DESIGN AND TECHNICAL FEATURES OF THE VACUUM SYSTEM AT COSY

H.Stechemesser*, W.Bertram*, K.Döring*, A.Hamacher**, H.Jaegers*
H.B.Müller*, J.Zeumann*, A.Zumloh*, G.Riepe**
Kernforschungsanlage Jülich GmbH
*Zentralabteilung Allgemeine Technologie
**Institut für Kernphysik
D-5170 Jülich, Fed.Rep.Germany

Abstract

The state of design and technical features at the COSY Vacuum System is according to the project /1/ in the status of transposition from given requirements and specifications into a fixed technical design. Therefore limiting conditions are analysed and matching solutions studied, designed and tested.
One point of special interest of COSY Vacuum System is the lay-out of the circular and rectangular cross-sections and the use of Inconel 625 for parts of the rectangular beam lines. An other point of interest are requirements related to the bake-out procedure at 300 °C, like elliptic compensators with included rf-grids, a roller guide system to prevent expansion of the radius of curvature and fundamental the selection of a sufficient flange system.

COSY Vacuum Requirements

The vacuum pressure in the COSY beam line is defined to be 10^{-10} mbar or better, measured as total N_2-equivalent. As a consequence all components of the vacuum chamber are bakeable up to 300 °C and the use of none metallic materials is reduced to ceramics only for electrical insulators.
The COSY vacuum beam line can be divided by gate slide valves into 8 sectors. Each sector can be baked out separately.
The high frequency of the COSY beam ask for special design features to avoid major rf-disturbtions. So all cavities, pump parts, bellow flanges etc. shall be shielded by special rf-grids.

Specifications

- Design pressure: $< 10^{-10}$ mbar (N_2)
- Length of vacuum beam line: 184 m
- Vacuum chamber free cross-section: Ø 150 mm or ▭ 60x150 mm
- Pumping at higher pressures and bake-out procedures: 1 turbomolecular pump (330 $l \cdot s^{-1}$) per sector (8 sectors)
- Pumping at lower pressures:
  - 71 sputter ion pumps (triode typ) with a total of 13.000 $l \cdot s^{-1}$ (N_2), gives about 70 $l \cdot s^{-1}$ per meter beam line
  - 112 titanium sublimation pumps with a total of 170.000 $l \cdot s^{-1}$ (N_2), gives about 900 $l \cdot s^{-1}$ per meter beam line
- Material:
  - chambers and components from stainless steel SS 316 LN or Inconel 625
  - flanges with metallic seals, type CF or alternatives
  - valves metallic sealed
  - treatment prior to installation by standard UHV cleaning procedures and vacuum firing at 950 °C
  - outgasing rate $< 10^{-12}$ $mbar \cdot l \cdot s^{-1} cm^{-2}$
  - bake-out in situ at 300 °C for 48 h
- Pressure measurement:
  - down to 10^{-10} mbar: Pirani and Penning
  - down to 10^{-12} mbar: ionisation gauges
  - gas analyser: quadrupol mass spectrometers

Vacuum Chamber

The optical free cross-section of the COSY beam line is of two different shapes:

- circular 150 mm in the telescop sections
- rectangular 60x150 mm in the bending sections

The circular vacuum chambers are sub-divided into mounting length of about 3 meters and fitted out with metallic sealed flanges. Material is chosen SS 316 LN.

The rectangular vacuum chamber is necessary inside the dipol gaps /2/. Outside of the dipol gaps the cross-section could be changed to the cheaper and in the interest of vacuum aspects better round one, but this would need always a long and smooth transition zone to avoid RF-interferences of the beam /3/. Therefore most of the beam line chambers of the bending section are rectangular. To achieve a minimum wall thickness for the vacuum chamber inside the dipol magnets Inconel 625 was chosen as material. The thickness of the upper and lower chamber plate is calculated to 2,5 mm, the side plates are increased to 4 mm to get a certain mechanical stiffness.
A first 1200 mm long dipol test chamber made from Inconel 625 and fitted out with CF-type flanges Ø 200 mm was manufactured to check previous welding and treatment specifications. In a pump down test with pumps of chosen type and pumping speed and after one 300 °C heating cycle of 48 hours a final pressure of $3x10^{-11}$ mbar was obtained.

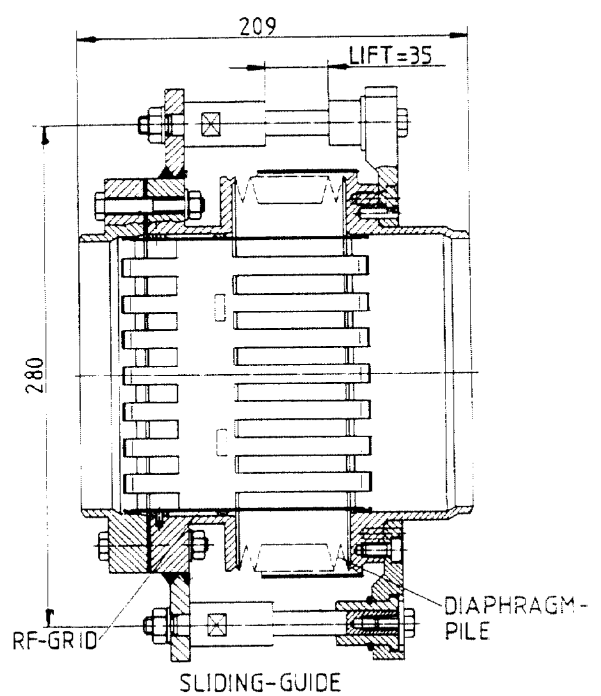

Fig.1 Diaphragm-Compensator with inserted rf-grid

Compensators

The requirement for baking the vacuum chamber of COSY has the consequence of thermal expansion. By heating up the system to 300 °C the axial elongation will be about 3,6 mm/m for SS 316 LN and about 4,6 mm/m for Inconel 625. To avoid uncontrolled axial forces compensators and matching fixed section points have to be arranged in the course of COSY ring. As a speciality these compensators needs an inner rf-shielding grid (fig.1).
In the straight telescop sections the diaphragm type compensators are of circular cross section and equiped with circular connection flanges.
In the bending sections of COSY the situation is different. On the one hand the cross section of the vacuum chamber inside the dipol magnets is rectangular, on the other hand to save space the compensators as well as flanges have to be placed inside the gaps between the coil ends close to the dipol yokes. To fit into this gap a hight of nominal 190 mm can only be used and consequently the compensator has to be of elliptic cross section.
The integrated rf-grid inside the compensator is always slotted to allow a sufficient vacuum pumping of the large diaphragm pile area.
The rf-grids are designed as a spare part and can easily be changed.
A special test facility is under construction to test the reliability of the diaphragm pile as well as the function of the sliding guides, but special the electrical conductivity of the rf-grid sliding contacts. Test will be carried out under vacuum for 100 cycles at 300 °C and for a glide-path length of 35 mm. The electrical conductivity will be measured continuously.

Universal Pump Terminal

To achieve a most steady pressure profile along the COSY vacuum ring likewise the vacuum pump positions must be distributed most steadily. With regard to different gas yields on different beam line positions also different pumping capacities by arranging certain types and numbers of pumps have to be installed on certain pump positions. To allow a combination of up to 4 pumps at one pumping position an universal pump terminal was designed. The universal terminal consists of a basis tubular body-tube, which contains a large tubular rf-grid cylinder for a minimum reduction in pump speed. The basis body can be equiped with up to four pump parts. In fig.2 a version in the outfit with three integrated titanium sublimation pump-bodies and one connection port for a sputter ion pump is shown.

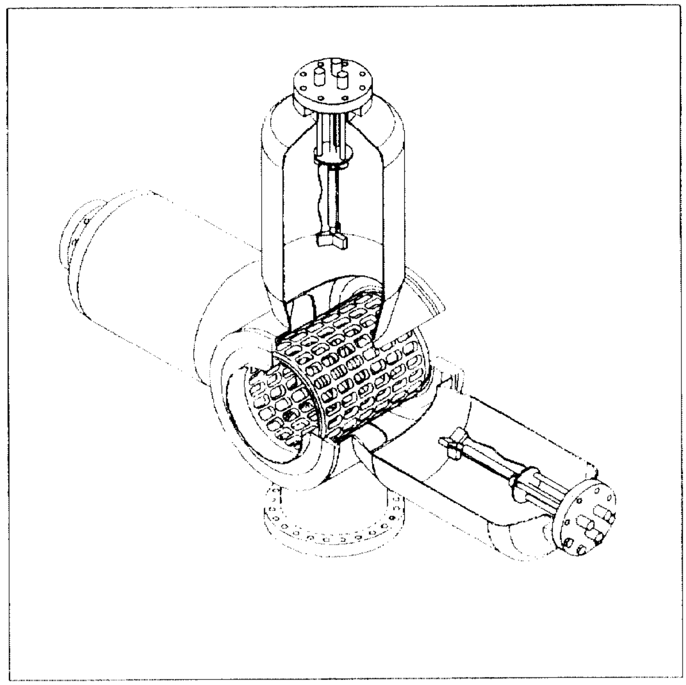

Fig.2 Universal Pump Terminal with large integrated cylindrical rf-grid

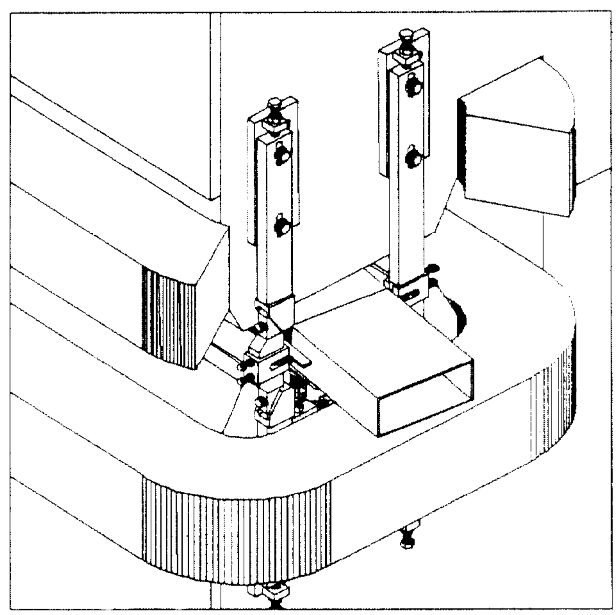

Fig.3 Roller Guide Traverses mounted on the dipol magnet yoke

Guide Traverses for Vacuum Chamber

In the bended sections of COSY the vacuum chamber fit so tight into the quadrupoles, that no radial movement can be allowed due to thermal expansion in case of baking out. Special roller traverses (fig.3), mounted on both ends of the dipol magnet yokes, block any radial way but let free the tangential direction.
It was shown in a finite element calculation, that the radial forces due to thermal induced bending moments can be controlled by roller bearings, running on special straps on the chamber walls.
In fig.4 the resulting radial forces on four selected roller-bearing positions are given. At this arrangement of bearings the maximum radial displacement in the area of the two included quadrupols is less than 0,5 mm.

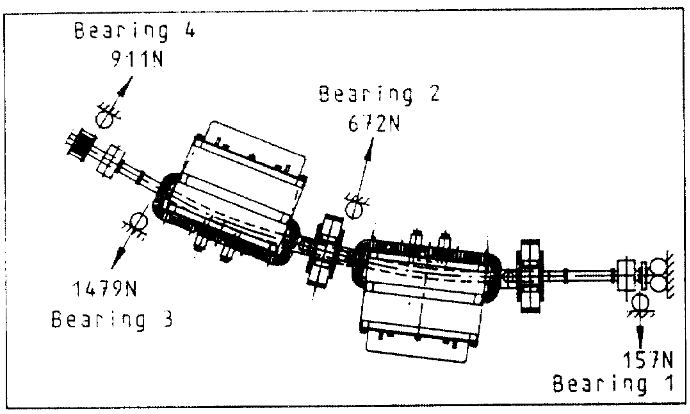

Fig.4 Arrangement of force loaded guide bearings on a bended vacuum chamber section

Flange Test Facility

The blocked thermal expansion in radial direction procedures in the vacuum chamber high bending moments as well as axial forces, which loads also the flanges mounted in the coarse of the beam line. This is an unusual stressing of UHV-flanges. In a special test facility (fig.5) different types of flanges are treated under simulated conditions to select a sufficient type of flange, special a flange of rectangular cross-section for the bending section.

Test Specifications

heat up and cool down rate:	50 $K \cdot h^{-1}$
heating period:	48 h/2 h
max. traction:	2000 N at 20°C
max. compressive force:	7000 N at 300°C
bending moment:	0 Nm at 20°C
	1200 Nm at 300°C

Each flange typ is treated for 10 heating cycles, whereof the first heating period last for 48 hours, the following nine cycles last each for 2 hours.
Two tested flanges Ø 200 mm, type CF, failed each in the first cycle during the cool down phase.
A new type of metallic flat seal flange Ø 150 mm (VATSEAL VAT Haag, Swiss) fulfilled the test without any leakage. Sealing material was copper with silver coating.

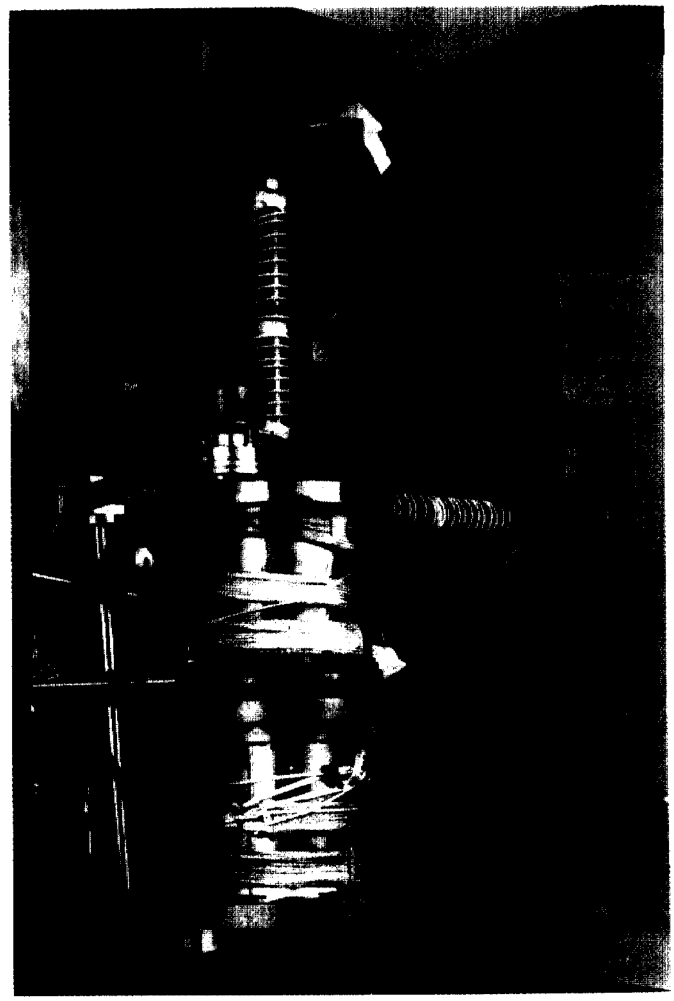

Fig.5 Test Facility for flange testing under thermo-cycling as well as force- and bending treatment

/1/ U.Pfister, "Status of COSY-Jülich", presented at European Particle Accelerator Conference, Rome, June 7-11, 1988

/2/ U.Bechstedt et.al., "Magnets and Power Supplies for COSY", presented at European Accelerator Conference, Rome, June 7-11, 1988

/3/ G.Berg et.al., "RF System of COSY Jülich", presented at European Accelerator Conference, Rome, June 7-11, 1988