The Vacuum System of CRYRING

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Abstract

The features of the main UHV components in the accelerator/storage ring of CRYRING are described. Using ion-pumps and NEG-pump modules, but without baking, a vacuum in the low 10^{-11} mbar region has been achieved in the 52 m circumference ring. After the on-going addition of jackets for baking the whole system (300 °C) it is expected that the design value, the low 10^{-12} mbar region, will be reached.

1 INTRODUCTION

CRYRING is an accelerator facility dedicated to low-energy research mainly using highly charged, heavy ions [1]. The main part of CRYRING is a synchrotron/storage ring, which allows a heavy ion beam to be accelerated to a maximum energy of $96(q/A)^2$ MeV/u. The ions are produced in different ion sources placed on high voltage terminals (< 50 kV) and are pre-accelerated to 300 keV/u (for q/A> 0.25) in a four-rod type RFQ before injection into the ring. The ring circumference is about 52 m and the total length of the injection lines is about the same (see Fig. 1 in [1]).

The very low injection energy and the ambition to work with low energy ions asks for special precautions in order to minimize losses due to rest-gas collisions. This implies that the ring has to be operated in the 10^{-12} mbar region. Also, fast magnet ramping (7 T/s) allows the ion energy to be increased to its maximum value in 150 ms and thereby decreasing the losses in those cases where the rest-gas collisions still are disturbing.

2 THE RING

The vacuum system of the ring is built up of different specially designed chambers connected with ϕ 100 mm tubes. The ring vacuum is divided into six sections separated by gate valves. Every section is equipped with a right-angle valve for pump-down operation. Only all-metal valves are used. The tubes, flanges, and chambers are all made from stainless steel of a refined AISI 316LN quality which is also used for most parts inside the vacuum. After adequate cleaning the different pieces have been subject to a vacuum-firing process at 950 °C in a 10^{-5} mbar atmosphere. Afterwards, the surfaces that will be exposed to vacuum have been kept well protected and have — whenever possible — not been in contact with any organic materials. A summary of significant data is given in Table 1.

Table 1: Characteristics of the CRYRING UHV-system.

Ring circumference	51.63 m
Beam tube diameter	0.10 m
Total volume	750 l
Total area	30 m^2 (> 99% 316LN stainless steel)
Design vacuum	$5 \cdot 10^{-12}$ mbar (N_2 eqv.)
Pumping speed	20000 l/s (H_2)
Expected desorption/ diffusion rate	$2 \cdot 10^{-13}$ mbar cm^{-2} s^{-1} [2]

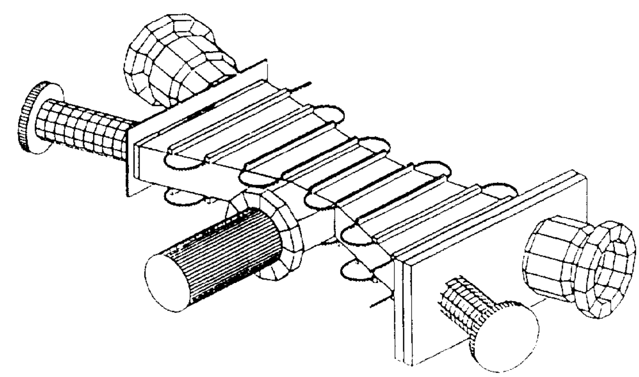


Figure 1: Dipole chamber.

The dipole chambers are constructed as a compromise between the following constraints:

- Optimize the ratio of useful height inside the chamber to the pole-gap height.
- Minimize secondary induced magnetic fields due to eddy currents.
- Optimize heating and insulation for baking-out at 300 °C.
- Apply cooling to compensate for eddy current heating.
- Allow spectroscopic instruments to be mounted inside or connected to the vacuum chambers.

The dipole chambers are made of 2 mm AISI 316LN stainless steel sheets welded to the shape shown in Fig. 1. The top and bottom are reinforced with 5 x 5 mm^2 ribbons also containing cooling tubes. For baking, thermo-coax heating elements are attached on all sides of the chambers. Finally, the chambers are wrapped with four layers

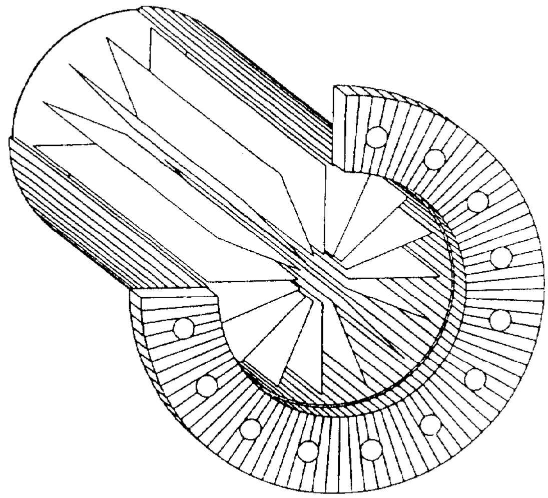
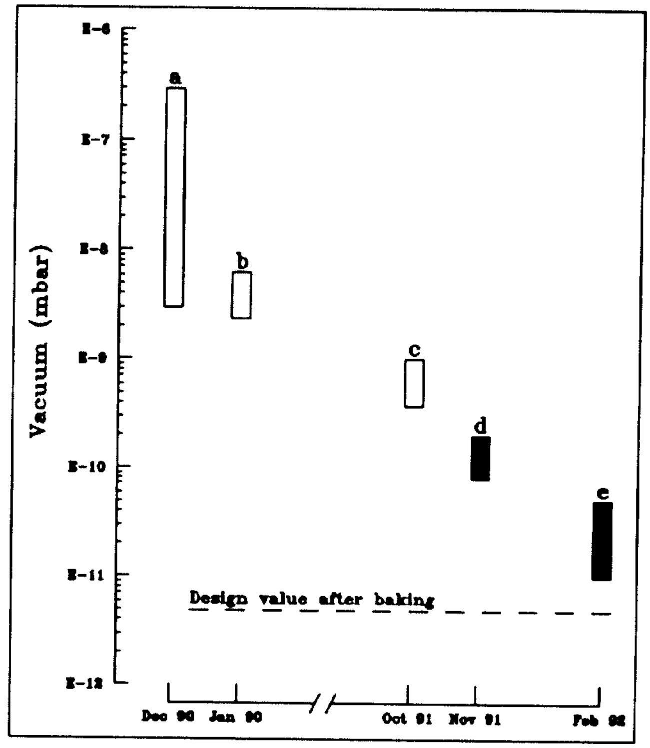


Figure 2: NEG-pump module.

of ceramic paper. This allows a baking temperature of 300 °C, while the outer surface of the insulation is kept at around 100 °C. Other magnet chambers as well as diagnostic pick-up chambers are made using a similar technique. The rest of the chambers and the beam tubes are equipped with specially designed heating jackets or — for the flanges — metallic heating collars. Here should also be mentioned that water cooling has been added also to these units. It is expected that keeping the whole system at a temperature slightly above the dew point, e.g. 12 °C, will lower the desorption significantly and then also improve the final vacuum. All flanges used are of conflat type and are sealed with silver-alloyed copper gaskets. The "down-stream" flanges on six of the dipole chambers are of a rectangular shape to allow more space for different spectroscopic instruments to be attached. These flanges are sealed with special shape, helicoflex gaskets [3].

3 THE ELECTRON COOLER

The electron cooler [4] represents one of the major individual gas loads on the CRYRING vacuum system. The two main sources of outgassing are the electron gun and the electron collector. In the gun, electrons are emitted from a ϕ 40 mm dispenser cathode heated to around 1000 °C. Between the gun and the main ion beam chamber, surrounding the electron beam, a NEG pump (Non-Evaporable Getter) is positioned, containing 25.2 m of NEG strips of type SAES St707 with an active area of 14000 cm^2. The NEG can be activated by resistive heating, thus avoiding that the entire vacuum system of the cooler has to be baked before a reasonable vacuum can be achieved. Behind the gun there is a 1500 l/s cryo-pump to improve pumping speed in general and also to pump rare gases and methane, which are not pumped by the NEG strips. Cryo-pumps are normally not associated with the high vacua aimed at in CRYRING, but tests have shown that a clean, mildly baked (60-70 °C) cryopump can reach final vacua in the



The heights of the bars represent the pressure distribution in the ring :

a. 3 weeks after first pumpdown.
b. 3 weeks after installation of new equipments and elimination of minor leaks
c. After 40 weeks pumping.
d. 3 weeks pumping after the NEG-pumps were installed.
e. After 15 weeks pumping with NEG-pumps.

Figure 3: Pressure evolution and distribution in the ring from the start, December 1990.

10^{-12} mbar region. The electron collector is a water-cooled vessel of OFHC copper hit by the electron beam which dissipates a maximum power of 10.5 kW. The collector is pumped by a 19.2 m long NEG strip in a similar arrangement as used on the gun-side. Behind the collector there is a 120 l/s ion pump, which — if needed — can be replaced by a second cryo-pump.

4 PUMPS AND VACUUM GAUGES

The pumping down of the individual sectors to approximately 10^{-6} mbar is done with a 80 l/s turbomolecular pump, which is connected to the right-angle valves. Such pumps are also used during the bake-out process. To pump below 10^{-7} mbar, 12 star-cell ion-pumps of 60 or 120 l/s capacity and 50 NEG-pump modules (see Fig. 2) are distributed around the ring. A NEG-pump module consists of a 0.3 m long stainless steel cylinder, ϕ 0.1 m, in which an active surface of about 3000 cm^2 of NEG-strip (type St707) is mounted. To activate the module, the whole cylinder is heated to about 350 °C at the end of the bake-out procedure. The NEG-pumps have been subject to test procedures and have proven to make the low 10^{-12} mbar

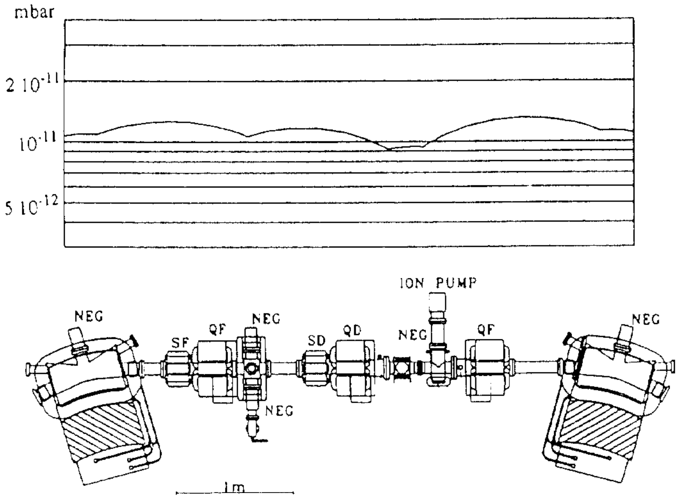


Figure 4: Magnet section with expected UHV-distribution.

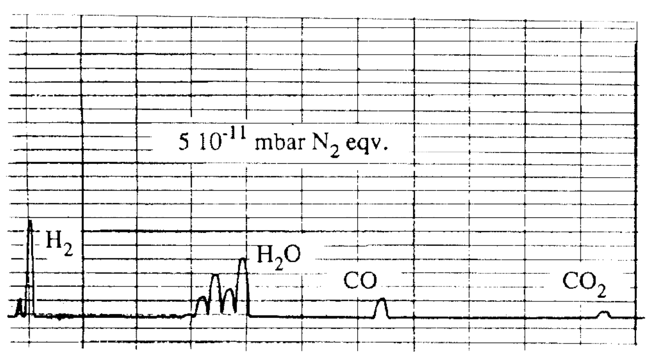


Figure 5: Rest gas spectrum.

region reachable. The measured pump speed of a module is 400 l/s. At present most of the modules have been mounted in the ring and the vacuum in the whole system has after activation but without baking reached the low 10^{-11} mbar region (see Fig. 3). It is also noticeable that after the system has been up to air pressure, the same vacuum region is reached within one week of pumping.

In the ring the magnetic elements are concentrated to every second section. These sections also contain the major part of the pumps (see Fig. 4). On top of Fig. 4 is also shown the expected vacuum distribution in such a section. The curve is calculated using a Monte Carlo technique [5] and is normalised to experimental data.

The vacuum measurements have so far mainly been performed using cold-cathode gauges of inverted magnetron type with a low pressure limit of 10^{-11} mbar. Later, every section will be equipped with hot filament ionization gauges of the Bayard-Alpert type equipped with modulators allowing measurements down to 10^{-13} mbar [6]. In order to measure the residual gas composition, the individual sectors are all prepared for the connection of a quadrupole mass analyser with special UHV performance. A rest gas spectrum is shown in Fig. 5.

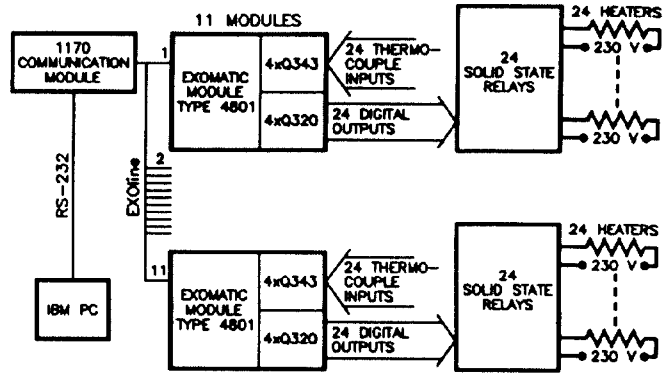


Figure 6: Block diagram baking.

5 BAKE-OUT SYSTEM

As mentioned above the system is dressed in prefabricated heating jackets or with multilayers of ceramic paper on top of thermo-coax heating elements. During the bake out procedure the temperature is measured using about 250 non-magnetic, type E, thermoelements, which are connected to an Exomatic microprocessor control system [7] operating the bake-out power via 250 solid state relays. The whole system is supervised by a 386 PC providing the contact with the operator. Special care is exercised when lowering the temperature in order to prohibit sensitive parts to form "cold spots" where condensation can occur. After the baking process the NEG pump modules are activated for about one hour at a 350 °C. A block diagram of the baking system is presented in Fig. 6.

6 REFERENCES

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