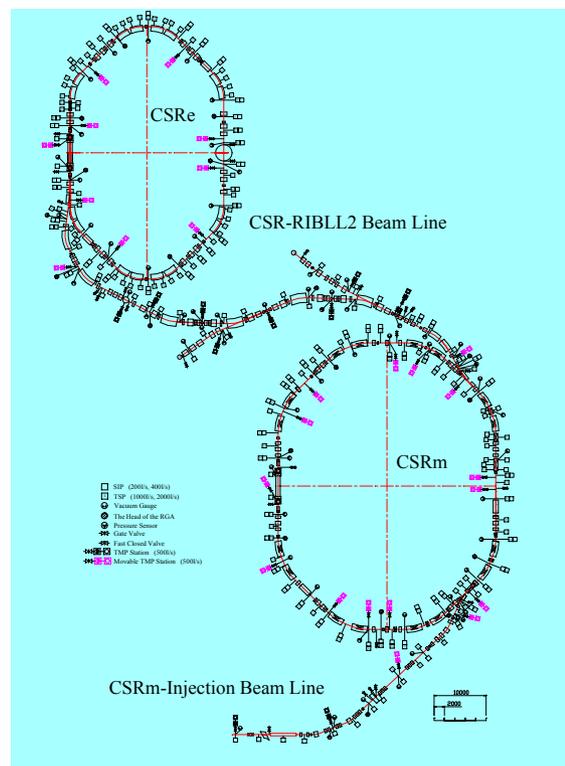


Figure 1: The layout of the vacuum system of HIRFL-CSR

THE TREATMENT METHOD FOR THE VACUUM CHAMBERS

In an ultra-high vacuum system, the gas load is mainly thermal outgassing of the chamber materials. Hence, the pretreatment of the materials is critical for obtaining minimum outgassing rate in order to obtain a low pressure. The treatment steps to reduce the outgassing rate are described below.

Degassing in a vacuum furnace

In a vacuum of 3×10^{-9} Pa the residual gas mainly consists of H_2 (about 90%) [1]. To achieve a low outgassing rate the H_2 can be reduced greatly by vacuum firing (degassing). At first, the vacuum components are throughout cleaned according to our UHV cleaning procedures [2]. Then, the copper gaskets can be degassed

in a vacuum furnace, at a pressure of 10^{-4} Pa and a temperature of 450°C for 6 hours. The stainless steel chambers or materials are degassed for 1 hour per mm wall thickness at a pressure of 10^{-4} Pa and a temperature of 950°C . At the end of the firing process the temperature should be reduced quickly (in about 15 minutes) from 900°C to 600°C to prevent segregation of carbon at the surfaces.

In our institute, a large vacuum furnace (Figure 2) with an operating pressure of $p \leq 10^{-4}$ Pa, with a diameter of 800mm and a length of 3000 mm is being used to treatment all the vacuum chambers of HIRFL-CSR.



Figure 2: The large vacuum furnace

In-situ bake-out

The *in-situ* bake-out can efficiently remove the water vapor and active gases such as H_2 , CO , CO_2 , N_2 etc. which were adsorbed on the material surfaces. The chambers and the vacuum components inside are designed to be bakeable *in situ* to 250°C . Thin heating jackets with 2mm of thickness and the insulation with 3mm of thickness are used for the dipole and quadrupole chambers because of the limited space of the magnet gaps. The thin heaters and the insulation material with the thermal conductivity of 0.027 W/m.K (in 300°C) were developed in an insulation material institute in China. They were successfully used in the magnet chambers to keep the outside temperature of the insulation lower than 80°C while the chamber temperature was 250°C . The other chambers were heated by integral heating jackets.

The bake-out process is controlled by computer. The rate of temperature change is $30^{\circ}\text{C}/\text{h}$. Ni-Cr-Ni thermocouples are used for each heater circuit. The signals are sent to the control modules to control the heaters on or off.

After the treatment mentioned above, the outgassing rate of the stainless steel material should be lower than $5 \times 10^{-11} \text{Pa.l/s.cm}^2$ [3].

THE TEST RESULTS FOR THE PROTOTYPES

The first prototype we developed was a small one which only has a CSRm dipole chamber and a pump chamber. In this prototype, we obtained the pressure of 1×10^{-9} Pa [3].

To further demonstrate the feasibility of the vacuum system of HIRFL-CSR design plan which include the material selection, main pump choice, the treatment methods for the chambers and so on, an unit of CSRm vacuum system with a length of 10m were prepared as the second prototype. The prototype consists of a dipole chamber, a quadrupole chamber, 2 beam diagnostic and pump chambers and 3 piece of bellows. The second one was completed and assembled in our laboratory in April 2002. The system were leak detected, baked-out and exhausted by 2 sputter ion pumps with the pumping speed of 330 l/s and 3 titanium sublimation pumps with the pumping speed of 3000 l/s. 48h after the bake-out stopped, the pressure reached 5×10^{-10} Pa. Figure 3 shows the test site and the pressure readings.



Figure 3: The prototype and the pressure readings

THE PROGRESS OF THE SYSTEM

The ultra-high vacuum obtained program mentioned above has been applied in the vacuum system of HIRFL-CSR. Up to now, the vacuum system of CSRm injection beam line has been finished and installed in site. The beam diagnostic devices were inserted in the chambers as well. The pressure in unbaked section were $1 \sim 5 \times 10^{-7}$ Pa and in baked section were $2 \sim 5 \times 10^{-9}$ Pa (figure 4).



Figure 4: The vacuum system of CSR injection beam line and the pressure readings

More than 100 various vacuum chambers of CSRm have been finished, which were all degassed in our large vacuum furnace. Before installed in site, the chambers were checked and trial-baked item by item in our laboratory. The standard equipment such as the pumps, the valves and the vacuum gauges have been sent to our institute and tested. More than 1000 piece of bake-out jackets for the CSRm chambers and the bake-out control devices have been prepared. The installation for CSRm vacuum system began in November 2003 (figure 5). Now, the ring with 161m in length has been assembled in site. The bake-out for the system hasn't been done. The pressures in the sections were $4\sim 8 \times 10^{-8}$ Pa without bake-out.



Figure 5: CSRm vacuum system is being installed

The design for CSR-RIBLL2 beam line and CSRe have been finished and more than 200 chambers are being manufactured in several plants in China. The components will be assembled in site in August 2004 and the project will be finished in end of 2004.

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