FIRST EXPERIENCE WITH THE VACUUM SYSTEM OF THE CYCLOTRON COMET

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The vacuum system of the cyclotron COMET was set into operation at PSI for the first time in 2004. The adopted design concept for the sealing and pumping system was successful. The total pumping speed of 4000 l/s from the installed turbo pumps is sufficient in spite of the conductance limitations within the vacuum vessel. The required operating pressure of $p \leq 10^{-5}$ mbar could be achieved within the targeted short pump-down time of 10 min. The final pressure of $p = 5 \times 10^{-7}$ mbar without the ion source provides sufficient reserve for operation with the ion source.

INTRODUCTION

The superconducting cyclotron COMET, manufactured by ACCEL, was delivered to PSI during 2004. During the design phase, a special focus was set on the realisation of the shortest possible service intervention and a very high availability of all machine components required for the operation of the cyclotron. Therefore, a close co-operation with the colleagues of the PSI vacuum group took place from the very beginning. At all times during the planning, construction, manufacturing, and assembly of the COMET vacuum system, a strong emphasis has been placed on a hydrocarbon free vacuum system and on a long term leak tightness of the cyclotron. Mistakes which are made at this stage can never be completely cancelled and would impair the overall quality of the cyclotron.

VACUUM SYSTEM

During the selection process for the hydrocarbon free vacuum pump system for the COMET cyclotron, we could show that several turbomolecular pumps with a low pumping speed have advantages compared to only a few cryogenic pumps with a high pumping speed. In this way, the total installed pumping speed of 4000 l/s could be distributed optimally in the whole cyclotron with eight turbomolecular pumps. The required pumping speed of 4000 l/s is calculated from the specified operating pressure of $p < 1 \times 10^{-5}$ mbar together with all sources of gas, such as the ion source gas inlet, leaks, permeation through gaskets and gas desorption. The conductance of the molecular gas flow, which often takes up a large fraction of the nominal pumping speed, should not be underestimated in the context of a cyclotron of such compact design. Leaks and permeation through gaskets are the most relevant gas sources for the final pressure.

The total leak load can be massively reduced by using optimal sealing surfaces and O-rings of high quality. Vulcanised or glued O-rings made from round cords are not suitable for this application because of the insufficient surface quality and dimensional tolerances. There was no suitable O-ring size available and it was therefore necessary to purchase a special tool for the production of suitable endless O-rings. Using this tool, it was possible to mould O-rings with an optimal rubber compound with suitable hardness and resistance to radiation damage. For the COMET cyclotron, we have used Viton FKM O-rings with a hardness of 70 Shore A.

With these O-rings, one already achieves a very high tightness of the vacuum system. Nevertheless, one single O-ring sealing is not sufficient to fulfil the required specifications. Viton O-rings harden with time, depending on their exposure to radiation or operation at higher temperatures, and therefore become leaky. To solve this problem, double gaskets with an intermediate isolation vacuum of < 1 mbar are installed wherever possible and guarantee a very high tightness on a long-term basis. This system was used for all large flange gaskets with nominal diameter DN 1800 mm and for all rotatable and linear feedthroughs.

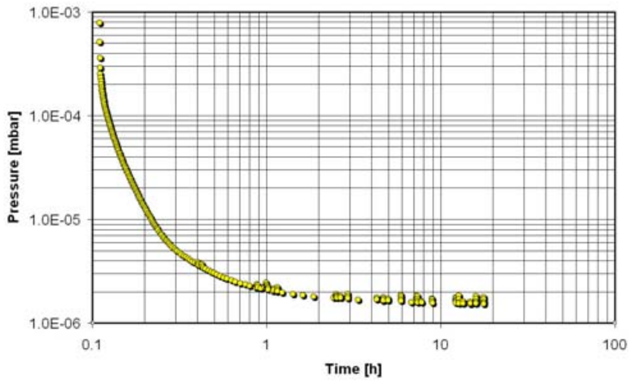

Fig. 1: The pump down curve, recorded on Nov 19th, 2004, shows that all requirements for the vacuum system have been achieved.

TURBOMOLECULAR PUMPS AND MAGNETIC FIELDS

Turbomolecular pumps cannot be operated in the presence of high magnetic fields. In magnetic fields higher than 50 Gauss, the rotor of a turbomolecular pump can heat up and lose mechanical strength. A disruption of the rotor after a short period of operation cannot be avoided. The magnetic fringe fields of the superconducting cyclotron magnet; about 500 Gauss in the region of the turbomolecular pumps; are a factor of 10 above the maximum permitted values. Only with a massive and strong iron shielding (Fig. 2) was it possible to protect the pumps against the high magnet field.

With the installed magnet shielding for the turbomolecular pumps, the maximum allowable value of 50 Gauss for the magnet field at the rotor position was achieved at the nominal cyclotron magnet current of 160 Amps (Fig. 3).

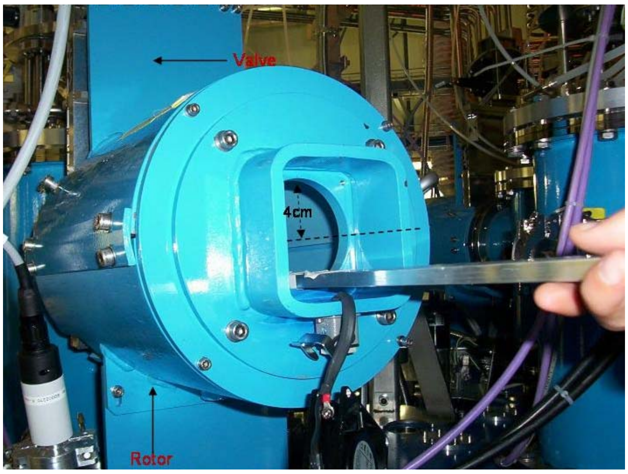

Fig. 2: Shielding of magnet fields for the operation of the turbomolecular pumps.

In order to guarantee secure operation, the magnet shielding has to be further improved. The installation of more iron in the region of the high vacuum flanges of the turbomolecular pumps is under development and will reduce the maximum magnet field at the rotor significantly.

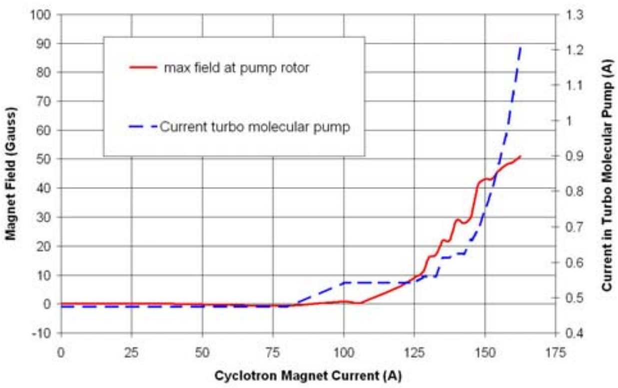

Fig. 3: The measured magnetic field inside the shielding at the rotor position and the pump current vs. current in the superconducting coils of the cyclotron magnet.

CHAIN CLAMPS FOR VACUUM FLANGES

Chain clamps are used in the vacuum technology to close KF flanges and ISO-K flanges with metallic gaskets. Chain clamps have only one screw and therefore one can open and close a flange connection very quickly. This type of clamp is used very often at PSI, especially at locations with high radiation background, to reduce the exposure time in case of a service intervention. Recently, we discovered some broken clamps at other locations in PSI related to a design error in a new series of chain clamps of the size KF 40. The same type of chain clamp was also installed at several locations in the cyclotron. We made a risk analysis for the vacuum system of the COMET cyclotron and decided to replace all installed KF 40 chain clamps. Many of the installed chains could be easily removed and replaced with the new design. However, one problem remained: The cold cathode gauges at the cryostat are also connected with the unsafe chain clamps. Unfortunately, the cryostat was already in use and had already reached its final temperature. A warming-up and venting of the cryostat was no longer possible due to lack of time.

The vacuum group developed a procedure to exchange the chain clamps in-situ without venting the cryostat. We used modified grippers to keep the flange connection under pressure during the exchange of the chain clamp (Figs. 4 and 5). During experiments in our vacuum laboratory, we could determine the optimum force required to keep the metal gasket under pressure without deforming, lifting, or moving the gasket. After performing some preliminary tests, we could start with the implementation at the cryostat. The procedure was successful and now guarantees a secure operation of the cyclotron.

Fig. 4: In-situ exchange of chain clamp KF 40.

Fig. 5: The new (above) and the old (below) KF 40 chain clamps.