18.72
154

Sh. 2377

LA-5075-MS

INFORMAL REPORT

MASTER

Computation of Magnetic End Fields, and Comparison with Measurement

los alamos
scientific laboratory

of the University of California

LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

In the interest of prompt distribution, this LAMS report was not edited by the Technical Information staff.

Printed in the United States of America. Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.95

los alamos
scientific laboratory
of the University of California

LOS ALAMOS, NEW MEXICO 87544

LA-5075-MS
Informal Report
UC-28

ISSUED: November 1972

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Computation of Magnetic End Fields, and Comparison with Measurement

by

H. F. Vogel

R. J. Lari*

*Argonne National Laboratory

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
GG

COMPUTATION OF MAGNETIC END FIELDS, AND COMPARISON WITH MEASUREMENT

by

H. F. Vogel and R. J. Lari

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.

I. 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 taper 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 $0.75 B_0$, the model used for the computations is a good approximation for $B_0 < 20$ kG.

II. 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 $B_0 = 11.95$ kG and $B_0 = 22.03$ 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_0 . Plotted are the measured data¹ 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 $11 < B_0 < 15$ 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. 2 for $B_0 = 11$ kG and $\Delta L = 2.69$ in.

III. FRINGE FIELD CORRECTION CONSTANT k_1

The computed fringe field correction constant³ given by

$$k_1 = \frac{1}{B_0^2 G} \int_{-\infty}^{\infty} B(z) [B_0 - B(z)] dz$$

is plotted in Fig. 5 vs the central field flux density B_0 . The k_1 value at $B_0 = 7919$ G as obtained from the measured data agrees with the computations to $1 - k_{\text{measure}}/k_{\text{computed}} = 0.56\%$.

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 $B_0 = 11.95$ kG.

Fig. 3. Flux Plot for $B_0 = 22.03$ kG.

Fig. 4. B_0 vs $\Delta L_{\text{effective}}$

Fig. 5. B_0 vs K_1 .