Document Title	**Detailed Specifications of Sputter Ion Pumps for the Vacuum Systems of the FAIR and GSI Accelerator Facilities**
Description	This document describes the technical requirements of Sputter Ion Pumps which will be used at the FAIR Accelerator Facility
Division/ Organization	VAC
Field of Application	FAIR GmbH and GSI GmbH

Document History

Version	Prepared/Checked by	Date	Date of Release	Comments
V1.1	Phe Suherman	23.01.2017		Creation of a new document and changing most of the contents, based on older specification created in 2015
V1.2	Phe Suherman	19.06.2017		Feedback from CSVS Group
V1.3	Phe Suherman	20.07.2017		Feedback from CSVS Group
V1.3a-b	Phe Suherman	09.08.2017		Feedback from CSVS: Change from Detailed Specifications to Common Specifications, Addition of cable information for a suitable connector on the pump
V1.3c	Phe Suherman	26.07.2019		Feedback from VAC: Back to Detailed Specification, New Template from QA, Simplification the specification due to the use for “standard component”, so many sections are deleted
V001	Phe Suherman	11.11.2019		New filename
V002	Phe Suherman	11.12.2019		Feedback from VAC: add information of connectors and cables.
V003b	Phe Suherman	13.02.2020		Feedback from VAC: delete the quantity and PSP codes, delete all the information of connectors and cables, add section for “Packaging”, use of new template (V006)
V004a	Phe Suherman	09.03.2020		Feedback from VAC: change Table 1, delete some abbreviations, modification on some vacuum performance
V005b	Phe Suherman	31.03.2020		Feedback from VAC: addition of ISO KF flanges and doube-ended flanges in Table 1, Changing of SAT and Documentation procedure
V006b	Phe Suherman/Andreas Kraemer	14.04.2020		Feedback from VAC: correction of some abbreviations, some dimension and pumping speed changes in Table 1
V007	Phe Suherman	20.04.2020		Feedback from VAC: corrections of some mistyping in Table 1, correction of ISO Standard compliance, removal of some items in Table 1, some dimension changes in Table 1
V008	Phe Suherman	27.04.2020		Final version for EDMS

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Abstract

The FAIR accelerator facility shall consist of a heavy ion synchrotron SIS100, storage rings (Collector Ring (CR) and High-Energy Storage Ring (HESR)), a proton Linac (p-Linac), an anti-proton separator (pbar), a Superconducting Fragment Separator (Super-FRS) and connecting/transport beam lines (High Energy Beam Transport (HEBT)). The existing accelerator facility of GSI will serve as the injector for the FAIR accelerator via the Universal Linear Accelerator (UNILAC) and heavy ion synchrotron SIS18. The remaining GSI acceleratory facility, i.e. high energy beam line (HEST) and the experimental rings (Experimental Storage Ring (ESR) and Cryring), will operate in parallel with the FAIR accelerator facility.

During operations of the GSI/ FAIR accelerator, the majority of the beam lines will be pumped solely with sputter ion pumps (SIPs), after an initial pumping by turbo molecular pumps and roughing pumps. This document describes detailed specifications for the sputter ion pumps intended for use at the GSI and FAIR accelerator facilities.

Table of Contents

1. Purpose and Classification of the Document

The objective of this document is to provide comprehensive technical specifications for production and delivery of sputter ion pumps for the FAIR and GSI accelerator facilities. Basic and common technological issues, including properties and descriptions of pumping features are specified in this document. In this document, FAIR GmbH and GSI GmbH are referred to as the “Company” and the supplier is referred to as the “Contractor”. This document only represents a “Technical Part” of the contract. All commercial and organisational conditions are not considered.

2. Abbreviations, Terms and Definitions

Abbreviations	Definition
CE	European Conformity
CID	Component Identification
CR	Collector Ring
EDMS	Electronic Document Management System
ESR	Experimental Storage Ring
FAIR	Facility for Antiproton and Ion Research
FAT	Factory Acceptance Test
GSI	Gesellschaft für Schwerionenforschung
HEBT	High Energy Beam Transport
HESR	High Energy Storage Ring
HEST	Hochenergiestrahlführung
p-bar	Antiproton Separator
p-Linac	Proton Linear Accelerator
QA	Quality Assurance
QR	Quick Response
SAT	Site Acceptance Test
Super-FRS	Superconducting Fragment Separator
SIP	Sputter Ion Pump
SIS18	Schwerionensynchrotron 18
SIS100	Schwerionensynchrotron 100
RGA	Residual Gas Analyser
RoHS	Restriction of Hazardous Substances
TG	Technical Guideline
UNILAC	Universal Linear Accelerator

3. Scope of the Technical System

3.1. System Overview

The Sputter Ion Pumps (SIPs) will be used to generate and maintain the operating pressures required in the FAIR and GSI accelerators. Depending on the specific beam line, the required operating pressure can vary from 10^{-8} mbar to less than 10^{-10} mbar. While in some beam lines, SIPs are used solely to generate the required pressures, other beam lines use SIPs in combination with other type of pumps. Preliminary pumping is performed by means of mobile pumping stations, consisting of turbo molecular and roughing pumps. The SIPs are then used once the required starting pressure has been reached.

3.2. Scope of Delivery

A general specification of SIPs required for both FAIR and GSI accelerator facilities is shown in Table 1. The required pumping speed, the flange type, and maximum dimensions of the SIPs are listed in the table. The pumping speed shown in Table 1 refers to the saturated state. The types ending in “D”, as listed in the first column in Table 1, refer to “double-ended” flanges or additional side ports.

Each SIP must be delivered complete with the necessary parts, such as connectors, feedthroughs, and other fittings, that enable the pump to function as an operable unit. The SIPs should not be equipped with an internal heater for bake-out. The required controller to operate the pump and its associated cable are not a part of the delivery. However, the Contractor must provide information about the connector/feedthrough on the pump side.

The SIPs are preferably current standard catalogue items. If new or recently developed SIPs are offered, which are not standard items in the supplier's catalogue, the Contractor must be able to demonstrate that those SIPs have the same characteristic as the standard SIPs.

Table 1 List of SIPs for the FAIR and GSI Accelerator Facilities

Types	N_2 Nominal Pumping Speed (l/s)	Ar Nominal Pumping Speed (l/s)	Flanges	Maximum Dimension (mm) (L x W x H)
50CF	≥ 50	≥ 35	DN63CF	310 x 138 x 235
50CF_D	≥ 50	≥ 35	2 x DN63CF	310 x 138 x 260
150CF	≥ 100	≥ 70	DN100CF	390 x 130 x 380
150CF_D	≥ 100	≥ 70	2 x DN100CF	390 x 130 x 460
150ISOK	≥ 100	≥ 70	D100 ISO-K	390 x 130 x 380
150ISOK_D	≥ 100	≥ 70	2 x DN100 ISO-K	390 x 130 x 460
200CF	≥ 170	≥ 60	DN100CF	430 x 250 x 290
200CF_D	≥ 170	≥ 60	2x DN100CF	430 x 250 x 330
300CF	≥ 240	≥ 150	DN160CF	450 x 250 x 350
300CF_D	≥ 240	≥ 150	2x DN160CF	450 x 250 x 390
300ISOK	≥ 240	≥ 150	DN160ISO-K	450 x 250 x 330
300ISOK_D	≥ 240	≥ 150	2x DN160 ISO-K	450 x 250 x 390
500CF	≥ 400	≥ 250	DN160CF	460 x 310 x 530
500CF_D	≥ 400	≥ 250	2x DN160CF	460 x 310 x 570
800CF	≥ 650	≥ 270	DN200CF	500 x 350 x 700
8500CF_D	≥ 650	≥ 270	2x DN200CF	500 x 350 x 750
1000CF	≥ 900	≥ 550	DN250CF	630 x 510 x 720
1000CF_D	≥ 900	≥ 550	2 x DN250CF	630 x 510 x 830

3.3. Spare Parts

The Contractor has to prepare a detailed list of spare parts needed to ensure only short periods of downtime in case of failures. The following spare parts, of the required quality, are essential to be kept in-stock for SIPs:

- Pump elements (element cells, ceramic insulators)
- Feedthroughs

4. Technical Specification

4.1. Vacuum Performance

- The SIPs must be of the triode type.
- The operating range of the SIPs must cover a pressure range between 10^{-11} and 10^{-3} mbar.
- The SIPs must be able to start operating at a pressure of 10^{-3} mbar, without any problem of instability during the start-up phase.
- The SIPs (including the feedthrough) must be bake-able at a temperature of 300°C or higher for more than 100 hours and be able to withstand at least 100 bake-out cycles, without removing the magnet.
- The SIPs must be capable of operating for a minimum of 70,000 hours at $1x10^{-6}$ mbar (N_2 equivalent) without failure or a reduction in the pumping speeds.

4.2. Pump Flanges

- The dimensions of the CF-type flanges for the SIPs must be compliant according to ISO 3669.
- The dimensions of the ISO-K-type flanges for the SIPs must be compliant according to ISO 1609.
- The flanges must be made exclusively from hot forged round blanks or forgings of austenitic stainless steel grades typically used in UHV technology.

4.3. High Voltage Feedthrough

The feedthrough on the SIPs must fulfil the following criteria:

- The feedthrough on the SIPs must be a single pin Fischer type connector for high voltage application of at least 8 kV, with a mounting flange of the DN16CF type.
- The body/outer part of the feedthrough must be made of austenitic stainless steel, which is typically used for UHV technology.
- The feedthrough must contain a built-in safety function, i.e. equipped with an interlock system, which immediately shuts down the high voltage, when the connector to the feedthrough is removed from the pump.
- The feedthrough must be able to withstand a high level of radiation of $4x10^4$ Gy. The Contractor must specify the allowed radiation level.
- The feedthrough must be designed in such a way, that any force placed on the connector is not transmitted to the ceramic/metal seals.

- The current generated from the SIPs will be used to read and monitor the pressure in the beam line vacuum system, as well as for the control of the interlocks. The high voltage insulation of the pumping elements in the SIPs must be optimised, to guarantee low leakage currents due to the deposition of conductive material on insulators or field emitting tips over long periods of operation.

4.4. System Environment and Constraints

Apart from fulfilling the technical requirements, the SIPs must conform to other constraints that will exist at the FAIR and GSI accelerator facilities. These constraints may involve:

- The dimension of the SIPs must fit to the allocated space of the beam lines (see Table 1).
- All equipment referred to in this specification shall be in full compliance with the European Safety Regulations and German High Voltage Regulations.

5. Quality Assurance (QA), Tests and Acceptance

5.1. Quality Assurance System of the Contractor

- The Contractor shall be certified according to ISO 9001 or equivalent.
- All the equipment and tools required for testing and inspection must be calibrated and certified with a calibration certificate (ISO/EN/DIN certificate).
- The Contractor shall deliver a significant track record concerning the manufacturing, supply, and maintenance of the pumps and all relevant components.

5.2. Factory Acceptance Test (FAT)

All FAT results must be carefully recorded and documented. The documentation from the FAT must be submitted to the Company, at the latest one week prior to delivery. The shipment may only commence after the agreement with the Company.

The following FAT must be carried out **on each SIP**.

- All pump components and materials shall be visually checked for damage. Knife edges and vacuum sealing interfaces shall be examined in detail to ensure that there is no defect that may cause vacuum leaks.
- Functional and electrical test must be performed at maximum operating voltage.
- A leak check must be performed. A leak rate of ≤ $1x10^{-10}$ mbar·l/s must be proven. The Contractor shall provide a proposal for the leak test procedure.

The following additional FAT must be carried out on at least **one randomly selected SIP of each batch.**

- A residual gas analysis must be carried out during normal pump operation. The spectra from the Residual Gas Analyser (RGA) shall show no evidence of heavy hydrocarbons with masses greater than 44 amu.

The Contractor may offer other types of tests performed on randomised samples of SIPs. The Company reserves the right to witness any tests at the Contractor´s or Subcontractor´s site.

5.3. Site Acceptance Test (SAT)

The SAT shall be carried out at the Company's site, which may involve some tests that have been conducted for FAT.

- The Company may carry out any test on random samples to ensure complete compliance with the present Detailed Specification.
- Failures occurring during any of the aforementioned tests shall require rectification by the Contractor as part of the contractual conditions. Successful completion of these inspections and tests shall be the basis for final acceptance.

6. Labelling

Each pump shall be labelled with a CID number and QR code. The label shall be a metal tag securely attached to the pump, or permanently engraved on the outer surface of the flange. The CID number and the QR code will be provided by the Company.

7. Packaging and Delivery

Once each SIP has successfully passed the FAT, it must be packaged carefully and protected in such a way that it retains the vacuum condition during shipment, and remains clean and free of damage. It is recommended that each SIP is wrapped in a weather tight and water-proof packaging. The delivered SIPs must be accompanied by operating manuals in both German and English, and in both paper and electronic formats. The transport of the SIPs must be conducted in such a way that it retains the shape, original conditions, and cleanliness.

8. Warranty

A minimum downtime and availability of the spare parts of the pumps have to be assured, for an operation period of at least 10 years. In addition, the Contractor has to guarantee that the pumps can be stored for a minimum of 5 years after delivery and still perform as specified. The compliance with these basic rules has to be proven and documented by the Contractor.

9. Documentation

All documentation will become property of the Company and must be written either in German or in English. The documents must be delivered in electronic format in the following way:

- The documents shall be uploaded to the web-based/electronic document management system (EDMS). The Company will provide an EDMS account number to the Contractor for uploading and organising the documentation in the EDMS.
- Details about the organisation of the documents within the EDMS shall be agreed upon by the Company. The Company will provide an appropriate project folder structure in the EDMS.
- In agreement with the Company, the Contractor will initiate the release procedures for each set of documentation.
- No set of documents will be accepted by the Company, which has not been fully released and approved in the EDMS.

The documentation shall include the following:

- FAT documentation
- Operating Manuals, including troubleshooting procedures
- Declaration of conformity (e.g. CE, RoHS)
- Material and Process Related Documentation and Certificates
- Information on the magnetic stray fields of the SIPs
- 2D drawings and 3D-models in stp-format