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RESULTS OF FIELD MEASUREMENTS FOR PETRA MAGNETS

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Abstract

PETRA consists of 232 dipoles, 300 quadrupoles and 152 sextupoles. The field integral for all dipoles as well as the multipole distribution of the field integral for all quadrupoles and sextupoles has been measured for different currents using fast automatic measuring machines. The results are collected in distributions showing the spread in the magnetic performance for each kind of magnet. Measurements of the hysteresis effects are shown, too.

Introduction

PETRA consists of several series of different magnets: 232 dipoles, 284 standard quadrupoles, 16 interaction region quadrupoles and 152 sextupoles.

Before production the special field profile of each type was calculated with the aid of the 2-dimensional computer program MAGNET[1]. Endfield corrections were determined at some prototype magnets.

Dipole cores and coils were produced by different commercial companies. These magnets were assembled at DESY. Quadrupoles and sextupoles were built completely outside our laboratory. All cores are of laminated steel. All magnets have passed a test program at DESY. Systematic field measurements were made to check the desired field profile and the field length distribution for each kind of magnet.

Measuring Equipment

Two types of measurements [2, 3] were performed on the dipoles. In the first type each magnet was compared with a reference magnet. For this purpose a long measuring coil covering the whole length of a dipole was moved between the test magnet and the calibrated reference magnet along the axis of both magnets. This was done for several currents from injection fields up to saturation. The measuring accuracy was about 10^{-5}. The results of such comparing measurements have been collected in distributions important for the performance of PETRA.

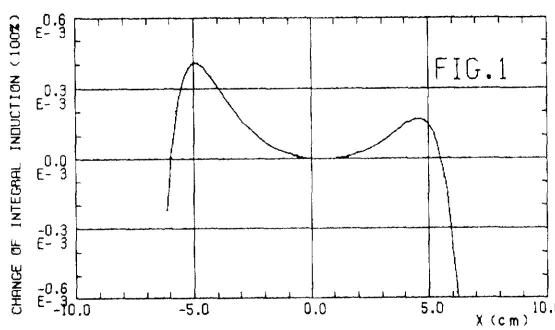
In the second type of measurements the same measuring coil was put to a position symmetrical to the test magnet. The magnet itself was then moved horizontally across the coil. The result of such a measurement is the integral field profile in the gap of the magnet.

The measurements of quadrupoles and sextupoles were performed with a long coil covering the whole length of each magnet and rotating around the magnet axis inside the magnet bore. The output signal was submitted to a harmonic analysis for 15 harmonics. For quadrupoles a second type of this measurement was performed by compensating the main amplitude with a second coil at a smaller radius, thus increasing the measuring accuracy for higher harmonics.

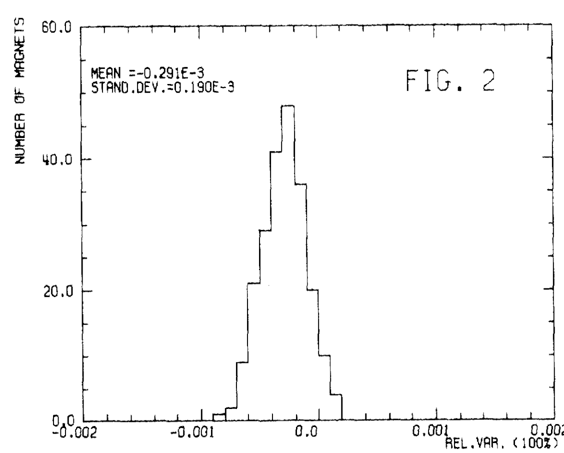
For all kinds of measurements the motion of the coils was controlled and the data were collected by a PDP 8 computer connected on line to our IBM computer centre. The IBM was used for a fit for the dipole field profile and the harmonic analysis of the multipoles.

Results for Dipoles

A total of 242 dipoles including some spare magnets was measured[3]. Some of them are supplied with smaller coils (5 turns or 1 turn instead of 6 per pole). We discuss here the 221 magnets of normal type. These magnets have a core length of 5.31 m and a gapheight of 70 mm (200 m wide). They are designed for about 40 GeV corresponding to 0.7 Tesla at a current of 3500 A. The saturation loss in the iron is about 5 % at this current.



DIPOLE, HORIZONTAL DISTRIBUTION OF INTEGRAL INDUCTION, 1500 A



DIPOLES, RELATIVE DISTRIBUTION OF INTEGRAL INDUCTION, 1500 A

The field quality of a dipole is shown in fig. 1, giving the integral field profile horizontally in the gap at a medium current (1500 A). The field changes are within $\pm 3 \times 10^{-4}$ over a ("good") region of ± 6 cm.

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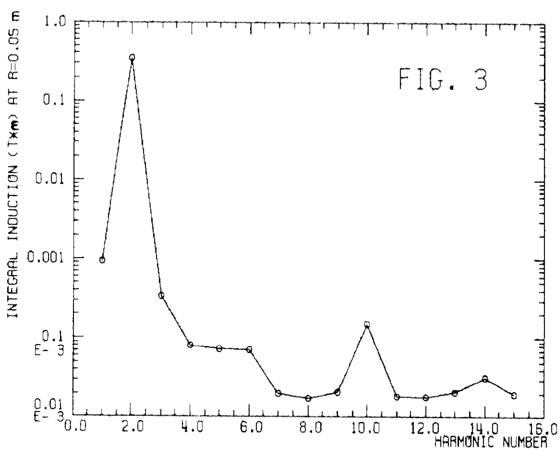
At higher currents saturation at the inner side of the pole produces a small gradient in the gap and a slight decrease of the "good" region.

The relative distribution of the central field integral of all 221 magnets with respect to the reference magnet is shown in fig. 2 for a medium current of 1500 A. The standard deviation is 0.19×10^{-3}. It increases up to 0.81×10^{-3} at highest currents (3500 A).

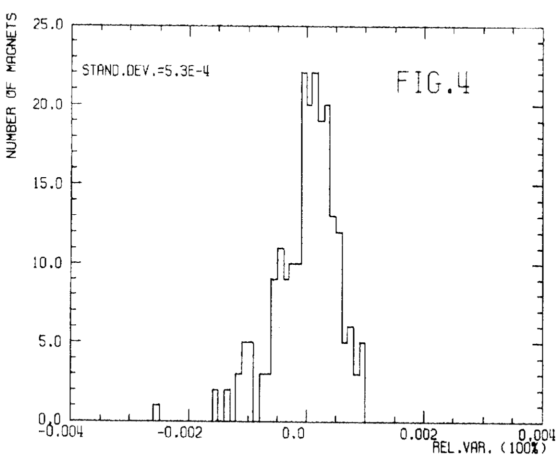
Results for Quadrupoles

Two types of quadrupoles are used in PETRA. The first type has a bore radius of 50 mm and is used in two core lengths (QA: 0.6 m; QA1: 1.0 m).

The second type (QB) has a bore radius of 80 mm and a core length of 1.8 m. It is used near the interaction regions. The maximum integrated gradient is 16.6 T·m/m (QA) and 21.4 T·m/m (QB) at currents of 1500 A and 1200 A respectively. The saturation losses at these currents are about 5 %.

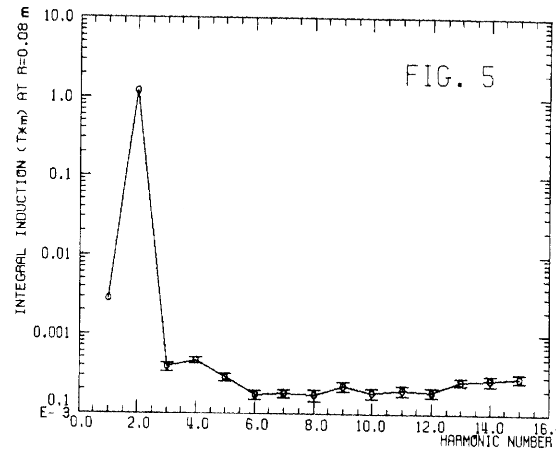


QA, INTEGRAL MULTIPOLE DISTRIBUTION, 900 A



QUADRUPOLES, TYPE QA, RELATIVE DISTRIBUTION OF N=2 AMPLITUDE, 900 A

An absolute measurement of multipoles up to n = 15 was performed for all quadrupoles at different currents [4]. At a medium current a compensated measurement has been made with all quadrupoles, giving a higher accuracy for higher multipoles. The multipole distribution for QA-type magnets (mean of 224 magnets) is shown in fig. 3. A similar distribution for QB-type magnets is shown in fig. 5 (mean of 17 magnets).

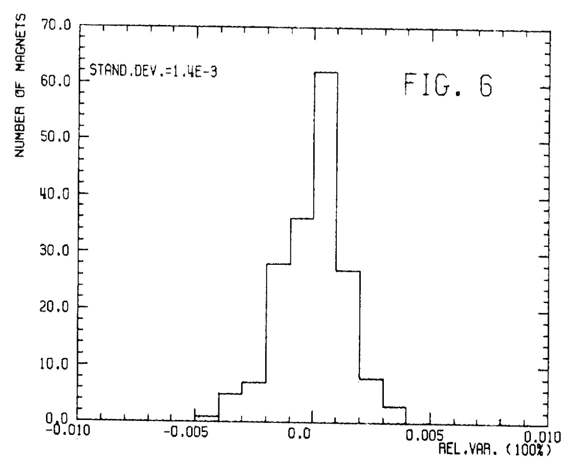


QB, INTEGRAL MULTIPOLE DISTRIBUTION, 800 A

The relative variation of the n = 2 amplitudes of 224 QA-type quadrupoles is given in fig. 4 for a medium current. The standard deviation is 5.3×10^{-4}. For the QB-type magnet a standard deviation of 3.5×10^{-4} is achieved at a medium current.
It increases to 5.2×10^{-4} at highest currents.

Results for Sextupoles

The sextupoles of PETRA have a core length of 0.25 m and a bore radius of 0.06 m. A 1% deviation from linearity in the integrated



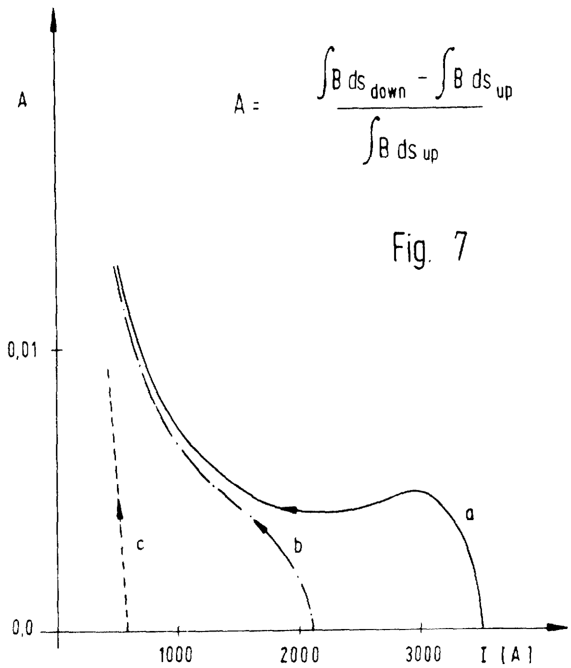
SEXTUPOLES, RELATIVE DISTRIBUTION OF N=3 AMPLITUDE, 400 A

sextupole strength as a function of radius was allowed up to a radius of 0.05 m. These field requirements could be fulfilled with a circular pole shape. The total number of sextupoles measured on the multipole measuring bench was 178.

The relative distribution of the n = 3 amplitudes for all sextupoles shows a standard deviation of 1.4×10^{-3} at a medium current of 400 A (fig. 6). The saturation losses are below 4% at the highest measured current of 800 A, giving an integrated sextupole strength of $a = 34.75\ T/m^2$ ("a" is defined by $B(r) = a \cdot r^2$).

Hysteresis Effects

The fields in a magnet depend on the magnetic history. Therefore it is necessary to submit



Dipoles,Hysteresis Effect

each magnet to a certain current setting procedure. A current sequence from a current I_{min} to a current I_{max} and back again to I_{min} is called a current cycle. How the fields can deviate at same currents in different current cycles is shown in fig. 7 for dipoles. The fields have been normalized to the fields obtained in the cycle with maximum I_{max} (3500 A) for increasing currents. Curve a shows the relative variation of fields in this cycle. If I_{max} is decreased to 2100 A curve b is achieved. Curve c gives the field variations for I_{max} = 500 A. Fig. 7 shows that field variations at the same current of up to 0.5% and more can occur. The situation is even worse for lower currents. Similar curves are obtained for quadrupoles and sextupoles.

Conclusions

Because of small fabrication tolerances and good magnetic steel properties measured field distributions and field qualities of all PETRA magnets are well within specifications. Effects of magnetic history must be eliminated by control of the magnetisation cycle.

Acknowledgements

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