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Adaptable Cryosorption Pump System for SIS100

Sandra TIPPMANN[(a)], Thomas JANDE[(a)], Sebastian HEMPEL[(a)], Andreas KADE[(a)], Jürgen KLIER[(a)], Stefan WILFERT[(b)], Ivan PONGRAC[(b)]

[(a)] Institut für Luft- und Kältetechnik gemeinnützige Gesellschaft mbH
Dresden, 01309, Germany, sandra.tippmann@ilkdresden.de, andreas.kade@ilkdresden.de
[(b)] GSI Helmholzzentrum für Schwerionenforschung GmbH
Darmstadt, 64291, Germany, s.wilfert@gsi.de, i.pongrac@gsi.de

ABSTRACT

This article gives a brief overview of the development and production of a special cryosorption pump system, consisting of 85 pumping components, which will be used in the cryogenic beam vacuum system of the heavy ion synchrotron SIS100 for the FAIR project at the GSI. In this publication we present results of our development and give an outlook for further applications. Operational steps necessarily needed to achieve the high quality requirements for this special application are described in this paper. Included among others, the parameters leak rate, pressure loss, volume flow, quality of the required active charcoal particles and pumping speed are of most important interest.

Keywords: cryosorption pump, cryogenic vacuum system, adsorption, charcoal, liquid helium, pumping speed

1. INTRODUCTION

The cryogenic beam pipe vacuum system of the heavy ion synchrotron SIS100 for the FAIR project at the GSI, currently in its construction phase, will be operated at cryogenic temperatures between 5 to 15 K. At such low wall temperatures, residual gas pressures of <5E-12 mbar (related to cryogenic temperatures) will be generated and maintained in the beam pipes by means of distributed cryopumping. However, since the bare cold chamber walls have a strongly limited pumping capacity for H_2 and almost none for He at these temperatures, additional pumping speed for these gas species is required to ensure long-term stable low vacuum pressures in the beam line. As the pumping speed must be provided at exactly calculated positions in the cryogenic beam line sections, the integration of small-sized localized cryosorption pumping components had to be planned. So in total, this cryosorption pump system shall consist of 85 pumping components which must be implemented into the cryogenic vacuum system of the SIS100 in order to meet the vacuum requirements for beam operation. Since no cryosorption pumps are commercially available which meet the specific pumping requirements and due to the limited space conditions inside the SIS100 cryostats, a novel compact cryosorption pump type has been developed and successfully tested at the GSI. The ILK Dresden was commissioned to finalize the development and to convert it into the production of a complete cryosorption pump system.

The pump design described herein is based on the development work of Wilfert (Wilfert et al., 2012) who constructed a prototype of the pump at GSI. The pump is mounted on a conventional DN100CF flange, housed into a standard CF nipple, and consists of six charcoal-coated cryopanels screwed on a common axially running cooling tube. In operation, pressurized LHe is led through the tube to uniformly cool down all cryopanels to temperatures of 4.5 K. The pump as developed provides very high pumping speeds for H_2 and He.

2. CRYOSORPTION PUMP SYSTEM

The cryosorption pump is designed as a modular system which enables an easy adaption or replacement of subcomponents. This feature allows the pump to be variably used in a broad range of cryogenic vacuum applications.

The pumping elements of the pump are formed by cryogenically-cooled charcoal-coated copper cryopanels. On their highly porous surfaces gas molecules are cryosorbed and thus removed from the gas phase. The pump characteristics are mainly determined by the choice of the used charcoal type. One of the most important requirements was a high microporosity of the charcoal. The special granular coconut-shell based activated charcoal SC2 by Chemviron has excellent adsorption properties for H_2 and He at cryogenic temperatures (Hauer and Day, 2002). Unfortunately, this charcoal type is no longer commercially available. However, Chemviron offers the charcoal type AQUACARB 208C as an alternative charcoal type. It is also granular coconut-shell based and has similar characteristics in terms of mesh size, micro-porosity, hardness, and bulk density. In fact, H_2 adsorption measurements with this equivalent charcoal type carried out by GSI confirmed that AQUACARB 208C has adsorption capacities at 4.5 K for H_2 and He comparable to that of the charcoal type SC2.

One of the major challenges represented the bonding of the granular charcoal particles onto the cryopanel surface. The bonding process must ensure that particles can be distributed homogeneously across the entire panel surface with an average coating density of 0.04 g/cm^2 per panel side. Furthermore, the granular layer must remain firmly attached onto the copper panel down to LHe temperatures. This requirement is not only necessary for an optimal heat transfer, but rather for avoiding unwanted peeling off of charcoal particles from the substrate surface during operation. Various adhesives and catalysts have been tried and tested at the ILK Dresden, including shaking and repeated vacuum tests. It was found that charcoal coating by means of the epoxy adhesive STYCAST 2850 GT and catalyst 9 meets all requirements mentioned above. Figure 1 shows exemplarily a charcoal-coated cryopanel. Activated charcoal panels after installation and a complete pumping element is shown in Figure 2.

Figure 1: Prepared cryopanel coated with activated charcoal (carbon elements)

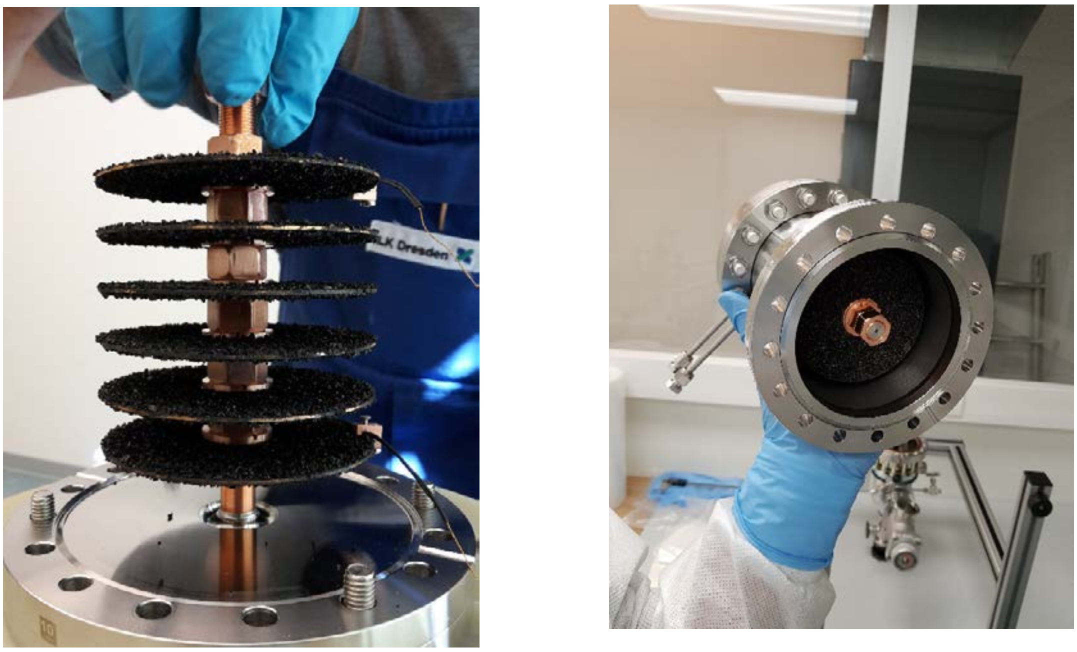


Figure 2: Activated charcoal panels after installation (left), complete pumping element (right)

In order to be able to carry out measurements regarding mass flow and pressure loss, a special test rig was designed and assembled, see Figure 3 and Figure 4.

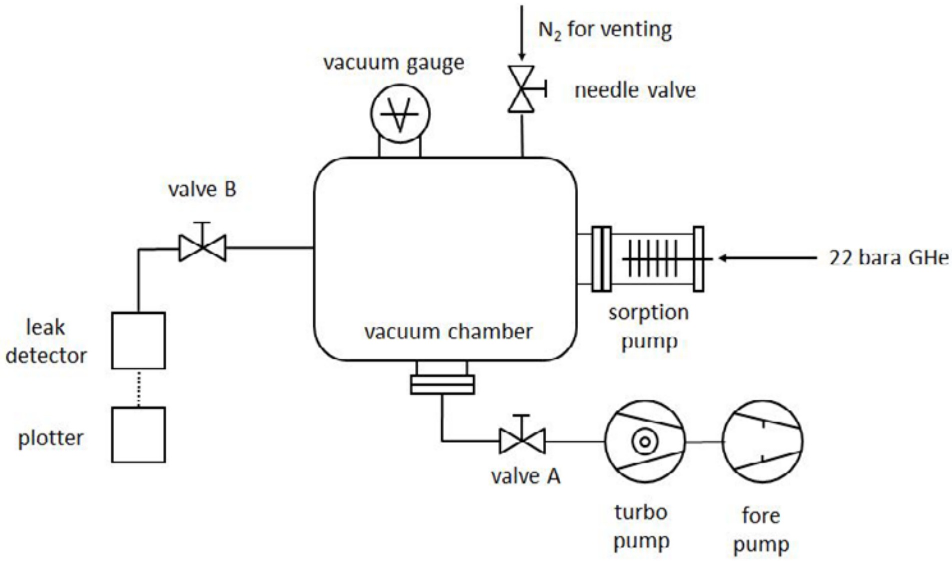


Figure 3: Schematic drawing of the test rig for mass flow and pressure loss measurements

Figure 4: Test rig for mass flow and pressure loss measurements

To meet the pressure drop requirements, we performed CFD simulations on the cooling tubes in advance, as shown in Figure 5 below. It can be seen that the maximum pressure loss in peripheral sections of the cooling tube does not exceed 39 mbar (in relation to the given outlet pressure).

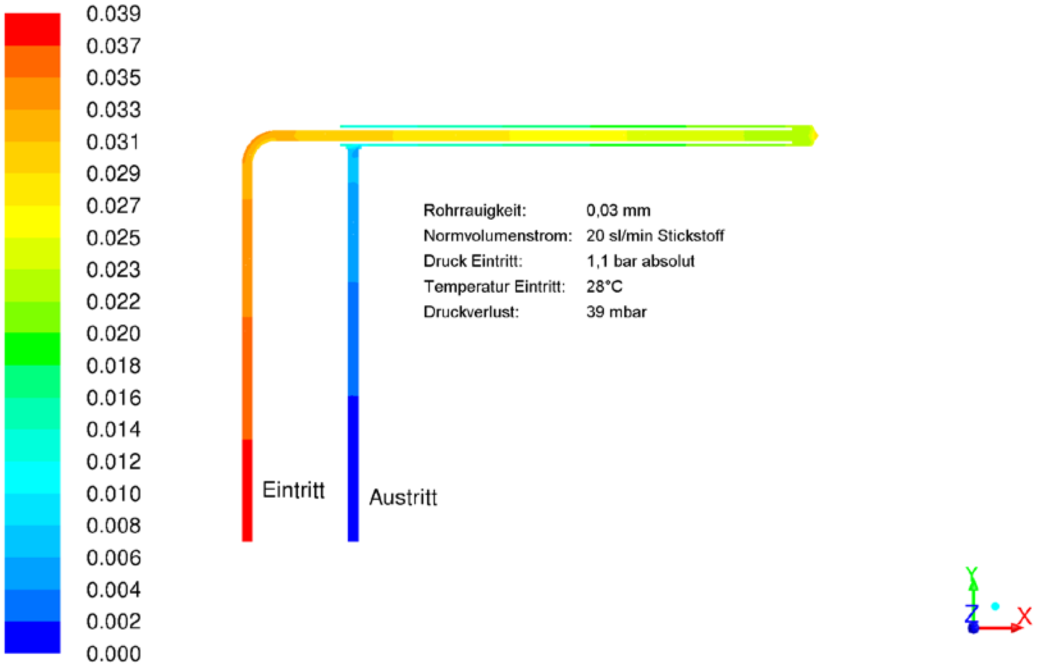
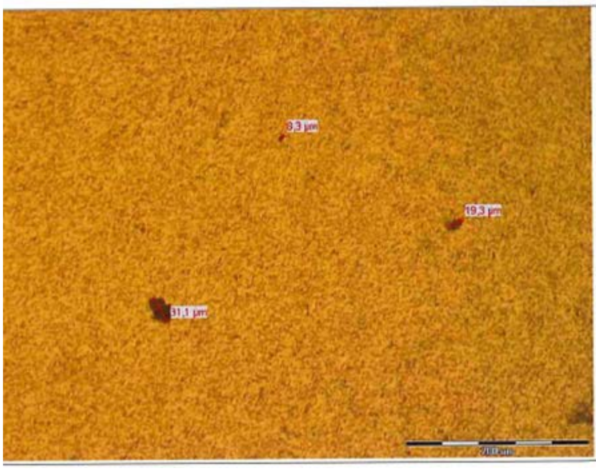


Figure 5: CFD simulation of pressure loss inside the cooling tube

The cryosorption pump system components were mounted in a special clean room (class ISO 7), see Figure 6. This provision was necessary in order to minimize the possibility of disturbing particles on the surfaces.

Figure 6: Clean room of the ILK Dresden

To ensure that the chosen bonding process meets the requirements of the SIS100 and that no larger particles detach from the panels during pumping by means of vacuum pumps, particle measurements were carried out by optical microscope after extensive pumping, see Figure 7.



Areal 1
Länge [µm]
8,3
19,3
31,1

Figure 7: Particle measurements after pumping (by usage of camera Olympus PEN Lite E-PL 7)

One of the specification for the SIS100 cryosorption pumping system was that no particle larger than 100 µm should detach from the surface. The measurements show that the requirements are fulfilled.

After production and delivery of the cryosorption pumping system, various measurements were performed at the GSI (Wilfert and Pongrac, 2016). The measured pumping speed vs pressure characteristic is shown in Figure 8. The pump delivers a pumping speed of at least $S_{\text{eff}} \approx (600 \pm 150)$ ℓ/s for H_2 and approximately (350 ± 200) ℓ/s for He at room temperature. Taking into account a gas temperature of 5 K, the pumping speed at cryogenic temperatures is reduced by the factor of

$$\frac{S(T=5\,K)}{S(T=293\,K)} = \sqrt{\frac{5\,K}{293\,K}} \approx 0.13 \qquad Eq.\ (1)$$

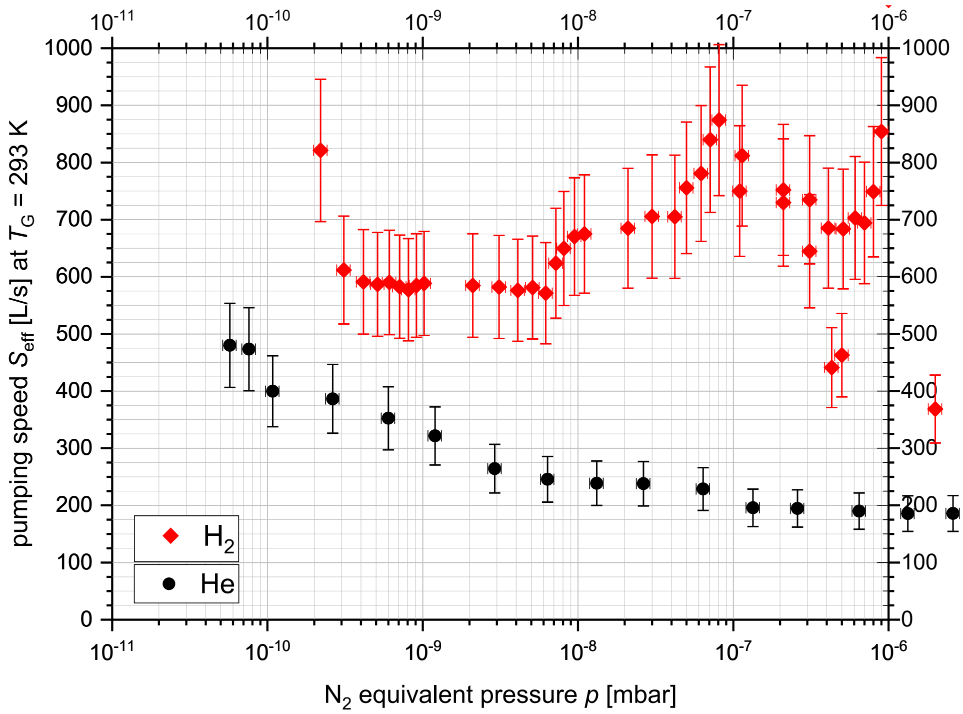


Figure 8: Pumping speed measurements of the cryosorption pump (GSI)

3. SUMMARY

Our development has enabled to meet the demanding specifications for a cryosorption pump system for the heavy ion synchrotron SIS100 of the FAIR project in all of its aspects. A large number of tests has been performed including the parameters leakage rate, pressure loss, volume flow, number of detached active charcoal particles and pumping speed. Depending on the requirements, the geometry and the number of cryopanels can be adapted to ensure other applications in cryogenics.

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