9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-WEPML029

VACUUM SYSTEM OF THE HESR AT FAIR, STATUS OF TESTS, LAYOUT AND MANUFACTURING

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Abstract

The Research Center Jülich is leading a consortium being responsible for the design and manufacturing of the High-Energy Storage Ring (HESR) which is part of the FAIR project in Darmstadt, Germany.

The HESR is designed for antiprotons within a momentum range of 1.5 - 15 GeV/c but can also be used for heavy ion experiments. Therefore the vacuum quality is expected to be in the range of $1\cdot10^{-9}$ … $1\cdot10^{-11}$ mbar or better, the best designated for future options in particular. That is a great challenge on the overall vacuum layout as well as on the surface quality of the chambers and beam tubes.

Whereas all bent dipole chambers are already installed, the manufacturing of the pumping bodies with integrated RF meshes as well as several diagnostic chambers are in the focus of investigation. To validate the intended pumping concept of both the bakeable arc sections and the non-bakeable straight sections, final tests at the operational test benches are planned. In parallel, the purchasing of valves and first pumps will be prepared.

The actual mechanical layout of the HESR vacuum system and its components will be presented as well as the progress of manufacturing of several vacuum chambers and the latest experimental test results.

VACUUM DESIGN OF THE HESR

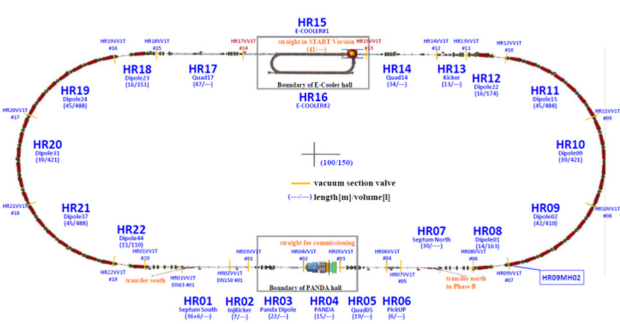

Figure 1: Present layout of the HESR w.r.t. vacuum.

Figure 1 gives an overview of the whole vacuum system of the HESR as well as Table 1. The system is divided into 22 vacuum sections separated with all-metal slide valves. In addition 7 fast closing shutter are foreseen to protect the system from severe damage due to a leakage in experimental setups. All in all 10 vacuum sections in the arcs are provided with a bake-out system both to heat up the system and to activate the NEG-coated dipole chambers. Within the straight sections the distance between the pumps are shorter and a bake-out system is not foreseen at all except the short vacuum section for the injection kicker magnets (HR02). The main aperture resp. inner diameter of the beam tube is Ø 89 mm, only interrupted by pumping bodies or diagnostic elements like BPMs. Large vacuum chambers only come upon for the stochastic cooling and the injection kicker system. If an extension of diameter occurs the transition will be very smooth (≤ 30° in total) or will be bypassed with Rf-meshes. Eight mobile pumping stations will be provided for roughing combined with a quadrupole mass spectrometer for RGA, two in parallel for large vacuum sections. Two types of ultra high vacuum pumps are foreseen, ion getter pumps and NEG pumps, and for pressure measurement each vacuum section will be equipped with at least 3-4 gauges (one Pirani and 2-3 Penning gauges).

The control system will be developed with UNICOS for Siemens S7-1500 (GSI standard), not discussed here in detail.

Table 1: Vacuum System of the HESR

Feature	Value /Description
Circumference	575 m
Arcs / Straights	r = 49.5 m / l = 132 m
No. bakeable sections	11
No. slide valves	24, all metal with Rf-mesh
No. high speed shutter	7
No. NEG coated dipole chambers	44+2, bended r = 29.43 m, length l = 4.40 m
Section length / vol.	max. ~ 45 m / ~ 500 l
Pressure range at RT	$1\cdot10^{-9}$ … $1\cdot10^{-12}$ mbar
Beam pipe	Ø93 x 2 mm, AISI 316LN low hydrogen, low permeability, electropolished
Vacuum chambers for stochastic cooling	3 x DN500 cryo cold heads at 20K, 4 x DN400 water cooled
Vacuum chambers for injection kicker	2 x DN600, bakeable
Pumping bodies	186 in total, 2 types for ports with DN150 and DN63, four ports each, Rf-mesh inside,
No. pumping station roughing	8, mobile design
No. ion getter pumps	~ 190, 2 types of pumping speed (50, 240 l/s N_2)
No. NEG pumps NEG	~ 190 (300 l/s N_2)

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VACUUM TESTS

In order to define the pumping concept for the non-bakeable straight sections and the bakeable arcs of the HESR, two test benches were built up at ZEA-1 (details to bakeable test bench see paper WEPML028). The test bench for the non-bakeable parts (Fig. 2) consists of two half dipole vacuum chambers, one quadrupole vacuum chamber and two pumping bodies. The aperture of the tube is Ø 89 mm with a wall thickness of 2 mm, a total length of 6285 mm and an approximate volume of 69 l.

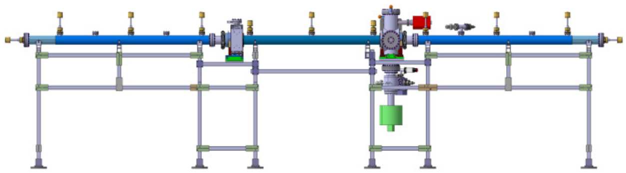

Figure 2: Layout of the vacuum test bench.

The two pumping bodies differ in their dimensions. The small one has four CF63 flanges and the large one has four CF150. To investigate the influence of different pump types on the reachable end pressure and the pressure profile along the tube, different test phases are defined (Table 2).

Table 2: Test Phases

Phase	Pumps					
	IZ55 #1	IZ55 #2	IZ300	D1000 #1	D1000 #2	D3500
(1)	x	x	x	x	x	x
(2)	x		x	x		x
(8)	x		x	x	x	

A mobile pumping station (HiCube Classic – Pfeiffer Vacuum) consisting of a membrane roughing pump and a turbomolecular pump is installed at the large pumping body. Furthermore, there are three NEG-pumps (two CapaciTorr D1000 and one CapaciTorr D3500 – SAES Getters), and three ion pumps (two VacIon Plus 55 StarCell and one VacIon Plus 300 StarCell – Agilent). To determine the pressure profile, nine vacuum gauges (IKR270 – Pfeiffer Vacuum) are mounted.

The results were evaluated concerning the reached end pressure, pumping speed and costs. Phase 8 provides the lowest pressure. Depending on the position of the pressure gauge a pressure of $8.4 \cdot 10^{-11}$ to $2.9 \cdot 10^{-10}$ mbar is reached after 800 h. In Fig. 3 the pressure profile is shown. The pumping process for the highest (9) and lowest (5) pressure is shown in Fig. 4.

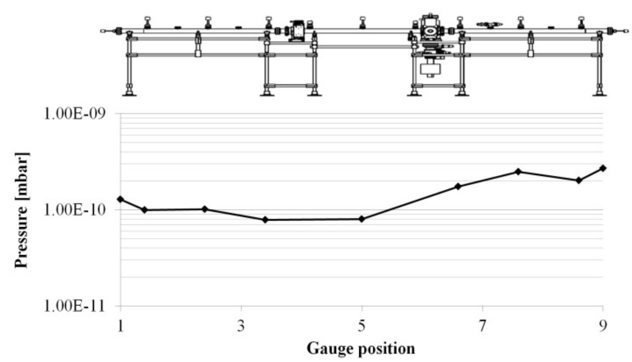

Figure 3: Pressure profile (Phase 8).

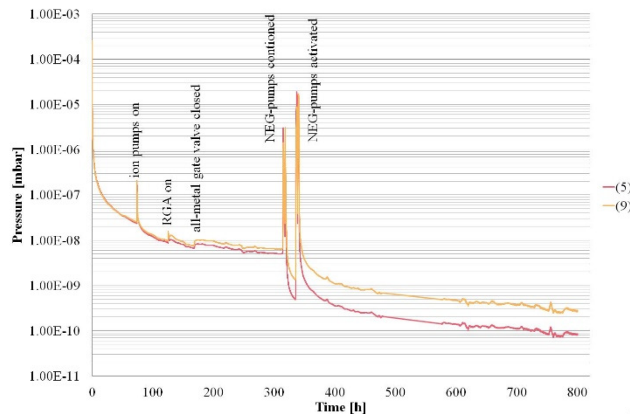

Figure 4: Pumping process (Phase 8).

MANUFACTURING OF VACUUM CHAMBERS

Although some vacuum tests are still going on the detailed design of many vacuum chambers has finished and manufacturing has started. In particular manufacturing of the dipole chambers is completed, the NEG-coating was well done at GSI and about 2/3 of them are installed into the dipoles and transferred to GSI (see Fig. 5).

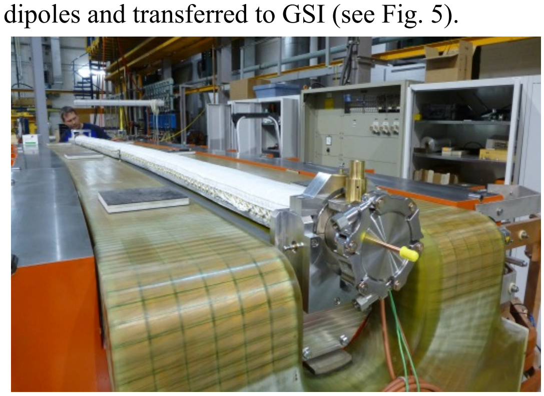

Figure 5: Installed dipole chamber with heating jackets.

The series production of the pumping bodies has started and overall 20 pieces are delivered already. Figures 6 - 8 show the two different types of chambers, the Rf-mesh before welding inside the chambers, the supports and a delivered pumping body wrapped with the heating jacket. The delivery of the last pumping body is expected until the end of 2018.

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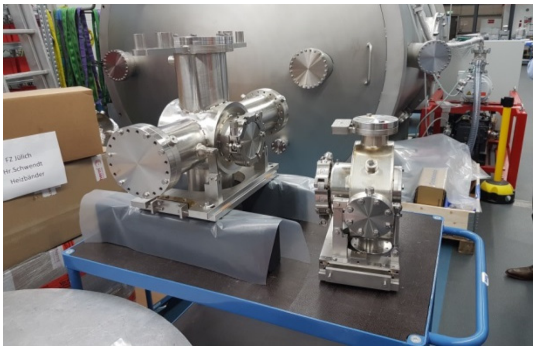

Figure 6: Manufacturing of two types of pumping bodies (DN63, DN150).

Figure 7: Rf-mesh (left) and supports (right).

Figure 8: Delivered with heating jackets.

Seven larger vacuum tanks for the stochastic cooling are produced already and four of them are almost assembled with ring elements and control units inside the clean room of ZEA-1. Figure 9 shows the prepared insert before mounting in the vacuum tank. One of the tanks is already completed and installed in the COSY accelerator for test purpose (Fig. 10).

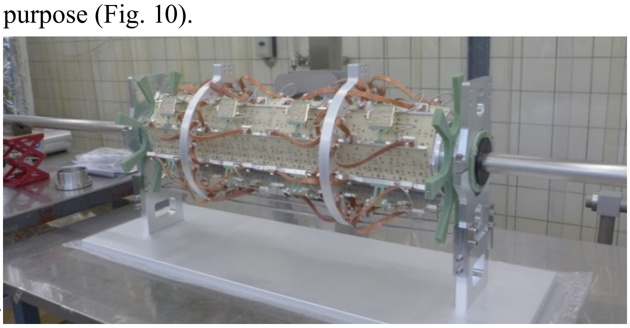

Figure 9: Insert for stochastic cooling tank.

Two other large vacuum tanks are manufactured as well housing the injection kicker magnets (Fig. 11). To prepare a smooth transition from DN600 to Beam diameter a conical adapter was manufactured (Fig. 12).

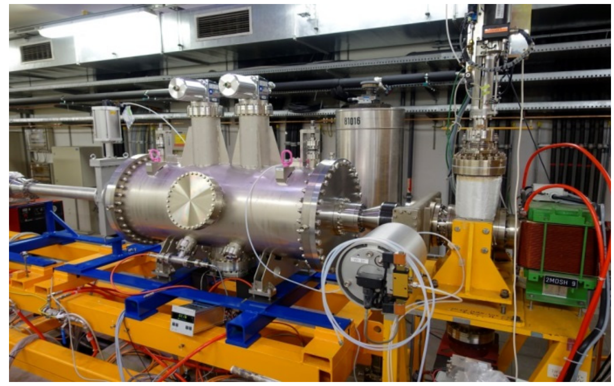

Figure 10: Installed chamber for stochastic cooling at COSY.

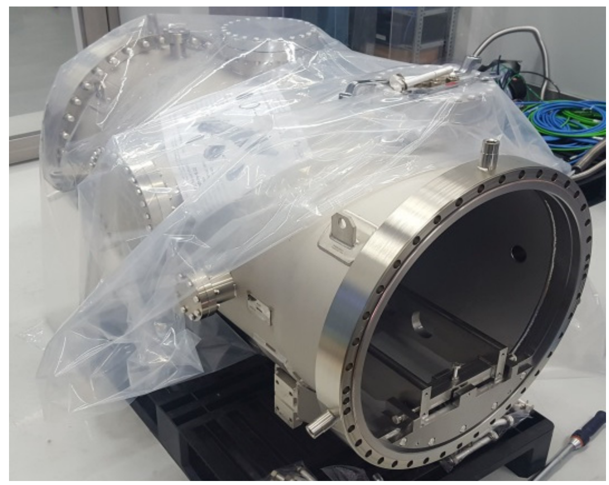

Figure 11: Vacuum tank for injection kicker magnets.

Figure 12: Conical adapter for injection kicker magnets.

CONCLUSION

Except for some diagnostic elements the mechanical design of the vacuum system of the HESR is completed in principle so that the designers started to prepare the drawings. Some selected vacuum chambers are already ordered resp. delivered but many meters of 'beam pipes' still have to be produced in addition with all supports. In parallel the heating and control concept for the HESR has to be designed terminally. All parts on the beam path will be ordered for pre-assembly. Pumps and gauges will be ordered later for installation once the magnets and chambers are at their final place in the tunnel.