INSTALLATION OF THE SUPERCONDUCTING MAGNETS IN THE HERA TUNNEL

I. Borchardt, D. Brauer, S. Chermenin, D. Degèle, K. Escherich, H.J. Fiebig, H. Grabe, J. Holz, D. Hubert, R. Kus, M. Leenen, H. Maywald, O. Peters, B. Petersen, K. Pieczora, U. Riemer, Z. Sanok, P. Schmüser, S. Schollmeier, W. Schwarz, G. Tödten, D. Trines, S. Wolff
Deutsches Elektronen-Synchrotron DESY, 2000 Hamburg 52, Notkestraße 85 - Germany

Abstract

The arcs of the proton storage ring of HERA are equipped with superconducting magnets. Installation, manpower involved, and experience gained are described.

I. INTRODUCTION

The collider facility HERA in Hamburg consists of two storage rings of 6.3 km length, a 30 GeV electron ring and a 820 GeV proton ring. The assembly of the rings was completed in October 1990. The arcs of the proton ring with a total length of 5.5 km are equipped with superconducting magnets [1] which are arranged in a regular FODO cell structure consisting of two quadrupoles and four dipoles. The cryostats of the dipoles and the quadrupoles have a length of 9.7 m and 4 m respectively. There are 422 dipoles and 224 quadrupoles in the ring including some special magnets. In addition there are about 1500 superconducting correction elements.

All magnets were subjected to an extensive acceptance test comprising checks on mechanical accuracy, alignment, and proper cable connections. In the magnet test facility [2] all magnets were cooled down to 4.7 K to measure the magnetic fields [3], determine the quench performance and test for leaks. The results from the mechanical and magnetic measurements were used to define the position of the magnets for an optimal performance of the machine [11]. For the same reason the dipoles from the two manufacturers were put into separate octants of the machine, as their magnetic properties were slightly different. In the middle and at both ends of a quadrant cryogenic boxes [9] are installed supplying the helium cooling of the magnet strings.

II. THE SEQUENCE OF INSTALLATION

After the cryogenic test and a final quality control the magnets were transported to HERA halls West or East for storage, which was made necessary by the selection procedure.

A special designed installation vehicle [4] with a hydraulic lift system was used to bring the magnets to their preselected position and put them onto their support (see Fig. 1). With the vehicle one could fit a magnet between two already installed magnets with an accuracy of a few mm.

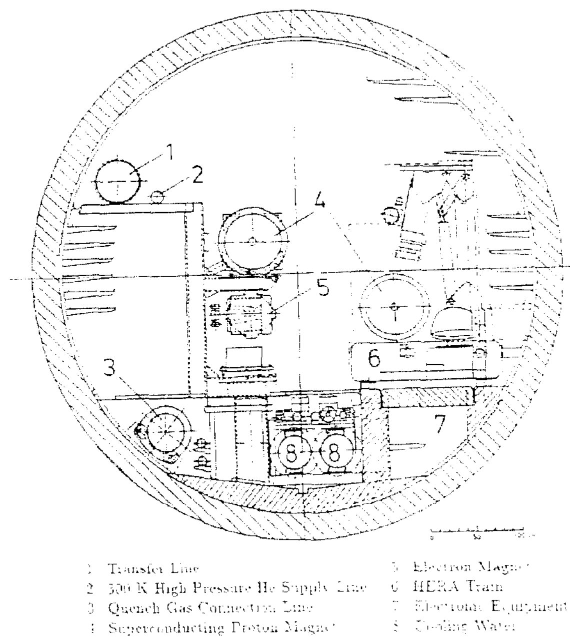

Fig. 1 Schematic Cross Section of the Tunnel

The installation started in most octants at the far end of the tunnel section with respect to the hall, where the magnets were stored. Thus the activities following the placing of the magnets were not affected by the passage of the vehicle.

Once the magnets rested on their supports, the fixtures which attached the inner magnet vessel rigidly to the outer vacuum vessel during transport were removed. Later on the suspension points were covered with superinsulation and the access flanges were closed.

When a string of at least 6 dipoles and 4 quadrupoles was mounted, the magnets were aligned and fixed in position [6]. Immediately after the alignment the beamtubes were flanged together and plastic. bags were put around the flange connections and the neighbouring bellows (see Fig. 2) in preparation of the helium leak test [5] which was performed once all the magnets of an octant were installed.

The superconducting cables for the main dipoles and quadrupoles as well as the 20 superconducting wires for the correction coils are guided within the single phase helium tube of the magnet string. First the main superconductors of adjacent magnets were soldered using a special soldering tool with rf heating and then insulated by

0-7803-0135-8/91$01.00 ©IEEE

Kapton foils. The cables for the correction coils are held in grooves on an epoxy fibreglass cylinder surrounding the main conductors (see Fig. 2).

Considerable effort was spent on the quality control of the solder connections. After a first manual check, which effectively eliminated wiring errors, a magnet string of 120 m length was tested by a computerized system. A current was fed into each of the 20 bus wires consecutively and the voltages at every interconnection were compared to the expected values. In addition high voltage checks were made.

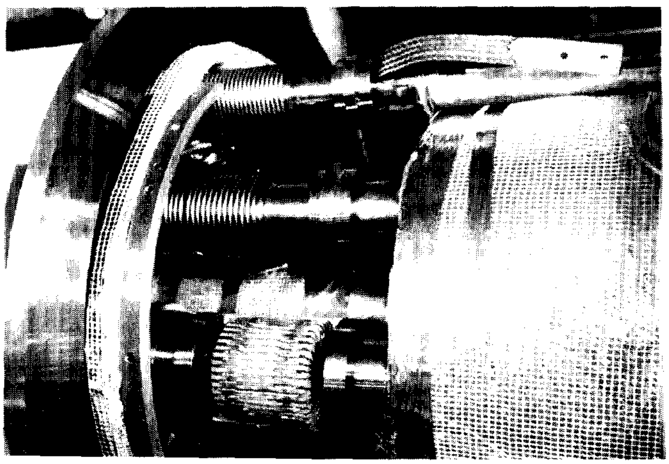

Fig. 2 Interface Between Magnets

After the electrical check welding sleeves (see Fig. 2) were slid over the flanges and the welding was done with a special machine. The tubes for the two phase helium and the shield line were connected in a similar way.

The bellows in the helium lines were secured by support shells to prevent buckling at the maximum pressure of 20 bar. After wrapping superinsulation around the tubes, the heat shield in the interface region was closed and insulated. Finally the sliding joints of the vacuum vessels were moved over the interface and fastened with screws (see Fig. 3).

Whenever a section between two quadrupoles was finished this way, the vacuum vessel was evacuated and tested for external leaks [7], [8]. (The quadrupoles contain vacuum barriers).

In parallel to the work described so far the safety valves (Kautzky valves [9]) for the single and two phase helium lines were mounted and connected to the quench gas return tube (see Fig. 1).

When an octant was installed and the insulating vacuum established, the helium lines of the magnets were pressurized one after the other

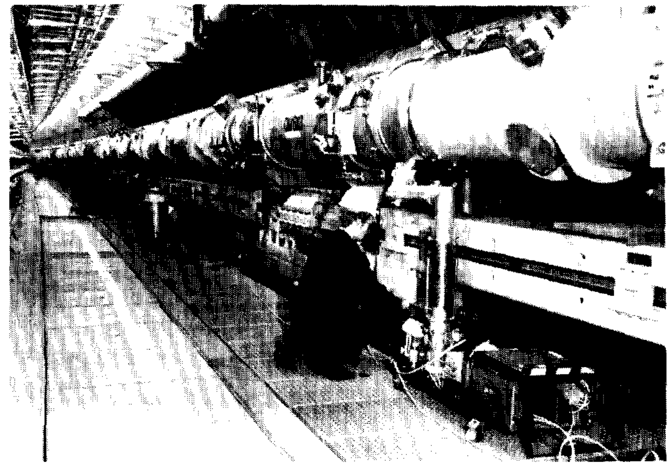

Fig. 3 Completely Installed String of Magnets

and an integral leak test was performed. For this purpose pump stations equipped with helium analysers were installed every 50 m [8], [10].

Towards the end of the arcs the magnet spacing deviates from the regular structure and magnets are spaced at larger distances. These drift spaces are bridged by special cryostats, which contain the beam pipe, the helium lines and the superconducting cables. The installation of these 28 cold straight sections was similar to that of the magnets.

III. MANPOWER AND INSTALLATION SPEED

Fig. 4 shows the progress of installation for a few key activities. The low speed of the installation in the beginning is partly due to the lack of experience of the people involved. In addition, the delivery of magnets from the various manufacturers had not yet reached the full rate.

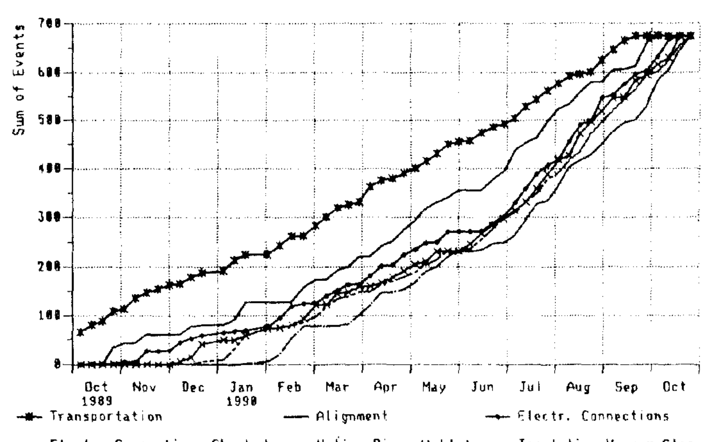

Fig. 4 Progress of Installation

Another restriction was caused by the selection procedure of the magnets.

A group of people was assigned to each task of the installation. The number of people working on the various tasks are given in Table 1, split into engineers and craftsmen. In the last few months of installation the number of people was increased to speed up the installation and to meet the planned completion date.

Task	Initial Phase Scientists Engineers	Initial Phase Technicians Craftsmen	End Phase Scientists Engineers	End Phase Technicians Craftsmen
Planning and Control	1	2	1	2
Transport	1	9	1	9
Alignment	2	3	2	3
Transport Securities		2		4
Electrical Connections	1	5	1	7
Electrical Checks	1	2	1	3
Welding		2		3
Insulation	-	7	-	9
Vacuum	2	6	4	12-14
Total	8	38	10	52-54

Table I Manpower

IV. EXPERIENCES

The installation and the following cryogenic and electrical test of the first octant revealed a few deficiencies of the design and the fabrication, which could, however, be fixed without major problems. The fact that the magnet string performed essentially as expected, for example that the welding joints between the magnets were leak-tight or that powering the magnets caused no problems, encouraged the installation crew and gave confidence in the techniques, which were applied during the installation.

During the installation of the first octant there was some interference between the different task groups, which reduced the efficiency. Later on, as the activities became more separated in the tunnel, the installation speed increased and gradully approached the design value of 15 magnet interfaces per week.

Each task group noted the completion of their work on a form attached to each magnet, thus informing the next group. It also allowed a simple control of the status and an analysis of the progress of installation.

The storage of magnets, which was made necessary by the selection procedure and the distribution of dipoles from the two manufacturers into separate octants posed a slight problem for some time. The available area in the halls was not sufficient, so that magnets had to be stored in the tunnel before they could be brought to their proper position. This complicated the logistics but did not introduce a noticeable delay of the installation.

In addition to the installation reported here there were people working for example on the cryogenics, on the various controls of cryogenics, magnets, monitors, and vacuum systems and on the installation of machine components in the straight sections. The coordination of all these activities without delaying the time schedule was only possible by shifting some activities to night hours. For instance most of the cabling in the tunnel was done at night.

To shorten the time, which was lost to cover the substantial distances between the halls and the actual working section in the tunnel, bicycles were supplied. Lighter equipment and tools were transported in light trailers. For heavy equipment the transport vehicle was used.

Delays caused by missing equipment or unforeseen difficulties were compensated by overtime work, contract manpower, and rearrangements of the installation schedule.

V. REFERENCES

[1] S. Wolff, Superconducting Magnets for HERA, 13th Int. Conf. on High Energy Part. Acc., Novosibirsk 1986, Vol. 2, p. 29
H. Kaiser, Design of Superconducting Dipole for HERA, 13th Int. Conf. on High Energy Part Acc., Novosibirsk, 1986, Vol. 2, p. 49

[2] R. Meinke, Methods for Production Measurements of Superconducting Magnets, DESY, HERA 90/06

[3] R. Barton et al., Performance of the Superconducting Magnets for the HERA Accelerator, DESY HERA 89/20

[4] Design and construction by K. Sinram and G. Wöbke

[5] D. Brauer et al., The Cold Bore Beam Pipe Vacuum System of HERA, to be published

[6] W. Schwarz, Hochgenaue dreidimensionale Punktbestimmung zur Justierung von Teilchenbeschleunigern, Zeitschrift für Vermessungswesen, 115, 7/8, p. 333

[7] D. Hubert et al., Internal Report in German, HERA PVAK No. 82

[8] M. Böhnert et al., The Insulation Vacuum Systems of the HERA Proton Storage Ring, to be published

[9] H.R. Barton et al., The Refrigeration System for the Superconducting Proton Ring of the Electron Proton Collider HERA, Adv. Cryo. Eng. Vol. 31, 1986, p. 634

[10] D. Hubert et al., Internal Report in German, HERA PVAK No. 84

[11] F. Willeke, Internal Communication, unpublished