Mechanical Design Philosophy and Construction of the Amsterdam Pulse Stretcher Ring AmPS

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Abstract

The AmPS ring is a 900 MeV electron pulse stretcher and storage ring with a circumference of 212 m. The ring will be completed early 1992. Apart from the UHV envelope for the beam the ring contains a large quantity of high precision components, e.g. 166 magnetic elements, 50 beam monitors, an r.f. cavity, 2 injection kickers, etc. An overview is presented of the design philosophy and the construction with emphasis on the vacuum components as well as on the alignment system and on the supports for the magnets and the monitors. The material of the vacuum components has been chosen on the basis of the requirement that outgassing, synchrotron radiation induced desorption, residual radioactivity and magnetic permeability should be as low as possible. The vacuum chambers in the bending sections therefore are fabricated from stainless steel 316 LN with a very low cobalt content. An advanced welding and cleaning technique has been developed to avoid the inclusion of impurities. The vacuum pump capacity and the pump distribution along the ring has been optimised as function of local conductances and outgassing. With eighty 60 l/s ion pumps a net pump capacity of 20 l/s/m should be obtained.

Vacuum aspects

The specifications of the vacuum system were presented in [1]. The determining factor for the vacuum pressure is the quantum lifetime of one hour for a stored beam at the lowest operational energy of 300 MeV yielding a pressure of < $1x10^{-8}$ mbar.

The vacuum pressure should be achieved with lumped Starr cell iongetter pumps only. It was calculated that a total pumping speed of 4320 l/s is required.

With respect to the article [1] the construction of the vacuum chamber and the positioning of the pumps has been changed. The overall advantage of using an antechamber to trap the gas desorption caused by the synchrotron radiation appeared to be rather small because of the slot structure required at the exit port.

Two mobile units each with a turbomolecular drag-pump as main pump and a membrane pump will be used as an oil-free roughing pump. The ring consists of 5 separate vacuum sections. Each section can be isolated by rf compatible straight through valves (VAT). All metal angle valves allow to connect the turbo pumps to the ring. A lifting mechanism brings the pump unit in position after which the unit is coupled directly to the ring without using a bellows connection. A quadrupole mass spectrometer (Balzers QMA 125) is integrated in the unit to leak chase or analyse vacuum problems.

Prior to assembly all parts are chemically cleaned. The assembled parts are then baked for 24 hours at about 250° C in a vacuum oven. Venting with dry nitrogen provides a good surface condition for the vacuum parts before installation. At this moment, March 1992, three of the four 22 m long curves of the ring have been evacuated and are at a pressure of $2x10^{-9}$ mbar.

Conflat type seals are used where ever possible because of the reliability.

Mechanical aspects

Vacuum chamber configuration

Optical studies [2] and safety margins for closed orbit errors determined the beam stay clear dimensions of the vacuum enclosures. The feasibility of the fabrication was then to be optimised within the budget constraints. In the curved sections the beam stay clear in the vertical direction is 32 mm and 65 mm in the horizontal direction.

Space for ion clearing electrodes increased the vertical inner dimension of the enclosures to 40 mm. The vacuum wall thickness could be reduced to 2 mm because stainless steel 316 LN [1] has been chosen instead of aluminium. Including a 1 mm clearance between the chamber and the magnet poles the magnet gap became 45 mm (fig. 1).

In the straight sections the quadrupole magnets have a bore of 95 mm. So circular pipe of 94 mm was suitable, except for the extraction and the injection region where additional space is required because of large beam excursions at these locations. The injection and extraction septa are described in [3].

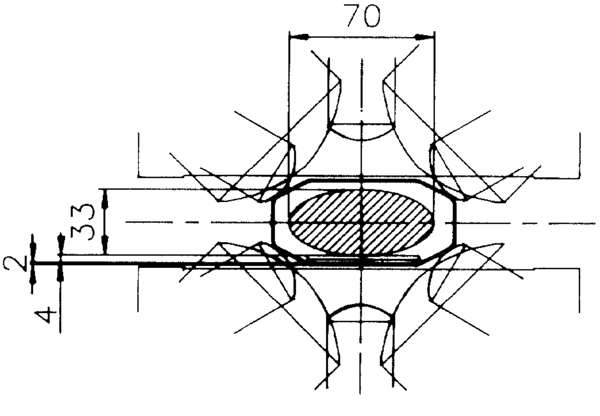

Fig. 1 The boundary conditions for the vacuum chambers

Alignment

The alignment accuracy of the magnetic elements of the ring were determined by beam optical calculations. These studies resulted in a positioning accuracy requirement of 0.1 mm for the quadrupole and sextupole magnets and 0.5 mm for the dipole magnets.

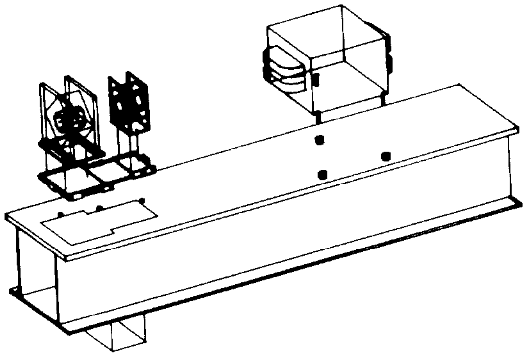

Fig. 2 Positioning and adjustment supports optical elements

All beamline components are aligned (fig. 2) and mounted on so called strongbacks. For the curved sections 16 strongbacks are use, each consisting of a heavy and rigid steel construction weighting 6 tons. The surface of these supports are milled within a tolerance of 0.1 mm. Numerical machined holes in the supports are positioned with an accuracy of < 0.1 mm. The bending magnets are supported and adjusted in height by three bolts. These bolts fit in accurately positioned holes in the magnet. The other components are pre-aligned on x y z tables. By means of a laser alignment system the beamcentre line is translated to an external reference line 50 cm above the beamline. This way the cells are aligned as one unit in the reference line in the tunnel (fig. 3).

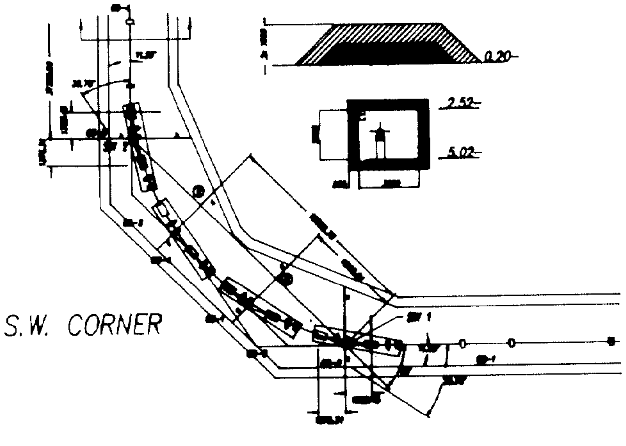

Fig. 3 Reference lines in the curved sections

A spare strongback fitted with exactly the same holes and reference points is available to allow easy reinstallation of repaired or modified components.

Manufacturing

Vacuumchambers

To minimise the costs the beam pipe in the curved sections is made by folding stainless steel sheet with a thickness of 2 mm. 316 LN material was chosen to obtain a low permeability remaining stable after machining and welding. The influence of welding on the magnetic properties of the material was compared for 304L, 316L and 316 LN by measuring the μ with a magnetic permeability meter (Dr. Förster Institut). The material 316 LN appeared to be much more stable with respect to this property. Depending on the intensity of welding the μ went to 1.1 or even 1.2 for the first two types of stainless steel. Baking the material to about 400° C almost did recover the 1.01 starting position. The increase of μ_r was much lower for the 316 LN (< 1.01). After annealing the value became 1.004.

Fig. 4 The different stages in folding the vacuum pipe

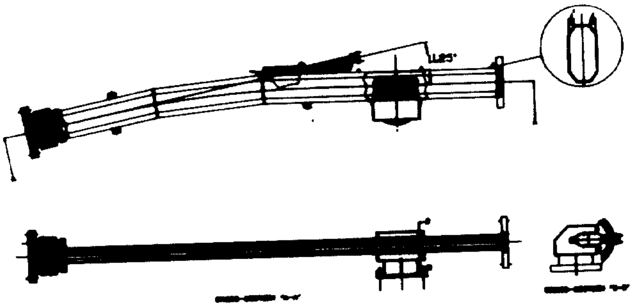

Fig. 5 The segmented vacuum chamber with integrated pump out

The way the vacuumchambers are folded requires only one closing weld (fig. 4). Argon arc welding was performed on a lathe semi automatically for the long seems while handwelding was used for the short welds. Backing with argon gas was done consequently in order to prevent oxidation on the inner surface. Inner welding was performed where possible. When there was no other way a completely through weld was applied to avoid gas enclosures in the vacuum system.

The curve in the dipole magnets was approximated by three straight parts which are welded together (fig. 5). Each curve contains 8 dipole vessels. In total 5 dipole vessels have a synchrotron light port for monitoring purposes. The heat load generated by the synchrotron radiation (3.5 kW at 900 MeV and 200 mA in total for the whole ring) can be handled without cooling. Nevertheless at the points where the radiation is extracted the mechanical tension could be high. Therefore a water cooled copper bloc has been soldered on the stainless steel wall.

In the straight sections 316L stainless steel is used because no permeability deteriorating welds were required in the direct vicinity of the magnets. The Conflat sealing flanges are welded to the beampipes. As no field welds were made because for cleanliness reasons all magnets can be splitted in halves to allow the installation of the vacuum pipes.

The stripline type position monitors appeared to be very sensitive for higher order rf modes generated by the beam. Therefore rf damping of these modes has been incorporated using aluminium oxide pipes coated with resistive paint [4]. The desorption properties of this material were measured [5] and compared to the desorption of an alternative absorber consisting of ferrite. Roughly the ferrite desorption is 10 times higher than the Al_2O_3 desorption. After 1 week of outgassing a desorption of 1×10^{-9} mbar $l/s/cm^2$ was measured for the Al_2O_3.

The clearing electrodes are made as smooth as possible and consist of a button of Ø 40 mm 2 mm above the bottom of the vacuum chamber (fig. 6).

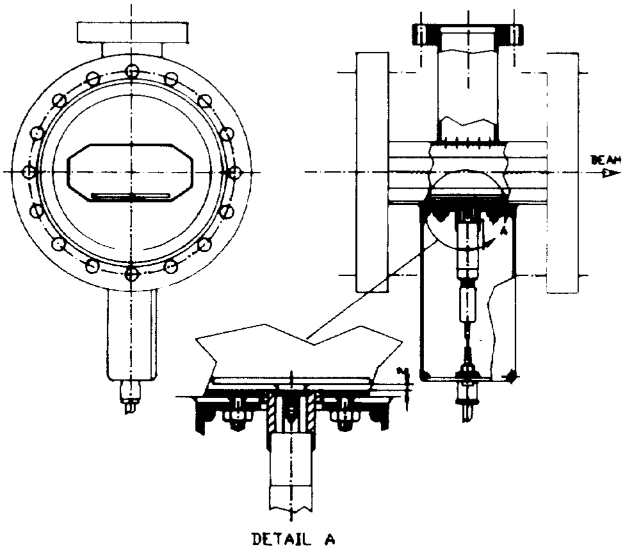

Fig. 6 Clearing electrode

The pump out design was optimised for maximum vacuum conductance and low rf impedance. At the locations where pumps are connected the vacuum pipe is perforated and a housing is build around that location such that the total conductance is twice as large as the conductance of the connecting pipe to the pump.

In order to bridge the slits in the Conflat flange joints a special spring contact shielding was developed that is mounted together with the sealing ring (fig. 7).

An rf shielding sleeve is fitted in each beampipe bellows. The sleeves were manufactured by photo-chemical etching.

Fig. 7 Rf shielding Conflat flange

Acknowledgment

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References

1) A.P. Kaan e.a. Vacuum/vol. 41/numbers 7-9, 1890
2) R. Maas e.a., Internal Nikhef report: AmPS 88-11
3) A. v/d Linden e.a., This conference.
4) D. Moffat et al., "Use of Ferrite-50 to Strongly Damp Higher Order Modes" Proc. IEEE Particle Accelerator Conf. San Francisco, CA, May 1991
5) Internal NIKHEF report 'Outgassing of damping material'