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MECHANICAL DESIGN OF THE BEAM CURRENT TRANSFORMERS FOR THE HERA PROTON RING

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Abstract

The warm sections of the HERA proton ring will be equipped with three DC and one combined fast and integrating current monitor. The toroids and associated electronics are of the Klaus Unser type [1]. Vacuum chambers with a DC gap, good RF properties and a maximum bakeout temperature of 300°C are designed. The toroids are completely passively cooled such that the toroid temperature will not exceed 70°C even for tunnel temperatures of 50°C. The DC monitor also has an extra 5-layer magnetic shield to allow high absolute accuracy in a varying magnetic environment.

I. INTRODUCTION

HERA is a complex of an 820 GeV proton accelerator and a 30 GeV electron accelerator with three common interaction regions [2]. Both rings share the 6.3 km long tunnel. The HERA proton ring itself consists of four "warm" straight sections operating at roughly tunnel temperature and the "cold" arcs with their superconducting magnets in a continuous cryostat. All current monitors are placed in the warm section and all are subject to vacuum bakeout of temperatures up to 300°C. The proton ring will contain a maximum of 210 bunches in 220 rf buckets. Each bunch consists of a few times 10^8 up to 10^{11} protons. The bunches will be between 0.3 m and 3 m long.

The current monitoring system has to supply the following information: bunch shape, fill status of the different buckets, total beam current and beam lifetime. The bunch shape is measured by two coaxial monitors with extremely wide bandwidth, the bucket fill status is measured by fast and integrating current transformers (FCT & ICT) and the last two properties are measured by up to three precision DC parametric current transformers (PCT). All three types of transformer monitors are based on toroids. The toroids with their associated electronics were developed at CERN [1] and built by Bergoz in Gex, France for us.

In the following the design of the beam current transformers shall be described. They consist of the vacuum pipe with its DC gap, two heating jackets, thermal insulation, a heat dissipating system, the toroid and in the case of the DC monitor of a good magnetic shielding.

II. THE VACUUM PIPE

It is important to choose a minimum pipe diameter to allow a simple thermal insulation. Also one needs at least one flange of moderate size to be able to mount and dismount the transformer without hazardous welding work. A 86 x 3 mm^2 pipe with a CA 100 conflat flange was chosen for the assembly side of the pipe. For the PETRA monitor a CDA 150 flange was necessary. Here the ring of the conflat flange had to be sawn into two pieces. The DC gap itself consists at the vacuum side of an alumina ring. The ceramic is brazed into the beampipe shock protected by a little bellow of two folds. The adjacent fold is made of a copper nickel alloy. It has a thermal expansion coefficient close to the ceramic one. Outside is a fold of stainless steel. Besides the added protection it allows to get the difficult and risky weld between steel and the copper alloy done early. The little, quite stiff bellow has to be relieved from all forces due to its adjacent beampipes. During bakeout the forces can be as high as 50 kp. The mechanical bypass is done by the space saving nut design shown in Fig. 1. It adds only very little to the pipe diameter. The DC gap is kept by a Vespel(r) ring. This material withstands routinely temperatures up to 260°C (shortterm up to 480°C) and has opposed to Teflon(r) an acceptable radiation resistance. The alternative Envex(r) was found to be quite brittle and the fragile ring for the DC gap is much more difficult and risky to machine precisely. The cavity between the nut and the ceramic bellow can be accessed from the outside with helium gas for leak searching by a thin steel pipe. A feature necessary for the routine operation of an accelerator.

Next we discuss the electrical properties of the beampipe. The DC gap forms with the nut design an electro magnetical cavity. The cavity was made as small as possible and the width of DC gaps were made thin to reduce the mode losses

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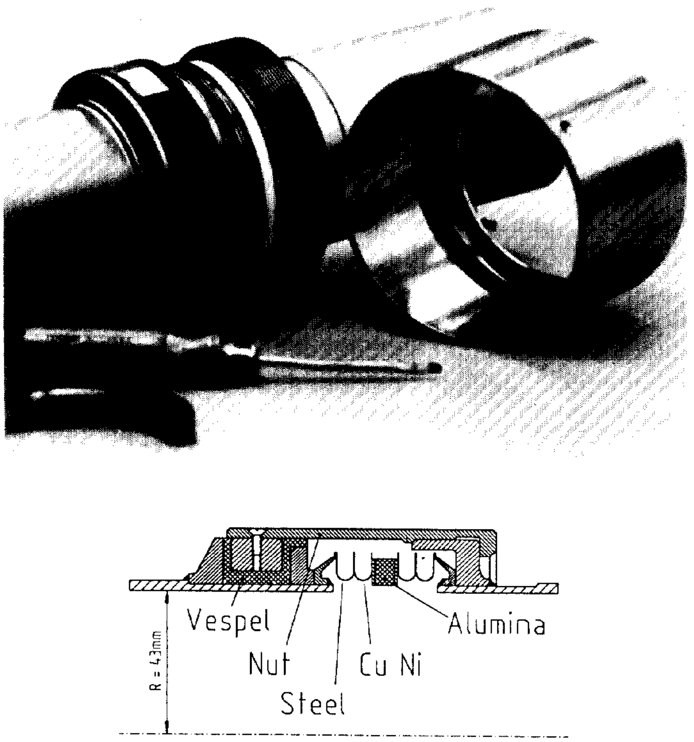

Fig. 1 Bakable DC Gap. The entire construction is secured by a stainless steel nut screwed into clamps isolated to the pipe by two thin half rings of Vespel (r). An extremely space saving design with good electrical properties.

of the beam optimally. Calculations with Urmel [4] show that gaps of up to 10 mm together with a cavity of the size of the entire toroid would still lead to acceptable impedances below 75 kΩ. At the low frequency end the resistance of the beampipe has to be less than 1 Ohm. This is done with copper braids connecting the flanges outside the pick up body. Obviously they need a good thermal isolation. Finally the pipe should not act as an RF transmitter. This is prevented by the thin long Vespel ring and the capacitance between the pipes of roughly 0.2 nF.

III. HEATING, THERMAL ISOLATION AND HEAT DISSIPATION

The current monitor station design allows beampipe bakeout at temperatures up to 300°C[1] in a 50°C warm tunnel. The temperature of the toroid will not exceed 70°C due to a totally passive and maintenance free isolation and cooling system. This is well below the maximum temperature allowed for the toroids of 80°C. Now the detailed description of the system (see Fig. 2): Each side of the beampipe is equiped with a separate heating sleave and a sensor to allow defined bakeout temperatures [5]. The necessary temperature gradient of more than 220°C requires excellent insulation over a very limited diameter range[2]. For our monitor between three and six layers of 3 mm Microtherm (r) panels were chosen leading to a 20-30 mm thick insulation. It has a heat conductivity of less than 0.03 W/Km in our temperature range. This is roughly a factor two smaller than still air.

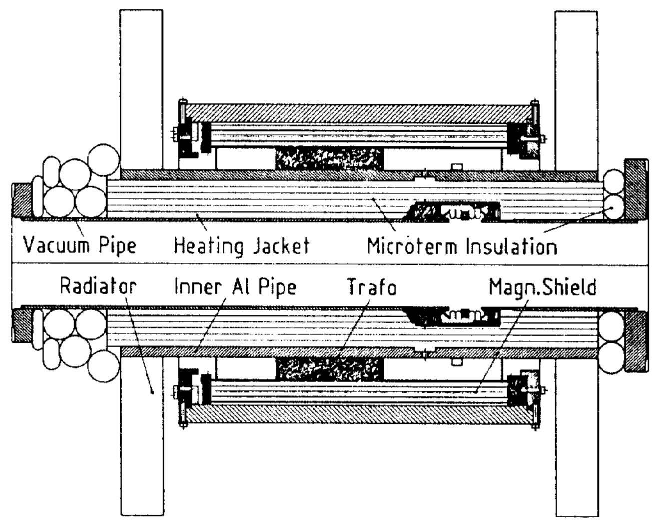

Fig. 2 Thermal design of the beampipe. The heating jackets around the pipe are isolated by microterm. The heat is conducted by the inner aluminium pipe away from the transformer to the two radiators and outer aluminium cylinder. Also the 5 layer magnetic shield of the CMPT is shown.

After getting the best insulation possible one has to dissipate the heat from the toroids efficiently. Therefore the insulation is surrounded by a 10 mm thick aluminium tube to allow the

[1]The vacuum group discusses currently to reduce the bakeout temperature to moderate 200°C.

[2]Although the more space would be helpful in our geometry the availability of considerably more space is of vanishing return in cylindrical insulation problems, since thicker insulation means higher diameter which in turn leads to a larger outer dissipation surface. Here only a material with a low heat conductivity helps.

heat to flow out of the well isolated toroidal area. The heat is then transmitted to the tunnel air by two large cooling radiators on both sides of the tube. We chose the same radiator type as used for medium sized electronic devices. Also the outer aluminium cover cylinder of the toroids constitutes an efficient radiator due to its good thermal connection to the inner aluminium tube. The entire layout requires for a 300°C hot beam pipe a tunnel temperature less than 20°C below the maximum toroid temperature. This should be even sufficient for the high tunnel temperature during bakeout after a long electron run at highest energies. As an added measure of safety there are two thermo relais in series which allow a maximum temperature of 67°C for the inner aluminium tube close to the toroids. A higher temperature will stop the heating of the monitor and the adjacent parts and an alarm will be sent to the vacuum controls.

IV. MAGNETIC SHIELDING

The DC stations need a good shielding against the varying magnetic fields of up to a few Gauß in its tunnel environment. It is basically done by five concentric Mu metal cylinders 297 mm long and 1 mm thick. Between adjacent cylinders there are air gaps of approximately 4 mm. The opening of the inner cylinder could only be closed a little because of the 10 mm aluminium tube for heat dissipation. The possible shielding of this setting is entirely limited to geometry and not to the quality of the shielding material anymore. It is for the important transversal magnetic fields up to 50 Hz better than a factor 100. The DC station for the PETRA II bypass with its extremly powerful current bars has added shielding with MU metal foils down to the beampipe. This was here and it is for the one in DESY III possible because their vacuum systems do not require a bakeout. In the design of the station we had to allow for tolerances of the cylinders higher than usual in mechanical engineering. They gave rise to quite a bit of touch up work and improvisations during the final assembly stage.

V. READOUT

The fast and integrating current monitor is located in HERA directly after the proton injection roughly 100 m inside the tunnel. It is connected to the control room West with two 7/8" coax cables for low losses over the long distance. The signals are fed into a 400 MHz digital scope, which can be accessed by the main control room via a GPIB bus. The scope screen is observed by a CCD camera and the video signal transmitted by optical cables to a screen in the main control room.

For the DC station the front end electronics is placed in a concrete shielded electronics tunnel within the storage ring tunnel next to the pick up station. Also quite some lead (15 - 30 mm) is required to keep the maximum radiation dose below the maximum allowed 1000 Rad. A long cable with many single shielded twisted pairs connects it then with the control room in the closest experimental hall. The first HERA DC station will be digitized by a precision voltmeter and read out via GPIB. The PETRA station signal is transmitted via V/f and f/V converters to the main control room. For DESY III a direct transmission via a line driver was for the beginning sufficient. Here one wishes for the future a computer readout to allow a display of the actual number of particles, since the current changes a factor of three just due to the acceleration of the modest energy protons. For both DESY III and PETRA II the DC monitors were found to be of vital importance.

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