Operational Experience of the K800 Cyclotron Vacuum System at L.N.S.

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Abstract

In this paper we present the status of the vacuum system of the L.N.S. K800 SC Cyclotron. The vacuum chamber of the accelerator (surface >50 m^2) has been pumped down to a pressure lower than $1 \cdot 10^{-6}$ mbar, in a time shorter than 5 days, mainly by means of 3 split refrigerators cooled cryopumps. The operation of these pumps in a magnetic field (5 T) has been verified. During the high power RF test of the accelerator the split cryopumps have been operated for some weeks into the RF cavities: the pumps worked successfully and the RF field hasn't produced any significant temperature rise of the pump cold head. Moreover the small mechanical vibration produced by the pump has no affection to the RF cavity operation. The first ion beam acceleration of the K800 SC Cyclotron was successfully conducted the 3rd of June 1994. The pressure of accelerator chamber was $3 \cdot 10^{-6}$ mbar.

1. INTRODUCTION

The compactness of the Superconducting Cyclotron K800 at L.N.S. Catania and the presence of several vacuum subsystems force to employ both internal and external pumping elements and lead to have 7 different vacuum plants operating independently [1,2,3].

This complicated vacuum system consists of 22 pumps, 70 valves, 53 gauges and is subdivided in the following 7 plants:

Acceleration chamber
Liner
Guard vacuum
Injection line
extraction line
Current probe
Cryostat insulation chamber.

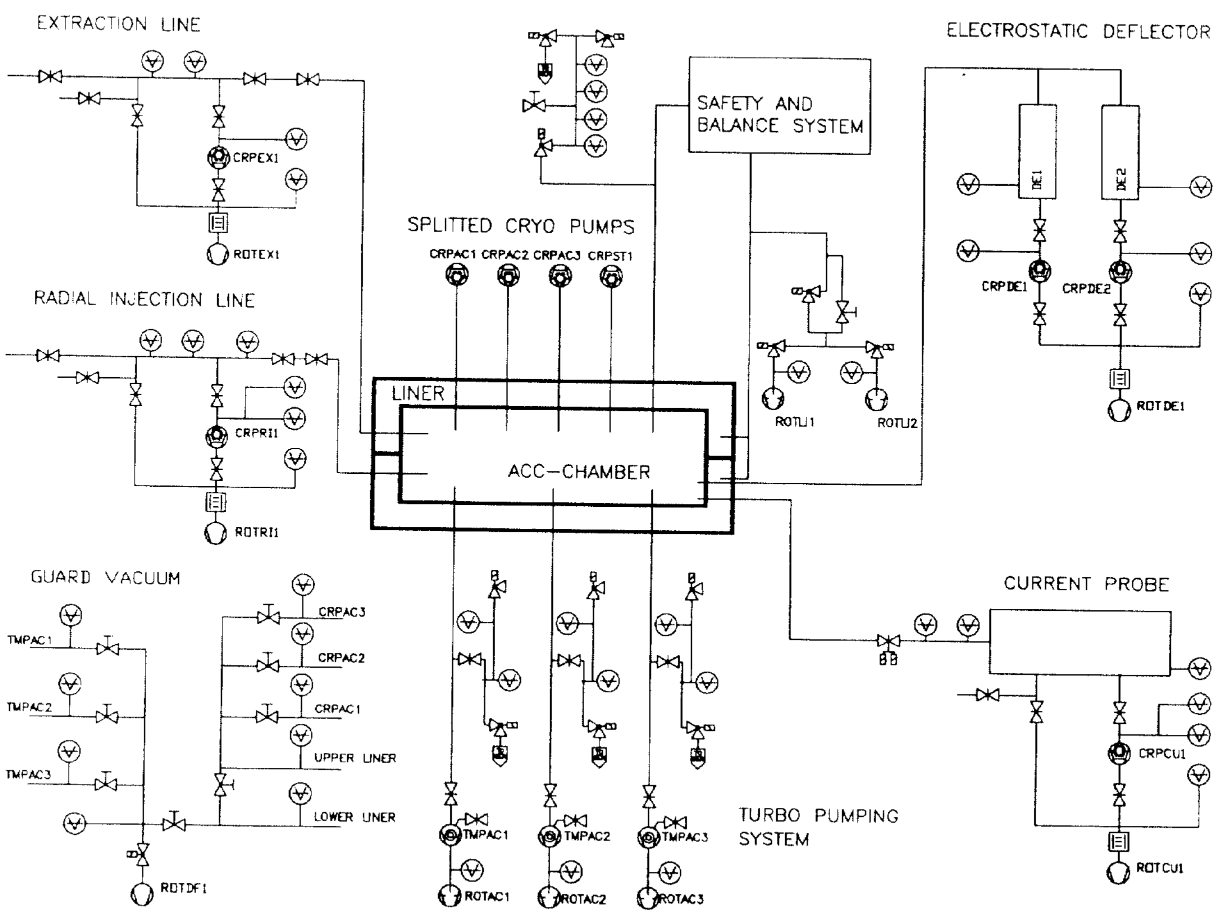

Figure 1. Schematic layout of the vacuum system.

2. ACCELERATION CHAMBER

The vacuum system consists of 3 special cryopumps and 3 turbomolecular pumping systems. The special cryopumps have the cold head with the moving piston assembled inside the upper dee accelerating structure and the motor driven valve assembly operates at 5 m from the cold head, far enough from the cyclotron magnet [4]. The turbomolecular pumps are assembled at the bottom of the lower RF cavities [1].

Table 1
Total pumping speed in the acceleration chamber

gas	l*s-1
H2O	30000
N2	1400
H2	1400
Ar	1300
He	400

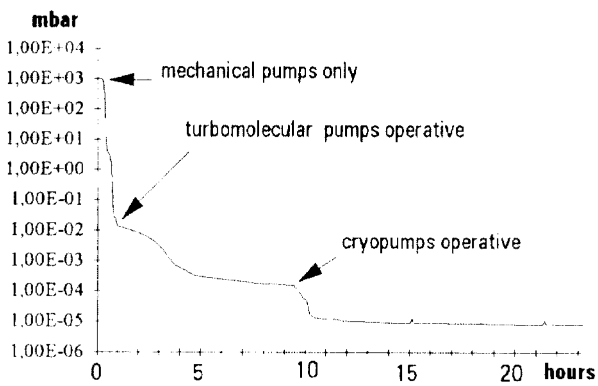

Figure 2. Pressure Vs time of a typical pumpdown

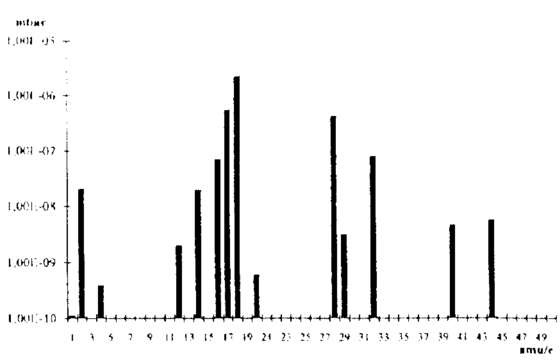

Figure 3. Residual gas spectrum after 24 hours pumpdown

The pressure in the acceleration chamber after 24 hours pumpdown is $8 \cdot 10^{-6}$ mbar (fig.2) and reaches the operative pressure of $3 \cdot 10^{-6}$ mbar after 35 hours pumpdown. The pressure in the liner in this condition is $7.1 \cdot 10^{-1}$ mbar. The residual gas spectrum (fig.3) confirms the presence of H_2O desorbed from the stainless-steel and copper constituents the acceleration chamber surfaces. The partial pressure of N_2 and O_2 has to be related the leaks between the liner and the acceleration chamber.

A Stripper and a high voltage Deflector are assembled in the acceleration chamber, their low vacuum conductance force to use 3 other pumping elements that consist of 3 traditional cryopumps (CRPST1, CRPDE1, CRPDE2) and mechanical rotary pumps for regeneration. Their contribute to total pumping speed is negligible (30 $l \cdot s^{-1}$ for N_2).

3. LINER

The region between the pole side and the copper liner is pumped by a vacuum system that consists of 2 mechanical rotary pumps of 30 m^3h^{-1} each. Since the liner structure is not able to support a differential pressure more than 100 mbar, a Safety and Balance system (fig.4), supplied by an uninterruptable system, has been designed [1,3].

Two differential pressure switches operate the balance valve VALLI4 at a differential pressure more than 15 mbar and in case of failure a safety diaphragm disk BRDL1 (fig.4) breaks when the differential pressure reaches 100 mbar. Figure 5 is a detail of a pressure Vs time record that shows how this system operates. After 30 minutes power failure the acceleration chamber and the liner are vented by the dry N_2 vent valve VALLI11 to avoid acceleration chamber contamination from the dirty region of the pole side.

The lowest pressure reached the liner is $5 \cdot 10^{-1}$ mbar after 170 hours pumpdown.

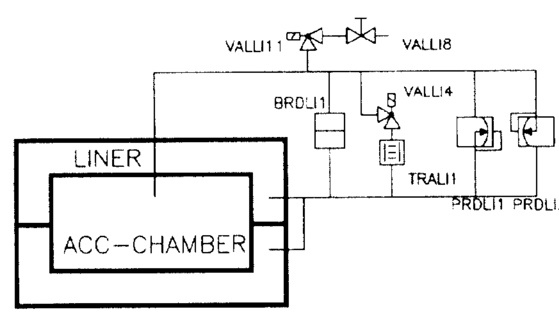

Figure 4. Schematic layout of the safety and balance system

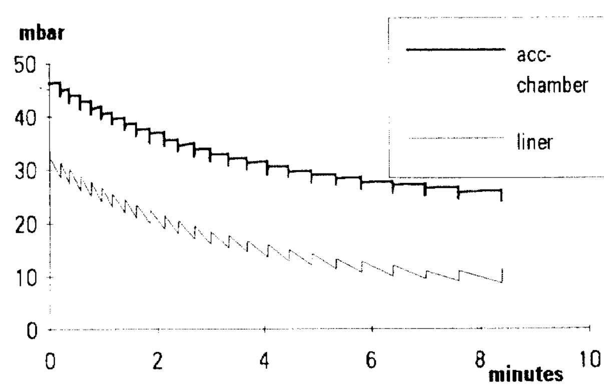

Figure 5. Acceleration chamber and liner pressure Vs time

4. GUARD VACUUM

This differential pumping is used on some sealing in order to let operative the cyclotron also if a leak is present [3]. It consists of one 30 m^3h^{-1} pumping speed mechanical rotary pump (ROTDF1). The lowest pressure is $8 \cdot 10^{-3}$ mbar after few hours pumpdown.

5. INJECTION, EXTRACTION, CURRENT PROBE

This 3 traditional pumping systems CRPEX1, CRPRI1, CRPCU1 (fig.1) consist of 3 cryopumps combined with 3 mechanical rotary pumps for the regeneration. The typical pressure is $7 \cdot 10^{-7}$ mbar after few hours pumpdown.

6. MAGNETIC SHIELDING

The cryopumps, the gauges and the valves operating close to the cyclotron magnet, work in a magnetic field of about 0.1 T [2]. Special magnetic shielding has been provided let standard pumps and standard gauges operate in a magnetic field up to 0.15 T. The valve electropneumatic actuators have been removed from the vacuum valve body and have been located in a shielded box.

7. LEAK TEST

The presence of several vacuum subsystems, the maximum liner differential pressure and the geometrical structure of the Superconducting Cyclotron K800 required a long and careful leak detection. Each vacuum system has been tested to detect leaks from atmosphere, from water cooling plants and from adjacent vacuum systems. In general no significant leaks were found.

The total leak between atmosphere and acceleration chamber is $< 1 \cdot 10^{-7}$ mbar l s^{-1}. The leaks between atmosphere and the liner are in total 0.7 mbar l s^{-1} distributed in the 60 electrical feedtrough of the trim coil located in the pole side. A large number of leaks were detected between the liner and the acceleration chamber, they are located in the liner copper welding and the total leak is about $1 \cdot 10^{-4}$ mbar l s^{-1} (with a differential pressure of $7 \cdot 10^{-1}$ mbar). An accurate map of the liner leaks was drawn to verify if the multipactoring [5] of the RF cavity will be responsible for leak increasing.

8. AUTOMATION AND CONTROL SYSTEM

The architecture of the vacuum control system consists of a personal computer (based on 486/33 CPU) which acts as a master of a network of 15 microcontroller boards and is connected to the control Ethernet lan. Bitbus is the protocol for the distributed network. It is an order/reply protocol based on IBM SDLC standard for data link level and on RS 485 for the physical level. The long distance connection between the master P.C. and microcontroller board is made with a fibre optic media: two optical transceiver are used to convert electrical Bitbus signals to optical informations and make link with high electrical noise immunity.

Microcontroller boards are fitted inside the racks where vacuum instrumentation is assembled and allow manual/automatic operation of the plant. With the aid of some custom interfaces and commercial vacuum instruments we designed racks to control specific plants. The structure of the application programs on each board is similar, specific functions for any type of vacuum part is performed to allows operative requests.

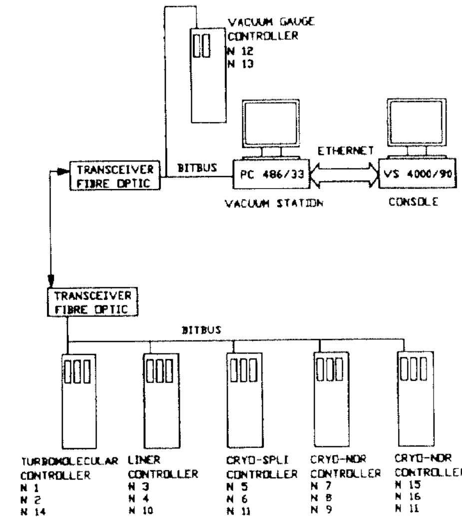

Figure 6. Architecture of the vacuum control system

9. CRYOSTAT

The vacuum system controlled by 2 PLC [3] has demonstrated high reliability and has been operating uninterrupted for about 12,000 hours. The pressure in the cryostat insulation chamber is $6 \cdot 10^{-8}$ mbar. Only few electromechanical failure has been occurred till now.

10. CONCLUSIONS

The RF conditioning maximum pressure [5] of $5 \cdot 10^{-6}$ mbar has been reached in a time shorter than 2 days, though the often venting of the acceleration chamber (every 4-5 days) occurs in this last months. Reducing the venting frequence and the air exposure time, we think to be able to reach $1 \cdot 10^{-6}$ mbar in 24 hours pumpdown.

The 3rd of June 1994, with an operative pressure of $3 \cdot 10^{-6}$ mbar, a $^{58}Ni^{16+}$ ion beam was successfully accelerated at 16 MeV·amu^{-1}, 0.66 m radius.

11. REFERENCES

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