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BAKEOUT CONCEPT FOR THE HESR AT FAIR

Heinz Jagdfeld, Norbert Bongers, Patrick Chaumet, Frank Martin Esser,
Frank Jordan, Franz Klehr, Georg Langenberg, Ulrich Pabst, Larisa Semke
Forschungszentrum Juelich, Germany

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Abstract

Forschungszentrum Juelich has taken the leadership of a consortium being responsible for the design of the High-Energy Storage Ring (HESR) going to be part of the FAIR project on the GSI campus in Darmstadt in Germany. The HESR is designed for antiprotons but can be used for heavy ion experiments as well. Therefore the vacuum is expected to be 10^-10 mbar or better. To achieve this also in the curved sections where 44 bent dipole magnets with a length of around 4.5 m will be installed, NEG coated dipole chambers will be used to reach the needed pumping speed and capacity. For activation of the NEG-material a bakeout system is required. The bakeout concept including the layout of the control system and the systematization of the heater packages for all components of the vacuum system are presented. Also the special design of the heater jackets inside the dipole will be shown where the geometrical parameters are very critical and space is very limited. The results of the simulation of temperature distribution in the dipole iron are compared to temperature measurements carried out at a testbench with different layouts of the heater jackets. The final design of the dipole heater jackets will be illustrated.

DESIGN DATA OF THE VACUUM SYSTEM OF THE HESR

The High-Energy Storage Ring for Antiprotons and Heavy Ions (HESR) will have a circumference of approx. 575 m and will therefore be the second largest accelerator ring in the FAIR facility. The low-loss, undisturbed acceleration, deceleration, and storage of the antiprotons and heavy ions in the synchrotron is only possible under UHV conditions at an average residual gas pressure below $1 \text{ x } 10^{-10}$ mbar, or preferably $1 \text{ x } 10^{-12}$ mbar for heavy ions, and at a very low magnetic permeability of the vacuum components.

The required operating pressure can only be reached if all vacuum components are manufactured in accordance with the dedicated specifications for the UHV system. As a result, special requirements apply to the materials used and their processing.

In detail the HESR will consist of 22 vacuum sections (incl. 2 for E-Cooler, 1 for PANDA), all separated with all-metal slide valves (max. section length 45 m). In the two arcs a bakeout system and a pumping system including NEG coated chambers inside the dipoles will be installed.

For roughing at least 6 mobile pumping stations with oil-free fore pumps are foreseen.

Every section contains at least two pirani and two penning test points and one mass spectroscopy. The design data of the HESR are listed below in Table 1.

Table 1: Design Data of the HESR@FAIR

Feature	Value /Description
circumference	575 m
radius arc	r = 49,5 m
length straights	l = 132 m
nb. dipoles	44 (l = 4.2 m), 50 Tm
nb. quadrupoles	84 (l = 0.6 m)
nb. sextupoles	60 (l = 0.3 m)
experiments	SPARC, PANDA, …
cooling systems	electron cooling 2-4 resp. 8 MeV stochastic cooling 2-4 resp. 6 GHz
dipole chambers	bended with radius of 29.43 m, 8.18°, length 4.40 m, NEG coated
spec. vacuum chambers	2 for inj. kicker, 7 for stoch. cooling
av. pressure range	$1 \text{ x } 10^{-9}$ - $1 \text{ x } 10^{-12}$ mbar at RT
beam pipe	DN93x2 mm, AISI 316LN with low hydrogen content and low permeability, electropolished
nb. pumping bodies	approx. 180, four ports each, with rf-mesh inside
nb. pumping station roughing	approx. 6 – 8, mobile design
nb. vacuum pumps	approx. 540 (IZ, TSP and NEG)
nb. slide valves	22 (24), all metal with rf-mesh
nb. high speed shutter	4

BAKEOUT CONCEPT OF THE HESR

In the curved sections 44 bent dipole magnets with a length of around 4.4 m will be installed. NEG coated dipole chambers will be used to reach the needed pumping speed and capacity (see Fig. 1).

For activation of the NEG-material a bakeout system must be installed. The bakeout concept including the layout of the control system and the systematization of the heater packages for all components of the vacuum system is shown in Fig. 2 and 3. The heater jackets for all components in the curved sections - the straight sections will not be NEG-coated and do not need a bakeout system – were combined to repetitive elements. The bakeout concept with the sequence and duration of the heating procedure as well as the switch on and off points of the vacuum pumps are shown below. The bakeout process starts with heating up the non-NEG-coated components to

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250°C for 24 hours while the NEG-coated dipole chamber is only heated to 100°C to get rid of the water on the surface. In the second step the temperature of the non-NEG-coated components is lowered to 150°C while the NEG-coated dipole chamber is heated up to 250°C for 20 hours to activate the NEG material.

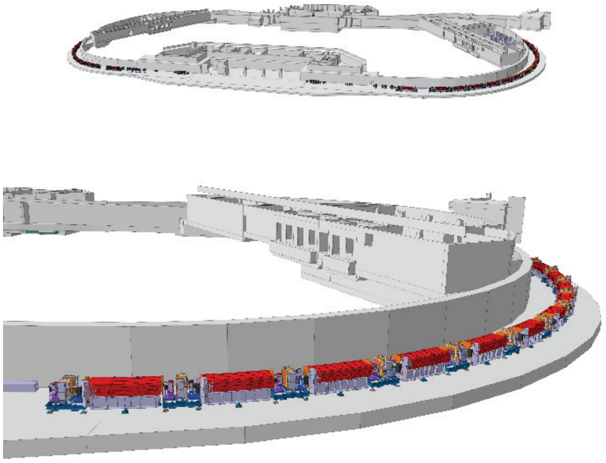


Figure 1: Layout of HESR (High Energy Storage Ring).

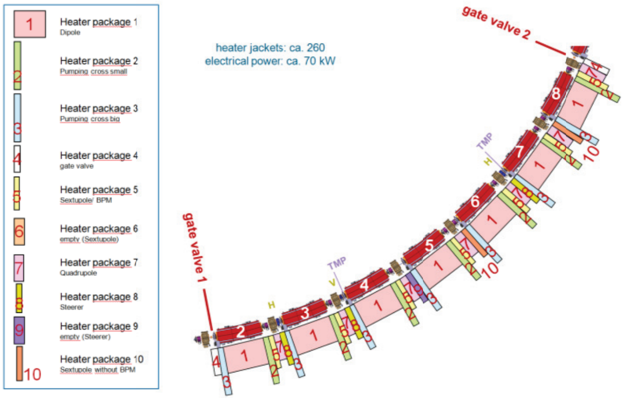


Figure 2: Systematization of the heater packages for one section.

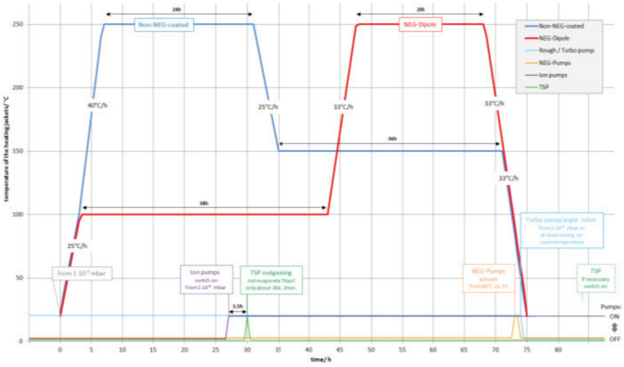


Figure 3: Layout of the bakeout concept.

Looking more into details of the available space for the heater jackets it is obvious that in many cases a special design of the heater jackets is required. One example is the limited space inside the dipole where the gap between the beam pipe and the magnet iron is only 3,5 mm (see Fig. 4 and 5).

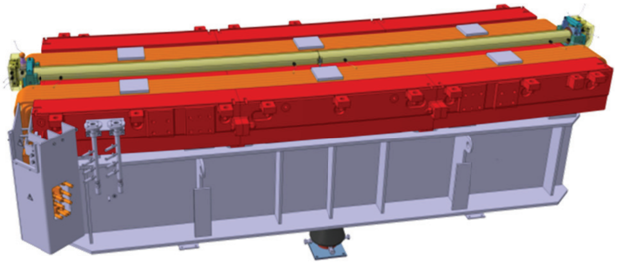
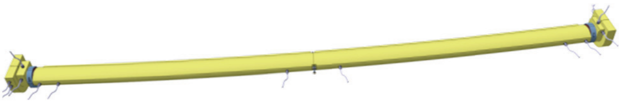


Figure 4: Arrangement of the dipole chamber inside the dipole magnet (upper yoke removed).



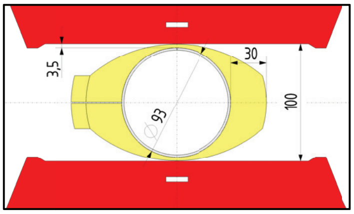


Figure 5: Limited space inside the dipole.

The maximum temperature for the dipole iron is 100°C and the minimum activation temperature for the NEG-coating inside the dipole chamber is 180°C. To meet both demands a special layout of the heater jacket was developed and tested on a testbench (see Fig. 6).

Figure 6: Special design of the dipole heater jackets.

The heater jacket has two small areas at the top and at the bottom with only 3 mm insulation where no space is left for a heater wiring. At the sides the heater wires are placed as near as possible to these areas to accumulate as much heating capacity there as possible. The insulation thickness is up to 30mm at the sides. The outer shape of the heater jacket has been optimized to an oval design due to the fact that the thermal losses increase when the surface of the jacket has direct contact to the iron of the

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magnet. The heater wiring and the thermocouple have been installed redundant (2 heater circuits and 2 thermocouples per jacket) to avoid the lifting of the heavy (13 t) upper yoke in case of a failure.

Figure 7 shows some results of the temperature measurements at the testbench.

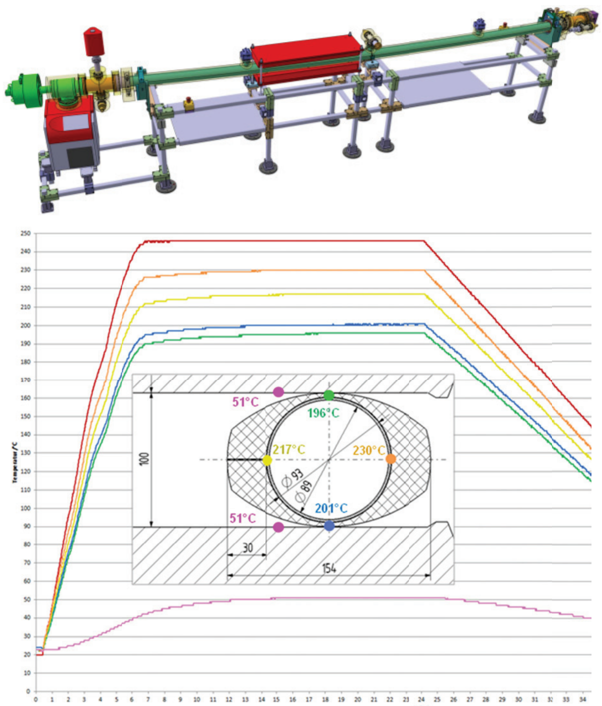
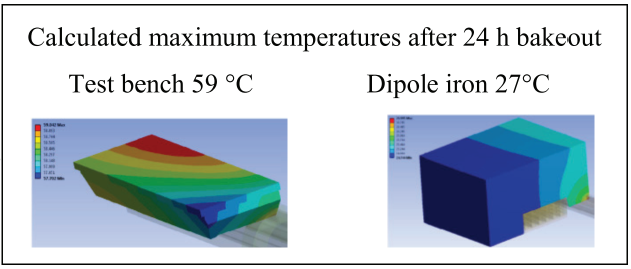


Figure 7: Temperature distribution in the dipole cross section.

The set temperature for the heater jackets was 250°C. The effective temperatures on the surface of the dipole chamber were 230°C respectively 217°C (caused by the disconnection point) on the sides where a thicker insulation could be realised. At the top and at the bottom the effective temperatures dropped to 201°C respectively 196°C due to the thinner insulation and heat losses to the magnet iron.

The maximum temperature for the dipole iron is limited to 100°C. In preparation of the tests a calculation for the temperature distribution in the dipole iron has been made. The results are shown in Fig. 8.


Calculated maximum temperatures after 24 h bakeout

Test bench 59 °C

Dipole iron 27°C

Figure 8: Temperature distribution in the dipole iron.

The predicted temperature of the iron at the test bench, where the dipole iron has been substituted by a dummy with the correct shape but reduced dimensions and much less weight , was 59°C compared to measured 51°C at the testbench. The measured temperatures correlate with the simulated temperatures very close and the maximum temperatures have a safe distance to the maximum allowed temperature for the dipole iron. Due to the much higher dimensions and mass of the real dipole the predicted temperature is only 27°C and guarantees an even bigger distance to the maximum temperature.

CONCLUSION

The systematization for the heater jackets of all components of the vacuum system into heater packages gives the basis for the layout of the control system and the bakeout procedure.

Considering the available space for the heater jackets in many cases a special design of the heater jackets is required. Using the example of the dipole heater jacket a special design was developed. The temperature distribution of the optimized heater jacket has been measured at a test bench to prove that the maximum temperature for the dipole iron will not be exceeded and the minimum activation temperature for the NEG-coating will be reached even in the worst case.

The comparison of the calculated temperature distribution with the measured temperatures showed a very high correlation and the optimized heater jacket design guarantees a clear distance to the maximum allowed temperature of the dipole iron.