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ACCELERATOR DEPARTMENT
Informal Report

STANDARD PRESENTATION OF MAGNETIC MEASUREMENTS
ON CIRCULAR OR SQUARE APERTURE DIPOLES

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Abstract

Definitions of magnet properties obtained from magnetic measurements are given and methods of presenting these properties are standardized.

In order to facilitate comparison of data from various sources the following standards should be adhered to. Not every report will include all of the following, and it may sometimes be desirable to include data or methods of presenting data other than those listed. Wherever data are available which can be presented in the following ways, however, these ways should be given, and alternative methods should be in addition.

I. DEFINITIONS

(1) Single magnets

The following expansion of the field near the center of a single long magnet will be used to define the harmonic coefficients:

$$B_z = B_o \left(1 + \sum_{n=1}^{\infty} b_n x^n \right)$$

$$B_x = B_o \sum_{n=1}^{\infty} a_n x^n$$

The $z = 0$ plane or median plane is defined by $a_0 = 0$; B_z is perpendicular and B_x is parallel to this plane. B_o is the value of B_z at $x = 0$.

The effective length is defined by

$$L_{ef} = \frac{1}{B_o} \int_{-\infty}^{\infty} B_z(s) \Big|_{x=0} ds$$

The harmonic content of the magnet ends is specified by Δb_n , defined by

$$\frac{1}{L_{ef} B_o} \int_{-\infty}^{\infty} B_z(s, x) ds = 1 + \sum_{n=1}^{\infty} (\Delta b_n + b_n) x^n$$

(2) Several magnets

If there are a number m of almost identical magnets, the mean values of the above quantities are defined by, e.g.,

$$\overline{B_o} = \frac{1}{m} \sum_{i=1}^m B_{o,i}$$

with all magnets at the same current, and similar definitions for $\overline{b_n}$, $\overline{a_n}$, $\overline{L_{ef}}$, and $\overline{\Delta b_n}$.

Deviation of a particular magnet from the mean values is defined by, e.g., $\delta B_o = B_o - \overline{B_o}$, with similar definitions for δb_n and δL_{ef} , and rms values of the deviations are defined as

$$\langle \delta B_o \rangle = \left[\frac{1}{m} \sum_{i=1}^m \delta B_{o,i}^2 \right]^{1/2}.$$

Many of these quantities are dependent on magnet history, therefore, values should be reported after as many cycles as are required to give cycle-number independent values. A cycle is taken to be zero current to near maximum current, and back to zero.

(3) The aperture D of a magnet is defined as the diameter of the largest circle which can be inscribed in the main dipole coils. This quantity is used for comparing different-sized magnets with respect to percentage of aperture having good field, etc.

II. UNITS

To conform with international usage, mks units (tesla, meter, $[b_n] = m^{-n}$, etc.) are the primary units with English equivalents given in brackets after the mks value if desired. For example, $b_2 = 3.1 m^{-2}$ ($2.0 \times 10^{-3} in.^{-2}$).

III. PRESENTATION OF DATA

(A) Tabular

(1) The fundamental presentation will be a table of the expansion coefficients b_n and a_n for both field increasing and field decreasing as a function of field from 0.5 T to near maximum in 0.5 T steps.

This table will be made for the following current configurations:

- (i) no correction current
- (ii) equal sextupole correction currents in each magnet (or in the case of a single magnet with the correction current adjusted to give minimum b_2)
- (iii) with sextupole and any other correction coils available energized as in (ii).

(2) L_{ef} as a function of field as in (1.i).

(3) Δb_n as a function of field as in (1.i) through (1.iii), for all values of n .

(4) If there are multiple magnets, the statistical quantities $\overline{B_0}$, $\overline{L_{ef}}$, $\overline{b_n}$, $\overline{a_n}$, $\overline{\Delta b_n}$, $\langle \delta B_0 \rangle$, $\langle \delta L_{ef} \rangle$, $\langle a_n \rangle$, and $\langle \delta b_n \rangle$ should be tabulated as a function of field as in (1.i) through (1.iii).

(B) Graphical

(1) Graphs of field flatness, gradient, and second derivative as a function of position with field as a parameter, for the case of field increasing. Specifically, graphs of the following:

- (i) $[B_z(x) - B_0]/B_0$ vs x ; $0 \leq |x| \leq D/2$,
 $B_0 = 0.5, 1.0, 2.0, 3.0, 4.0$ T and the maximum.
- (ii) $\frac{1}{B_0} \frac{dB_z^2}{dx}$ vs $|x|$, with $|x|$ and B_0 as in (i).
- (iii) $\frac{1}{B_0} \frac{d^2 B_z}{dx^2}$ vs $|x|$, with $|x|$ and B_0 as in (i).

Direct measurements of the three quantities are preferred, but in their absence, the three quantities are to be computed from all measured coefficients obtained with correction windings excited as in (III.A.1.ii) above and this procedure should be stated in the text.

(2) The same quantities obtained in (1) replotted as functions of B_0 with position as the parameter, specifically:

(i) $[B_z(x) - B_0]/B_0$ vs B_0 at $x = \pm 0.0254$ m,

(ii) $\frac{1}{B_0} \frac{dB_z}{dx}$ vs B_0 at $x = 0$ and $x = \pm 0.0254$ m,

(iii) $\frac{1}{B_0} \frac{d^2 B_z}{dx^2}$ vs B_0 at $x = 0$ and $x = \pm 0.0254$ m.

(3) If there is more than one magnet, $\delta B_0/\overline{B_0}$ and $\delta L_{ef}/\overline{L_{ef}}$ vs $\overline{B_0}$ for each magnet.