COMPUTATION OF MAGNETIC END FIELDS, AND COMPARISON WITH MEASUREMENT*

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Abstract

The dependence of the magnetic effective length and the fringe-field correction constant on the central field flux density are of particular interest in designing beam transport systems. It is therefore important to know the accuracy with which they may be calculated. Measurements on Argonne's bending magnet BM-111 have been compared with TRIM computations. The agreement between computed and measured effective lengths was within 1.7 percent in pole separation units for fields from 0 to 17 kG. The agreement between computed and measured fringe field correction constant, which determines the correction angle to the transverse focal length, was within 0.56 percent of the measured value of 8 kG.

Magnet Geometry

Figure 1 shows an oblique sectional view of the ANL, BM-111 bending magnet. Since TRIM is a two-dimensional program and it is desired to calculate the field in the YZ plane, an additional steel yoke must be used to return the flux from the pole to the midplane. This is shown in Fig. 2 as that steel having a permeability of 10^9. This additional yoke limits the universe and is arranged so its effect on the field in the region of interest is small. The tape aids in the convergence of the program. Since the geometry dictates that the flux density in any part of the field clamp is less than 0.75 B_o, the model used for the computations is a good approximation for $B_o < 20$ kG.

Effective Length Computations

The LASL/LBL version of TRIM was used to calculate the vector magnetic potential at each mesh point. It also plots the lines of constant vector potential shown in Figs. 2 and 3 for $B_o = 11.95$ kG and $B_o = 22.03$ kG, respectively. The effective length may be calculated directly from the vector potential at the steel yoke on the midplane. The results of the computations are given in Fig. 4 which shows the change in effective length as a function of B_o. Plotted are the measured data[1] with 0.1 in. accuracy and the computation.[2] It is seen that from 0 to 17 kG the computation and measurements agree within 0.1 in., which is 1.7 percent of the pole separation.

The difference between computation and measurement in the interval $11 < B_o < 15$ kG is probably due to small differences between the 1010 steel excitation characteristic of the actual magnet (annealed at 1300°F) and the characteristic used in the computations (annealed at 1500°F). A TRIM computation was repeated with the correct annealing temperature steel characteristics. The result is marked by an asterisk in Fig. 4 for $B_o = 11$ kG and $\Delta L = 2.69$ in.

Fringe Field Correction Constant k_1

The computed fringe field correction constant[3] given by

$$k_1 = \frac{1}{B_o^2 G} \int_{-\infty}^{\infty} B(z) \, [B_o - B(z)] \, dz$$

is plotted in Fig. 5 vs the central field flux density B_o. The k_1 value at $B_o = 7919$ G as obtained from the measured data agrees with the computations to $1 - k_{measure}/k_{computed} = 0.56\%$.

*Work performed under the auspices of the U.S. Atomic Energy Commission.

References

1. R. J. Lari, "The Magnetic Measurements of the Beam Transport Magnets in Use At the Zero Gradient Synchrotron," Argonne National Laboratory, Accelerator Division, Internal Report RJL-8, July 28, 1967, p. 47.

2. H. F. Vogel, "Computations of Magnet End-Fields," Los Alamos Scientific Laboratory, Internal Report MP-7-23, December 31, 1970.

3. K. L. Brown, "A First and Second-Order Matrix Theory for the Design of Beam Transport Systems and Charged Particle Spectrometers," Stanford Linear Accelerator Center, SLAC-75, p. 74.

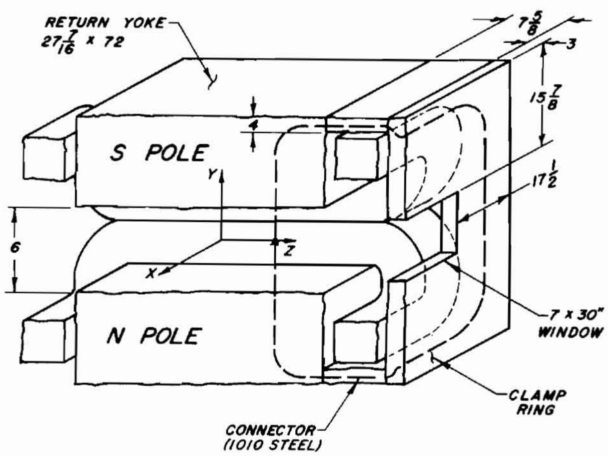

Fig. 1. BM-111 Magnet Geometry.

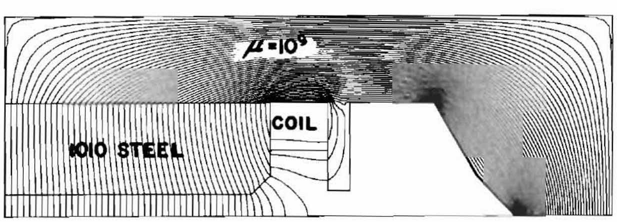

Fig. 2. Flux Plot for B_o = 11.95 kG.

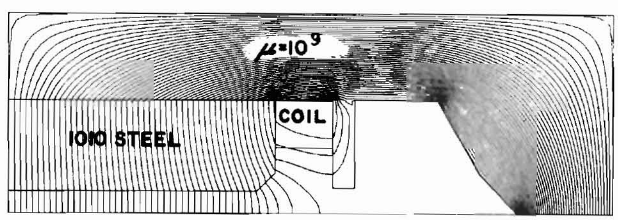

Fig. 3. Flux Plot for B_o = 22.03 kG.

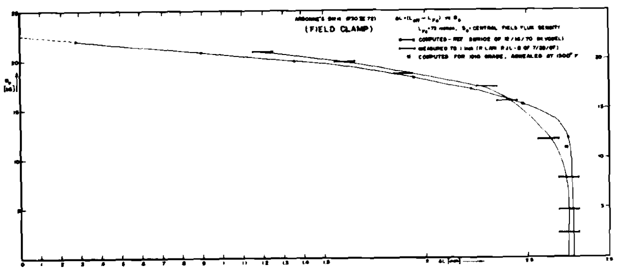

Fig. 4. B_o fx $\Delta\ell_{effective}$.

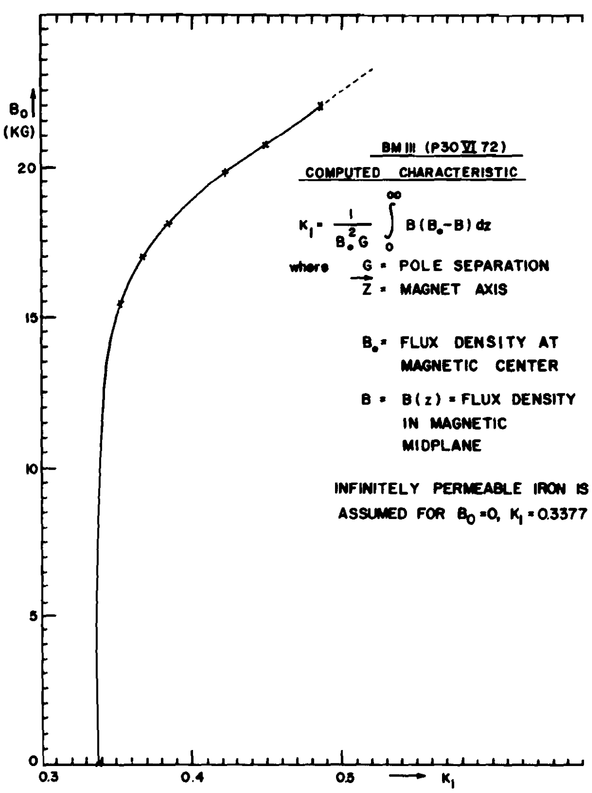

Fig. 5. B_o vs k_1.