VACUUM SYSTEM OF THE SSC FOR HIRFL

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ABSTRACT

The vacuum system of the HIRFL being designed and built is described. It is a large ultra-high vacuum system. A monolithic vacuum chamber for the entire SSC to have been completed is 10m in diameter and 4.5m high, weighing 65tn. The volume of it is 100m^3. The surface area exposed to vacuum is about 1,100m^2. Eight modified Balzers RKP 800 cryopumps with a total pumping speed of 160m^3/s for nitrogen are used to reach a pressure of 10^{-6} Pa region. Two Pfeiffer TPH 5000 turbo-molecular pumps are used for an auxiliary pumping system. A roughing pumping system is composed of two Model ZJZ 600 Roots pumping units. A supply of liquid nitrogen for the shields of the cryopump is fulfilled by a semi-open circuit of liquid nitrogen.

INTRODUCTION

Heavy Ion Research Facility Lanzhou is a multi-accelerator system for accelerating heavy ions in course of construction. It consists of a separated sector cyclotron (SSC) and a conventional sector focusing cyclotron (SFC). This project is a first attempt to build a separated sector cyclotron in China.

The vacuum pumping system for the injector SFC converted from a classical cyclotron uses original oil diffusion pumps. For the SSC, it is a large ultra-high vacuum system. All of main equipments of the SSC including the pole pieces of the magnets, cavities, injection and extraction elements etc. are enclosed in a monolithic vacuum chamber. A pressure required for sufficient transmission of heavy ions is about $1x10^{-5}$ Pa. Because of large volume, large surface area and intricate shape of the vacuum chamber to be evacuated, a cryogenic pumping system has been chosen to obtain very low operation pressure on the median plane. At present, the monolithic vacuum chamber for entire SSC has been installed in situ. The vacuum pumping system has been brought into operation. The results of these works we have done have provided a very promising design and manufacture for the vacuum system of the SSC.

VACUUM CHAMBER

The monolithic vacuum chamber is formed of eight triangular shaped sectors. Two valley regions are located in the east and west for the injection and extraction elements. Two radio frequence cavities are contained in another two valleys. The chamber is 10m in diameter and 4.5m high, weighing 65tn. The total volume of it is about 100m^3. There are 230 ports on the chamber for various purposes.

The chamber with shell construction is supported on four magnets. Besides its dead weight, the load of the chamber is mainly from atmosphere. The force from bottom and lids are about 800tn respectively, and from every one of eight sides is approximately 100tn. A mechanical analysis of the chamber have been completed using a finite element method by means of the procedure on a computer. The results of calculating deformation and stress of the chamber are satisfactory for evacuation. And they are in accord with actual measurement.

Special care must be exercised in selecting a suitable super-low carbon stainless steel grade with a very low magnetic permeability and good quality for mechanical and welding as well as vacuum technology. Uddeholm 23L type (AISI 316L) sheets are chosen as a structure material.

Because of very big size of the monolithic chamber, it was divided into eight bigger and several smaller pieces to be fabricated at the plant, then to be transported by a train and a truck to our institute. Finally, it was welded as a single vessel. The manual electric arc welding was a main welding method. To obtain the required geometrical accuracy and take into account the environmental conditions, some special measures were used for a precision welding fabrication for the vacuum chamber. In order to get good tightness, all of tight welded seams were inspected and checked by liquid penetration testing, x-ray examination and helium mass spectrometer detecting. Most of flanges were machined before welding at the plant. Some big ones had to cut after welding by a special way in situ. In China it is called ants gnawing at a bone --- a concentration of small machine on a big job; plot away at big job bit by bit. The Fig.1 shows the monolithic vacuum chamber being installed.

A extruded pure aluminium rhomb belt is in principle for most sealings. But four nitrile 0-rings are used for lids of the chamber. Nearly thousand electrical leads pass through the chamber by the ducts. Interior of the equipments is at stmosphere.

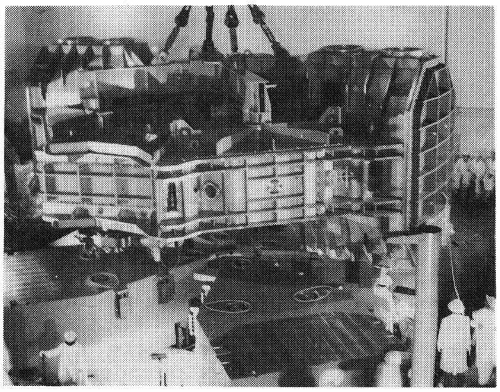


Figure 1 Monolithic vacuum chamber being installed

VACUUM PUMPING SYSTEM

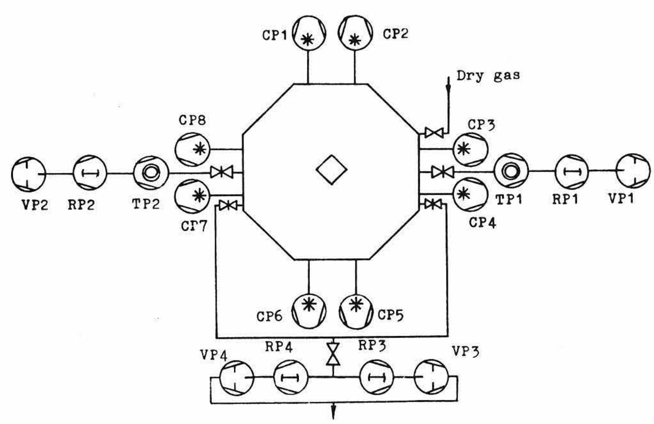
The major contribution to the vacuum load is outgassing inside of the chamber. The designed value of the gas load according to our experimental test for the prepared surface area of 1,100M^2 is 2.1 PaM^3/s after pumping 10 hours. To keep a pressure in the vacuum chamber at the 10^{-6}Pa region for estimated gas load, it requires a total effective pumping speed of approximately 160m^3/s. The pumpdown time is not to exceed 24 hours.

Various types of the pumps are assessed in relation to its application to the HIRFL vacuum system. A cryogenic pumping system with a small helium closed cycle mechanical refrigerator cryopump has been selected as a main pumping method. According to commecial products standard, Balzers RKP 800 cryopump with Model 208L refrigerator of Air Products & Chemicals were chosen for using. In the beginning, we were not satisfied with the characteristics of the pump. Having improved the cold panel and the baffle, the actual pumping speed reached up to 21m^3/s with a baffle and 38m^3/s without a baffle for nitrogen, and 20m^3/s for hydrogen in molecular range. The outside part of the baffle has been removed, the conductance for hydrogen is the same both situations with and without the baffle. Considering nitrogen is not much in the residual gas, the baffle is still reserved in the RKP 800 cryopump. In this case, a temperature of the cold head can be maintained under 15k. Eight units of cryopump RKP 800 have been errected on the vacuum chamber of the SSC. But in normal operating of the SSC, five or six units will be enough for reaching required pressure. In our case, it is better to use the cryopump with liquid nitrogen. These commecial products are easy gotten from the market, and they are very effectiv and useful to pump vapours which are the main composition of the residual gas. In fact, the liguid shields are independent cryopump which can be used by itself conveniently. The activated charcoal on the cold head may make a regeneration period to last one month under normal operating condition for the SSC. Owing to low,conducatance for the sector magnets, the pumps have to be placed in each valley.

The two Pfeiffer TPH 5000 turbo-molecular pumps with a measured pumping speed of 4.3m^3/s for nitrogen and 6.3m^3/s for hydrogen each have been chosen as an auxiliary pumping system for leak testing, pumping helium, regeneration of the cryopump and pre-pumping the vacuum chamber to a pressure of 10^{-4} Pa. At the same pressure, the cryopumps are brought into operation. The turbo-molecular pumps are connected to two valleys with two isolated swing gate valves. As a matter of fact, the turbo-molecular pumps do not work during the cyclotron operating.

The roughing pumping system is composed of two ZJZ 600 Roots type blowers with pumping speed of 1.2m^3/s in all and 30m stainless steel tube. It is capable of reducing the vacuum pressure from atmosphere to 10 Pa in about one hour. The schematic diagram of the vacuum pumping system of the SSC is shown in Fig.2.

The supply of liquid nitrogen for the shields of the cryopump is fulfilled by a semi-open circuit of liquid nitrogen system. Under steady-state condition, liquid nitrogen is transfered from a 5m^3 tank at the cyclotron building to every pump through a vacuum jacked pipes by static pressure. The maximum consumption of liquid nitrogen is about 30 l/h. In the interests of economy, a Philips type refrigerator is usd for the regeneration of exhausted cold nitrogen gas.



CP1-CP8 cryopump RKP 800
TP1,TP2 turbo-molecular TPH 5000
RP1,RP2 Roots pump 30 l/s
RP3, RP4 Roots pump 600 l/s
VP1,VP2 vane pump 8 l/s
VP3,VP4 piston pump 150 l/s

Figure 2: Schematic diagram of the vacuum pumping system

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