THE ELETTRA TRANSFER LINE MAGNETS

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ABSTRACT

ELETTRA's transfer line from the linac to the storage ring has a length of 103 m and is made of 30 quadrupoles, 5 bending magnets with a deflection angle of 31.4 degrees, 2 bending magnets with 15.7 degrees deflection and 34 steerers. The aperture tolerance of each magnets is +/- 25 mm. The C-shape bending magnets are running at 2 GeV with a flux density of 1.5 Tesla. With a gap length of 100 mm it is possible to reach a field homogenity of < +/-1*10^(-3) over a range of +/-30 mm. With a magnetic length of 0.5 m the maximum gradient of the quadrupole has to be 23 T/m. The pole shape was calculated to get a homogenity of the gradient < 1*10^(-3) over a radius of 20 mm. The steerer magnets with a length of 0.2 m are C-shape; a magnetic induction of 0.1 T produces a kick of 3 mrad at 2 GeV.

I. INTRODUCTION

The injection system for the ELETTRA storage ring is a full energy linac. It will be located underground and outside the storage ring so as not to interfere with the experimental area and in order to use the linac not only for injection but also for other purposes [1]. The linac will operate in two stages (1.5 GeV and 2.0 GeV). In the case of 1.5 GeV the transfer line has a length of 103 m and consists of 5 bending magnets (angle = 31.4 degrees), 2 bending magnets (15.7 degrees), 30 quadrupoles and 34 steerers [2],[3],[4]. According to the beam sizes within the transfer line the aperture tolerances of the vacuum system has to be +/-15mm * +/-25mm in the dispersion regions and +/-20mm * +/-20mm in the non-dispersion regions. For the aperture of the magnets it follows however: in the bending magnets a gap of 42 mm, for the quadrupole an aperture of +/-25mm and for the steerers a gap of 50 mm. Taking into account the beam sizes and including misalignment, the homogenity within the magnets should be over a range of +/-30mm better than 1*10^(-3). The same requirement exists for the gradient of the quadrupole within the radius of +/-17mm.

II. BENDING MAGNET

There are two types of bending magnets within the transfer line, one performing a deflection of 31.4 degrees and the other to make a deflection of 15.7 degrees. Both magnets should be as identical as possible in order to save production costs and therefore both magnets differ only in their length. The magnetic induction was choosen to be 1.5 Tesla (BESSY I is running with a 1.5T magnet) and both magnets are powered in series. The first layout of the bending magnet - especially the lamination profile - was made according to the BESSY-magnet design. To meet the requirements of the field homogenity for the stages of 1.5 GeV and 2.0 GeV detailed calculations for the pole profile were performed with the 2D package POISSON [4]. The calculated cross section of the lamination and the pole profile are given in figure 2 and 3 In figure 1 a top view of the 15.7 degree bending magnet is shown. The field homogenity for the cases of 1.5 GeV (B=1.125T) and 2.0 GeV (B=1.5T) are presented in figure 4 and 5. For B=1.15 Tesla the homogenoty of the field is in the region of +/-30mm better than +/-1*10^(-3) and for B=1.5 T better than +/-1.7*10^(-3). These values are in conformity with the requirements.

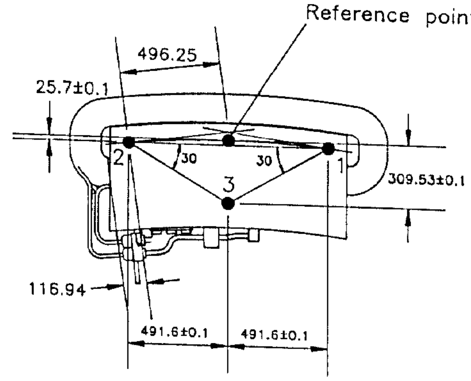

Figure 1: 15.7 degree bending magnet: top view.

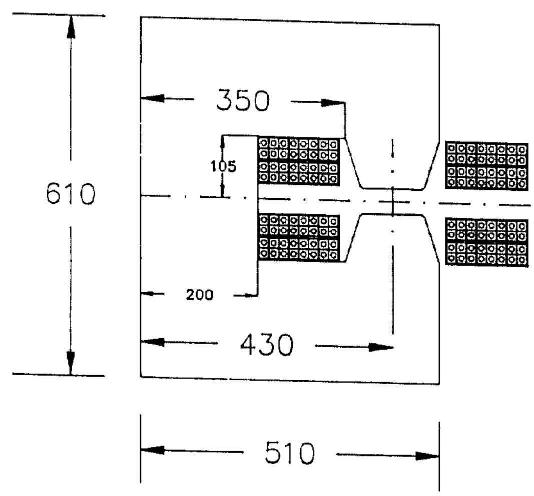

Figure 2: Cross section of bending magnets.

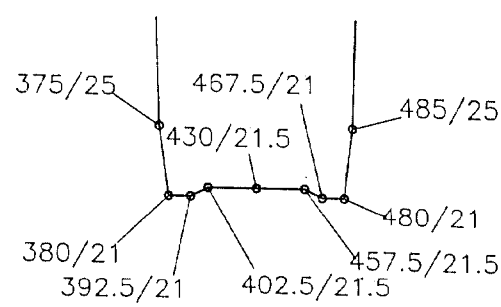

Figure 3: Pole shape of the bending magnet lamination.

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Table 1: Main parameters of the bending magnets

Central field	1.50	T
Bending radius	4.447	m
Pole gap	42	mm
Pole width	100	mm
Yoke lenght		
15.7 degrees	1215	mm
31.4 degrees	2407	mm
Current	938	A
Number of coils	4	
Number of turns per coil	32	
Amperetums	60000	A
Conductor dimensions	17*15	mm*mm
Cooling hole diameter	9	mm
Nominal magnet power		
15.7 degrees	19.3	kW
31.4 degrees	19.7	kW
Input pressure	15	bar
Pressure drop	10	bar
Water inlet temperature	20	degrees
Temperature rise	10	degrees
Weight of assembly		
15.7 degrees	2910	kg
31.4 degrees	5865	kg

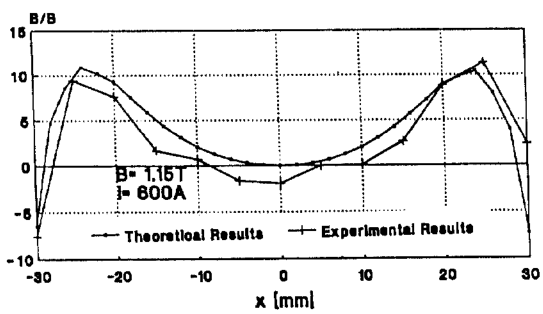

Figure 4: Field homogenity within the bending magnet at a magnetic induction of B = 1.15T.

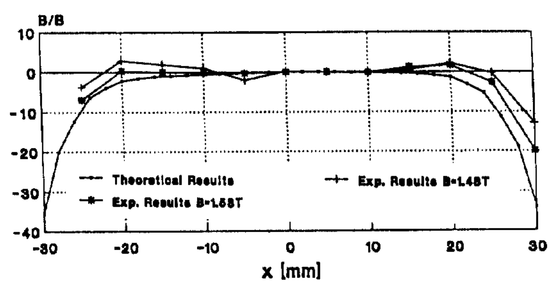

Figure 5: Field homogenity within the bending magnet at a magnetic induction of B = 1.5T.

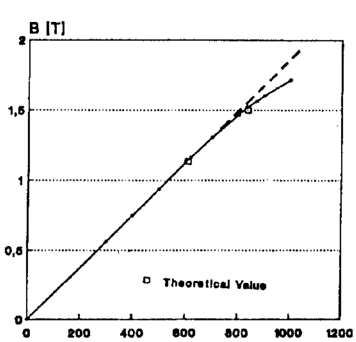

Figure 6: Excitation curve of 15.7 degree bending magnet.

A prototype of the 15.7 degree bending magnet has already been built and the first magnetic measurements have been carried trough with the Trieste measurement system [5]. The results are shown in figure 4 and 5, too. The agreement between the theoretical and experimental results are quite good. This is also the case for the excitation curve, presented in figure 6. For magnetic inductions larger than 1.5T in the gap of the magnet, saturation takes place according to figure 6. This is due to the fact that the magnetic flux density in some parts of the magnets then increases to values of 1.9T.

III. QUADRUPOLE

Taking a maximum induction at the pole faces of 0.55 Tesla and an aperture of 2*r=50mm, one obtains a gradient of G=22T/m. The largest integrated gradient is required by the quadrupole of the achromatic arc at point B [2] with a value of 11 T. Therefore the maximum length of the quadrupole has to be at least 500mm. Regarding the influence of the fringing field the physical length was choosen to 482 mm.

Table 2. Main parameters of quadrupole

Field gradient	22T	/m
Aperture diameter	50	mm
Yoke length	482	mm
Current	116	A
Number of turns per coil	47	
Conductor dimendions	6*6	mm*mm
Cooling hole diameter	4	mm
Nominal magnet power	2.5	kW
Input pressure	15	bar
Pressure drop	10	bar
Water inlet temperature	20	degrees
Temperature rise	10	degrees
Weight of assembly	280	kg

The first layout of the quadrupole lamination and the pole profile was based on the ESRF booster quadrupole [6] and that of the BESSY transfer line. The final shape of the pole profile was determined with the 2D package POISSON [4] (see figure 7 and 8). The gradient as a function of the radius according to these calculations is given in figure 9.

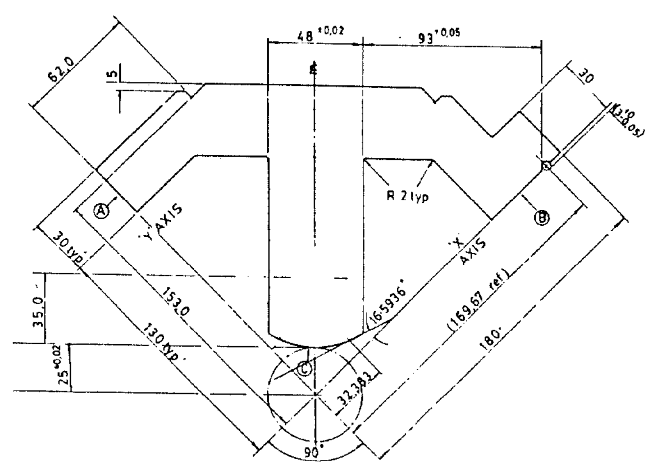

Figure 7: Lamination of quadrupole.

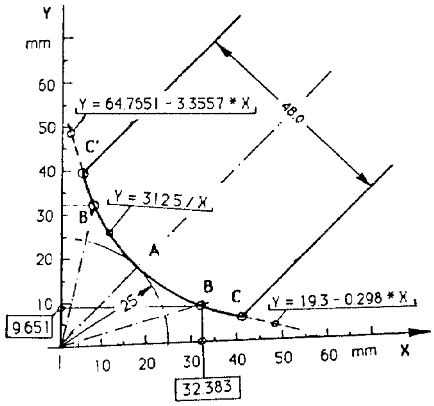

Figure 8: Pole shape of quadrupole

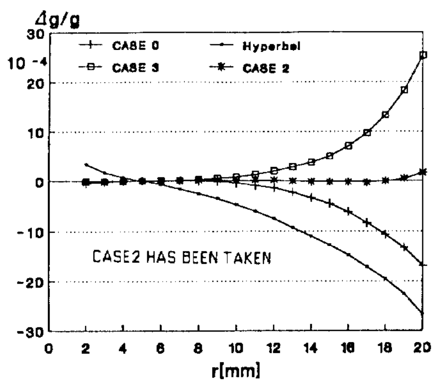

Figure 9: Calculated gradient of quadrupole for different pole shapes.

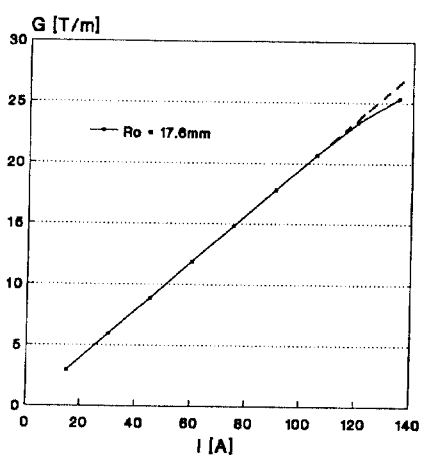

Figure 10: Excitation curve of quadrupole.

A prototype of the quadrupole has been built and first magnetic measurements have been made. The results (excitation curve) are given in figure 10. Without suffering from any cooling problems, a gradient of 25 T/m can be reached, however, at gradients larger than 20 T/m saturation will take place. That means only one of the 30 quadrupoles will have some kind of saturation during operation. The magnetic length of the quadrupole is - according to the measurements - 510 mm.

IV. STEERER

With the assumption of a beam offset of +/- 15mm at different positions of the transfer line, the calculations show that a steerer with a kick of 3 mrad is needed for guiding the beam through the transfer line. With a length of 200mm at 2 GeV, a magnetic induction within the steerer of 100 mT is required. With a gap of 50 mm and a current of 25 A, 170 turns are needed to reach this value. A cross section of the steerer lamination and the magnetic flux density within the steerer are given in figures 11 and 12.

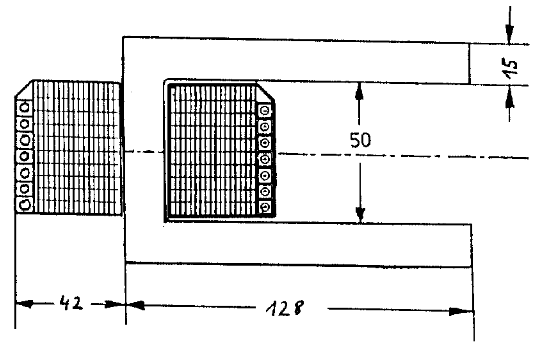

Figure 11: Profile of steerer magnet.

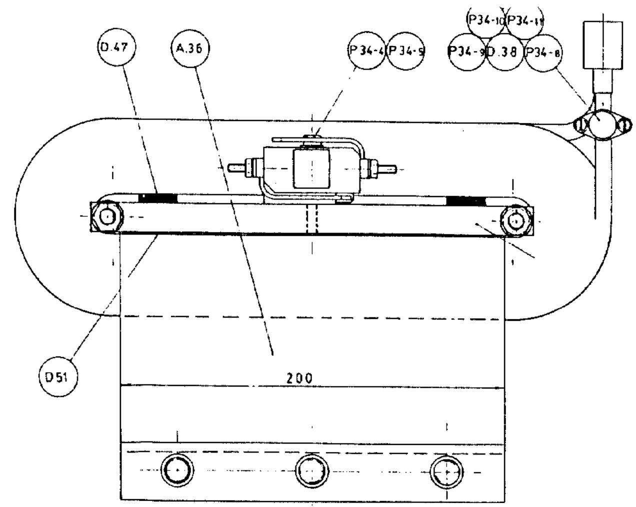

Figure 12: Steerer magnet: top view.

[1] ELETTRA Conceptional Design Report, April 1989
[2] D.Einfeld and R.Richter, 'The ELETTRA Linac to Storage Ring Transfer Line', this conference
[3] D.Einfeld, 'The Transfer Line from 1.5 GeV Linac to Storage Ring', Sincrotrone Trieste Report: ST/M-90/1
[4] D.Einfeld and F.Iazzourene, 'The ELETTRA Linac to Storage Ring Transfer Line', EPAC 90, Proceedings of the 2nd EUROPEAN PARTICLE ACCELERATOR CONFERENCE, Nice, France, June 1990, pp 1294-1297
[5] POISSON, M. T. Menzel, H. K. Stocker, Accelerator The and simulation Group, AT-G, Los Alamos National Laboratory
[6] G.Petrucci, S.De Panfilis, F.Gnidica, G.Stefani, 'The Calculations and the Measurements of the ELETTRA Magnets' EPAC 90, Proceedings of the 2nd EUROPEAN PARICLE ACCELERATOR CONFEREN. PACE, Nice, France, June 1990, pp 1139
[7] ESRF Foundation Phase Report, Grenoble, France, 1987