

# DEVELOPMENTS FOR THE INJECTION KICKER VACUUM SYSTEM OF THE HESR AT FAIR

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## Abstract

IKP-4 of Forschungszentrum Jülich (FZJ) has taken the leadership of a consortium being responsible for the design and manufacturing of the High-Energy Storage Ring (HESR) going to be part of FAIR. The HESR is designed both for antiprotons and for heavy ion experiments.

The injection kicker system of the HESR is located 17 m downstream of the injection septum. 4 ferrite magnets (in vacuum, 40 kV, 4 kA) will deflect the incoming beam by 6.4 mrad onto the path of the circulating particles.

The vacuum system comprising chambers, suspensions, alignment, bakeout system, and lifting mechanism for the HV heads is in the responsibility of ZEA-1. All current bearing parts (magnets, feedthroughs, pulsers) are in the responsibility of the company SigmaPhi, Vannes, France.

As well as the magnets, the adjustment frames will be installed inside the tanks. Due to the large surface of the magnets, the injection kicker system will be very sensitive with regard to the achievable vacuum quality that is expected to be in the order of  $10^{-11}$  mbar or better. Thus a sufficient vacuum pumping system is designed as well as a heating system to heat the whole system up to 250° C. In order to investigate the achievable end pressure and to develop the heating system a test facility was constructed.

Both the actual vacuum layout of the injection kicker system for the HESR as well as layout of the test facility is described and the first experimental test results are briefly presented.

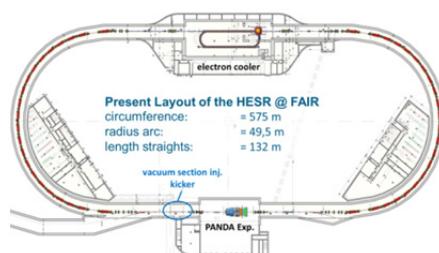


Figure 1: Present Layout of the HESR @ FAIR.

## INTRODUCTION

The HESR is a synchrotron and storage ring, which will be built for FAIR on the GSI campus in Darmstadt in Germany. ZEA-1 has the overall responsibility for the complete HESR vacuum system. Since there is no sufficient information regarding the outgas ratio from the ferrite magnets in UHV and also due to their sensitivity to higher temperatures, an experiment was conducted to

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monitor the total pressure and the temperature inside the vacuum chamber during the heating process without and later on with the magnets. Another important item to test is the correct velocity for the heating rate since the difference in temperature between the internal parts should be less than 50 K. For that purpose six thermocouples were installed inside the tank providing the information for the temperature profile in the vacuum vessel and in addition four thermocouples are pre-installed for the magnets. The vacuum tests without magnets were conducted at FZJ whereas the vacuums tests with magnets will be executed by the supplier as soon as the magnets are produced and tested at atmospheric pressure. After the vacuum tests are repeated with magnets the results can be compared and used to specify the pumping and heating procedure for the HESR.

## DESIGN OF THE VACUUM TANKS

FZJ designed the mechanical layout of all vacuum components of the injection kicker section as well as the parts inside the tanks to hold the magnets and the lifting mechanism for the electrical connector of the pulser system. For operation in the HESR accelerator a pair of two magnets will be mounted into each tank. FZJ has acquired three tanks in total whereof one was ordered in advance to use it as a test tank. All further mechanical parts (support and positioning structure for the magnets) were assembled and an automated heating and pumping system was developed.

The electrical cabinet houses the vacuum and heating power supplies and control equipment and provides the opportunity to adjust and monitor the system via a user friendly HMI. For the test tank numerous heating cycles are expected. After acceptance of the magnets they will be mounted into the clean ‘production’ tanks which will be later installed into the HESR.

## TEST TANK - ASSEMBLY PROCESS DESCRIPTION

After the test tank vessel was produced, properly cleaned and tested, it was delivered to the clean room where all the CF/COF flanges and feedthroughs as well as the magnet support frame were installed and the thermocouples were soldered. At the same time the pendulum supports and the PEEK insulation pads were mounted on the frame and later screwed together with the tank. After moving the vacuum vessel to the test facility all the vacuum components were installed and connected to the spe-

cially designed electrical control cabinet. An additional Helium leak test was performed before the heating jackets were mounted. At the end a dedicated lifting mechanism, designed to separate the upper HV connector from the tank during the heating process, was installed and successfully tested. Figure 2 is showing a 3D model of the injection kicker test tank with lifting mechanism.

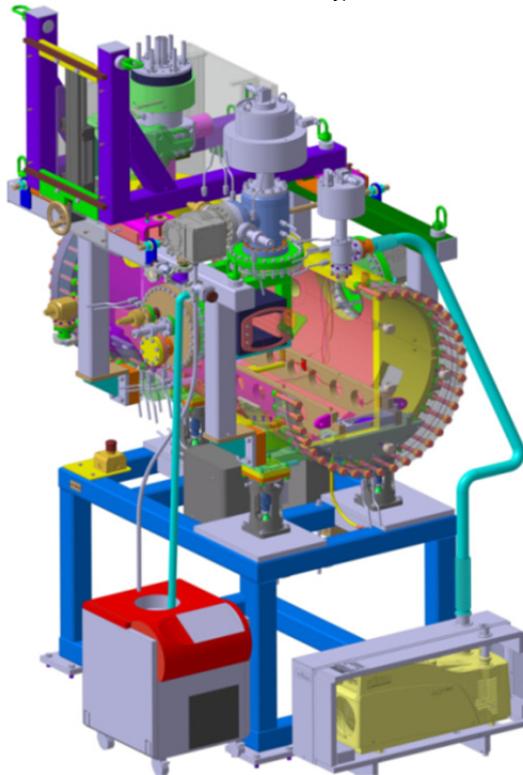


Figure 2: 3D model of the test tank.

As soon as the equipment is tested and the results are verified it is foreseen to perform a complete test of the whole injection section assembly (figure 6) with the purpose to simulate the behaviour in the real environment without beam as well as to perform a complete functional and vacuum test. After mechanically assembling the components a complete leak test will be performed to exclude possible leaks and verify the leak rate of the system. As soon as the system is tested for leaks the heating jackets will be installed and connected electrically to the control panel. It will be performed additional functional test with the pulser and compared to the results with the ones provided from the magnet manufacturer.

## VACUUM SYSTEM OF THE TEST TANK

The vacuum pumping system of the injection kicker prototype consists of a dry root type roughing pump with a maximal pumping speed of  $28 \text{ m}^3/\text{h}$ , a portable pumping unit with a small membrane pump and a turbo molecular pump with a maximal pumping speed for Nitrogen of  $880 \text{ m}^3/\text{h}$  as well as a large ion pump with a nominal pumping speed of  $860 \text{ m}^3/\text{h}$ . For the total pressure measurement two pairs of vacuum gauges are foreseen. Each pair consists of a cold cathode and a pirani type vacuum

gauge and covers overall the range from atmospheric pressure down to  $10^{-11} \text{ mbar}$  total pressure.

The partial pressure inside the injection kicker chamber is measured by a mass spectrometer with an open ion source making it possible to detect all gas components with atomic mass units from 1 up to 200 and also used to detect small leaks. Two pneumatically actuated angle valves are foreseen to provide the possibility to separate the tank from the roughing pump and the portable pumping unit as well.

To heat up the system heating jackets well adapted for each component were designed as well as a vacuum control unit together with a control cabinet was developed.

The test bench with all vacuum components, the heating jackets and the control cabinet is shown in figure 3.



Figure 3: Test bench for the injection kicker test tank.

## DESCRIPTION OF PRELIMINARY TESTS

The purpose of the tests is to define the correct temperature rise time for the system whereas the internal temperature differences between the components are not higher than 50 K. Therefore each heating jacket can be controlled individually and the temperature inside the vacuum tank is controlled by the six thermocouples (see figure 4). This is important because of the high sensitivity of the magnets to higher temperatures. In parallel the total pressure profile is measured.

After roughing and pumping with the ion getter pump down to a pressure better than  $10^{-9} \text{ mbar}$  the heating procedure can be described as follows. Each heating jacket is heated in parallel depending on their position up to  $80^\circ \text{C}$ ,  $170^\circ \text{C}$  or  $250^\circ \text{C}$ . The gradient is smoothly matched to the inner temperatures of the inserts. Figure 5 shows the measured temperature profile during heating of the system.

Since there is no sufficient information regarding the outgas rate of the ferrite magnets in UHV the tests have to

be repeated together with the magnets inside the tank. For that purpose four additional thermocouples are pre-installed for monitoring the magnet temperature inside the tank (see figure 4).

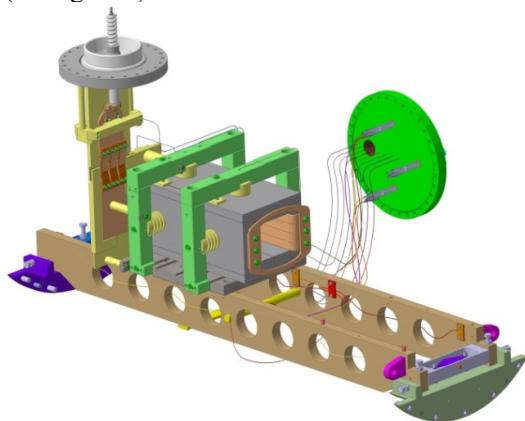


Figure 4: position of the thermocouples on the support frame, one magnet shown.

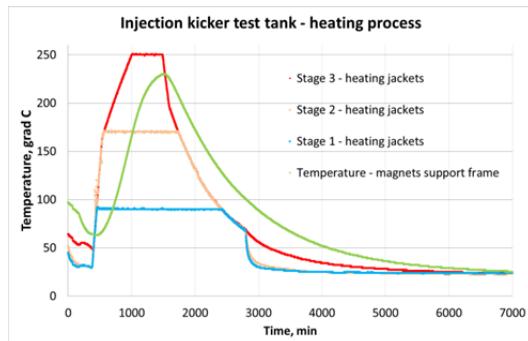


Figure 5: Measured temperature profile during heating up.

As soon as the ferrite magnets are produced and tested in atmospheric pressure the same test would be repeated this time with magnets and the results could be compared. The tests are already on-going at the facility of the contractor. It is expected to deliver the first results not later than the end of the year 2017.

## VACUUM SYSTEM OF THE INJECTION KICKER

The injection kicker section (figure 6) consists of two kicker tanks, each housing the ferrite magnets, two specially designed cone-shaped connectors, two pumping crosses for the vacuum pumps, gauges and the mass spectrometer as well as a compensating bellow between the tanks. Metal gate valves separate the injection kicker from the other vacuum sections.

## CONCLUSION

The injection kicker test tank provides the possibility to perform many experiments in order to find the best technical solutions for the different components of the kicker, e.g. vacuum pumps and gauges, control cabinet, heating jackets, magnets and pulser. So far thanks to the prototype a vacuum pumping as well as a heating concept for the HESR injection section are completely defined and experimentally proven. It was possible to analyse and compare experimental data with calculated values and to optimize and improve some of the equipment parameters providing a state of the art solution for the HESR.

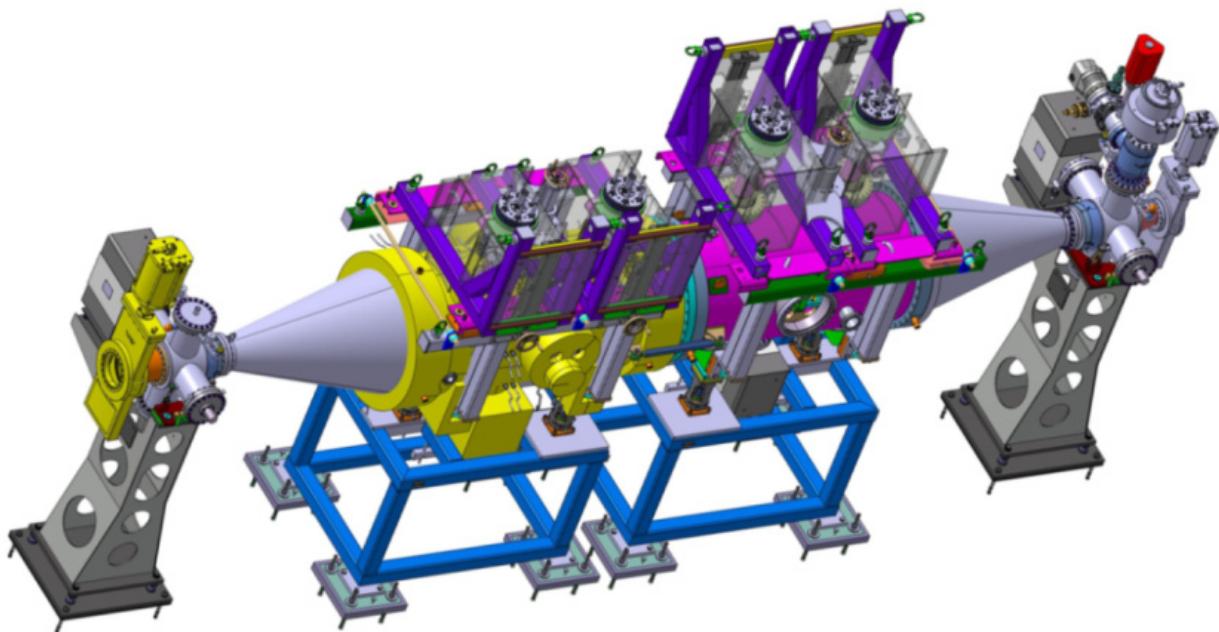


Figure 6: 3D view on the injection kicker vacuum section of the HESR.