THE MILAN K800 CYCLOTRON VACUUM SYSTEM

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Abstract

The Milan K800 Cyclotron has 3 separated vacuum systems, namely the acceleration chamber, the liner-pole region and the cryostat insulation chamber. A differential pumping system is also present in some parts of the machine. Axial injection vacuum system is in progress too.

Accelerating chamber vacuum

In order to reduce the beam loss, due to the particles collisions with the residual gas molecules, the pressure in the accelerating chamber must be reduced to a few 10^{-7} mbar, in a time ranging between 10 and 24 hours.

It is well known that the problem in reaching a low pressure is the evolution of the gases from the surfaces exposed to the vacuum. Particularly a large amount of gas and vapour would come from the pole faces and from the resin impregnated correction coils. So that, these components are separated from the accelerating chamber by a vacuum tight copper item (the liner) and the region in between is coarse pumped.

The main characteristic of our accelerating chamber is to have a large surface exposed to vacuum (>50 m^2) and a relative small volume (<1 m^3). Looking at the surfaces, Table I shows the different materials and the relative surfaces exposed to the accelerating chamber vacuum.

Table I - Accelerating chamber surfaces

Cu, Al and stainless steel	≃	45 m^2
Soft iron	≃	10 m^2
Pure alumina	≃	1 m^2
Soft soldering	≃	1 m^2
Elastomers (Viton)	≃	0.5 m^2

In order to reduce the total outgassing we nickel plated all the steel surfaces, and particularly the external wall of the vacuum chamber, which is a part of the magnetic circuit. Moreover this surface treatment eliminates any corrosion possibility on the soft iron parts. Chemical nickel plated (20 μm) steel outgassing rate was measured and the value was comparable with not baked stainless steel and, of course, lower than a typical oxidized steel.

In the Fig. 1 the outgassing rates of some materials of the vacuum chamber are presented as a function of time. The eventual contribution of the not nickel plated soft iron is also shown.

Since no baking operation is practical on most of the cyclotron components, they can just be cleaned "in situ" using solvents. For the elastomers greasing we use Fomblin Y VAC 3, a Montefluos vacuum grease with a very low vapour pressure. This grease had been successfully tested on the viton sealings of the RF

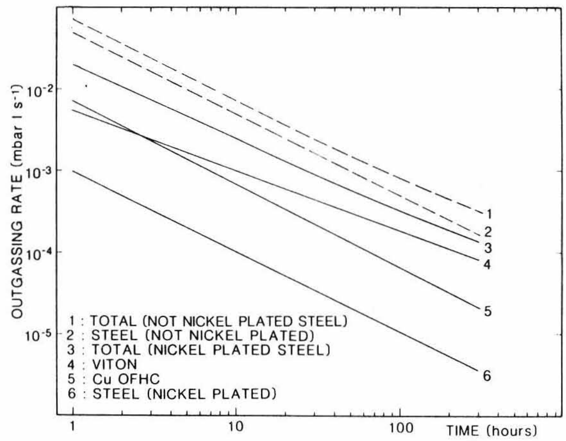

Fig. 1 - Outgassing rate of some materials and components of the acceleration chamber.

cavity dee stem insulator[1]. A fluorinated compound (Freon 113) is required for the Fomblin grease removing.

The total outgassing at 10 h is estimated to be $2.3 \cdot 10^{-3}$ $mbar \cdot l \cdot s^{-1}$, with an average degassing of $4.3 \cdot 10^{-9}$ $mbar \cdot l \cdot s^{-1} \cdot cm^{-2}$. Additional gas load can come from leaks that, in a such complex and compact machine, must be considered as acceptable if their repairing consumes too much time. Moreover an increment of the hydrogen outgassing in the first days of the RF operation, due to the RF induced desorption, is to be taken into account[2].

As a synthesis we need a total pumping speed of about 25000 $l \cdot s^{-1}$, the 90 % of which is relative to water vapour and the residual 10 % to nitrogen and hydrogen.

Because of the large conductance deficiency, due to the compactness of the machine, the main pumping system must be inside the accelerator and, of course, able to operate in the high magnetic field.

In 1983, room temperature not evaporable getter pumps were tested, but we had to abandon this solution because of their very low nitrogen sorption capacity[3,4]

So that we asked Leybold Heraeus to develop for our application a 20°K cryosorption pump able to operate in the K800 Cyclotron magnetic field[5]. This pump has the cold head with the moving piston separated from the gas distributor: i.e. only the moving piston is immersed in the magnetic field, while the synchronous motor, in the gas distributor, can operate far from the magnet. A 300 h test into the Milan AVF Cyclotron magnetic field shows that the pump can operate in a stress condition (eddy currents, power dissipated in the piston, linear and transversal forces) worse than those expected in the K800 Cyclotron. The test was made with B = 0.8 T and with an inclination between the magnetic field and the direction of the moving piston of 73°.

In the Table II the split pump refrigeration characteristics are presented for a 5 m distance between the cold head and the gas distributor.

Table II - Split pump refrigeration characteristics

First stage (80 °K) cooling power	=	6.0 W
Second stage(20 °K) cooling power	=	1.1 W
Cooldown time	=	120 min.
Second stage lowest temperature	=	13 °K

The pumping characteristics of the split pump, measured in our laboratory, using the inverted burette system at a constant pressure of $1\cdot10^{-6}$ mbar, are reported in the Table III. Only helium measurements were made at $1\cdot10^{-5}$ mbar.

Table III - Cryopump pumping characteristics

	PUMPING SPEED $[l\cdot s^{-1}]$	SORPTION CAPACITY $[mbar\cdot l]$
H_2O	10000	very high
N_2	450	$2\cdot10^5$
H_2	400	$1\cdot10^4$
Ar	400	$2\cdot10^5$
He	80	$1\cdot10^2$

The most important advantage of this pump, with respect to a 4.2°K liquid helium panel, is that no cryogenic fluid or cryogenic connections are needed. In fact this pump use only room temperature helium.

We planned to use 3 split cryopumps, fitted into the 3 upper RF cavities, rather than into the lower ones, as anticipated[6]. Fig. 2 shows a picture of the cold head assembled into the dee.

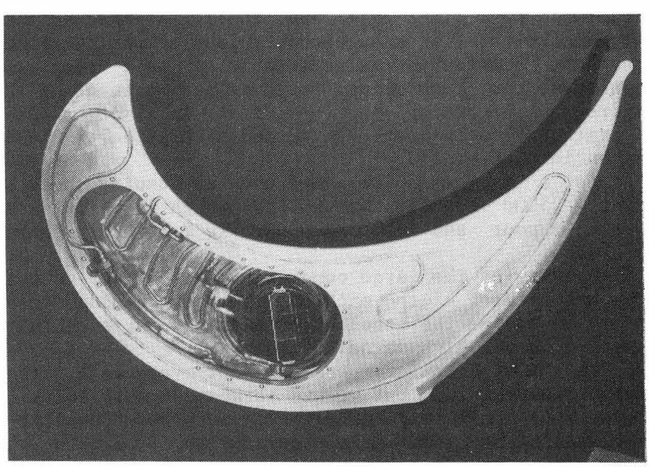

Fig. 2 - The split cryopump assembled into the dee.

In the Fig. 3 the estimated pressure vs time curves, using 3 split cryopumps, are shown. Moreover in the same figure they can be compared with the calculated curves for the getter pumping system (16 NEG modules + 100 cm^2 LN2 panel). The pressure vs time curves are referred to two different air leak rates: $\leq 1\cdot10^{-6}$ $mbar\cdot l\cdot s^{-1}$ and $1\cdot10^{-4}$ $mbar\cdot l\cdot s^{-1}$ respectively.

The final design of the cryopump (delivery date: November 1986) is characterized by a little increment of the cooling power and by an easier assembling, disassembling and testing than the prototype. Fig. 4 shows a drawing of the final pump, fitted into the cavity.

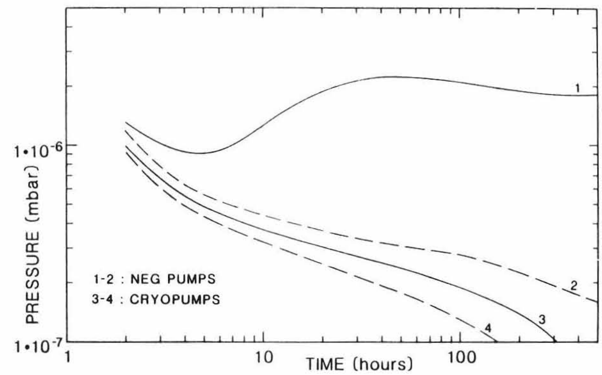

Fig. 3 - Estimated pressure vs time curves for the cryopumps and the NEG pumping system, with two different air leak rates: $\leq 1\cdot10^{-6}$ $mbar\cdot l\cdot s^{-1}$ (dotted lines) and $1\cdot10^{-4}$ $mbar\cdot l\cdot s^{-1}$ (solid lines) respectively.

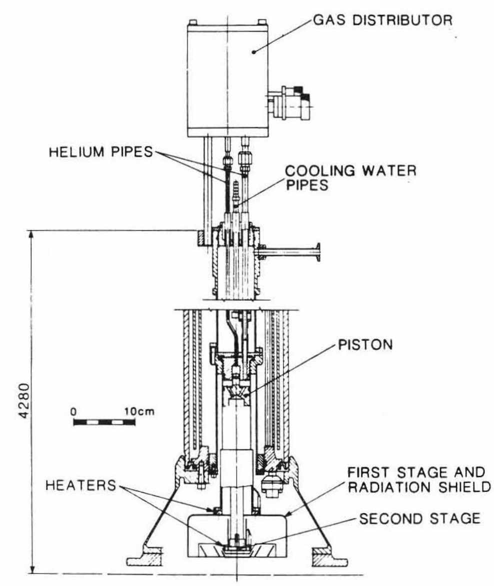

Fig. 4 - A sketch of the final version of the cryosorption pump.

In the final design the cold head is connected to the gas distributor with a stainless steel tube. So that, the pump can be tested, under the same conditions in which it will operate into the machine, without any helium change or refilling.

The assembling procedure of the old version was very critical because of solid and gaseous impurities that could contaminate the helium circuit during the assembling.

Each pump is provided with 2 independent electric heaters to obtain the rapid regeneration and cleaning of the pumping surfaces of both or just one stage. The temperature is detected by a Carbon Glass and a Pt100 resistors. The helium for the pumps is supplied by two conventional compressors, connected in parallel, with safety valves. In case of failure of one compressor, the system is able to guaranty the pumps operation, with only a little increment in temperature. On the contrary the cooldown is not possible with only one compressor.

The limit pressure for the switching on of the cryopumps is about $1\cdot10^{-4}$ mbar and it would be ensured by 3 turbomolecular pumps assembled at the bottom of the lower RF cavities and connected with 3 rotary vane pumps. These conventional pumps provide also a little pumping speed on helium (effective pumping speed ≃ 25 $l \cdot s^{-1}$ for each TMP).

A residual gas analyzer and an ion gauge are foreseen near the TMPs, while a fully immersed ion gauge, assembled inside one dee, provides direct vacuum metering during non magnetic field operation.

The pole-side region vacuum

The dirty region between the pole side and the copper liner is coarse vacuum pumped by means of mechanical pumps, in order to reduce the pressure difference between the accelerating chamber and the pole side region: the liner structure, as a matter of fact, is not able to support the atmospheric pressure from the pole side. Moreover this differential pumping ensures more reliability against any leak from this region. The materials exposed to the rough vacuum are: copper, steel, Fiberglas, a resin (Scotchcast 281) used for the correction coils impregnation and plastics. The estimated operative pressure of the pole side region is below 1 mbar. A safety system of mechanical (spring type) and electropneumatic valves protects the copper liner against vacuum failure, and particularly against pressure rises that can deform or collapse the liner structure. Two rotary vane pumps, connected in parallel, are used for the pole side region vacuum system, to ensure more reliability.

The cryostat vacuum system

Inside the cryostat, vacuum is used as thermal insulation among the room temperature parts, the LN2 shield and the liquid helium vessel.

Due to the cryostat characteristics[7], the vacuum system must have a long operative life and an high reliability. The choice of the high vacuum pumps was also dictated by the long time operation inside the magnetic field. So that, two identical and independent pumping systems are connected to the cryostat vacuum chamber, each one composed of a diffusion pump, a LN2 trap, a rotative pump and usual valves and gauges systems. No by-pass line is foreseen between the rough and the high vacuum pump, fore-vacuum being made trough the diffusion pump. All the pumps are filled with Fomblin 18-8 oil (a Montefluos perfluoropolyether fluid) to ensure a very long operative life.

The effective pumping speed for each system is 200 $l \cdot s^{-1}$ for nitrogen. A battery supplied inverter and a methane gas electric current generator provide power supply during line faults. Moreover a Westinghouse PLC (PC 1100), connected to the cyclotron computer control, controls each system[9].

A safety system, composed of 3 Penning gauges, connected to the computer control, is also present, for starting a rapid discharge of the magnetic energy stored in the superconducting coils, in case of cryostat vacuum failure.

The outgassing rate of some unusual vacuum materials used in the cryostat vacuum chamber are shown in the fig. 5.

The differential pumping systems

A differential pumping system is used on some high risk sealings in order to let operative the machine also if a leak is present: as an example, this technique is used on the sealing between the cryostat and the accelerating chamber. This is a very critical sealing because of the cryostat movements during cooldown. Particularly, in order to compensate for these movements we use two 20 mm viton O-Rings and rough pumping in between is guaranteed.

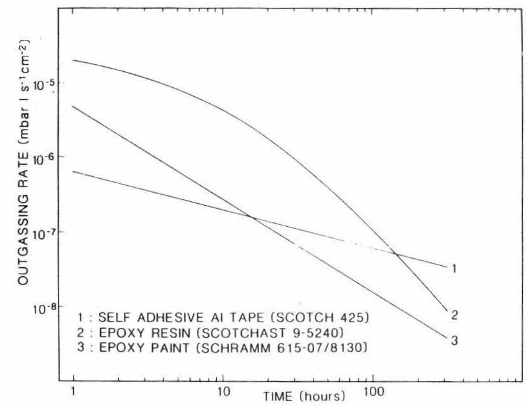

Fig. 5 - Outgassing rate of some materials used in the cryostat vacuum chamber.

The axial injection line pumping system

Axial injection system, as reported in a separate paper at this Conference[8], is in progress too. Axial injection vacuum line is about 10 m long, divided in 2 sections, with an average pipe diameter of 70 mm. The pressure in the injection line must be reduced to about $1 \cdot 10^{-7}$ mbar in order to avoid significant beam losses. We plan to use 6 high vacuum pumps : 2 turbomoleculars, 3 conventional cryopumps and, a split cryopump, similar to those used in the cyclotron, for operation in the magnetic field. The cryopumps are used without gate valves and the regeneration is made by means of the same TMPs. The pumps are connected at the diagnostic boxes, in order to compensate the high outgassing rate of the diagnostic devices. To limit the total outgassing we plan to use metallic seals with ISO and conical ISO compatible (EVAC) flanges.

Conclusions

All the components of the vacuum system for the Milan K800 Cyclotron are now completed or under construction and we are now attending to the vacuum system controls. More details on the project status[7] and on the envisaged computer control[9] are given in other papers at this Conference.

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