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Recent Work

Title
MAGNETIC MEASUREMENTS OF A SINGLE 8" LONG QUADRIPOLE WITH 4" BORE. SUMMARY OF TESTS MADE FROM 5-5-55 TO 5-10-55. 8" ASSEMBLY DWG. 5A3686-1 COILS DWG. 5A3576.

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Tests were made to check the design flux density of the magnet, to find the magnet current for a field gradient of 3000 gauss/inch, to check maximum power ratings and water interlocks, and to check the aberration and focus for both convergent and divergent rays.

The flux density was measured as a function of current at a point P located at $z = 0, \theta = 45^\circ, R = 1\frac{1}{2}$ inches. See page 4 of this note for a drawing of the coordinate system. A graph of flux density vs. magnet current is presented on page 5 of this note and a plot of field gradient vs. current appears as page 6. Magnetic field as a function of radius is shown on page 7. These measurements were made using a Rawson-Lush rotating coil gaussmeter whose absolute accuracy is ± 1%.

Maximum power ratings and water interlock requirements are presented in E, N, 7900-61 ML.

For measurements of aberration and focus a wire trajectory method was used. The energy of a particle and its motion in a magnetic field can be represented by the current and tension in a wire.

$$B^2 \text{ (gauss-cms.)} = \frac{T \text{ (dynes)}}{i \text{ (amperes)}}$$

$$B^2 \text{ (gauss-inches)} = \frac{T \text{ (grams)} \times 980 \times \frac{1}{i \text{ (amperes)}} \times 0.1}{2.54}$$

All tests were made with 50g,7 grams providing the tension on a wire consisting of 14 strands of No. 14 with a silk braid insulation,

$$B^2 \text{ (gauss-inches)} = \frac{1.947 \times 10^6}{i \text{ (amperes)}}$$

The quadrupole was mounted with axis horizontal and the pole tips at $45^\circ$ from vertical. Magnet current and wire current were in directions that the rays were convergent horizontally and divergent vertically.

Measurements were made by determining the coordinates of the wire in space at two planes separated by about one hundred inches. From these coordinates the slope of a trajectory for several rays was determined and the image focal distance $f_1$ found at the point of intersection. For these experiments the object distance $f_0$ was fixed at 151 inches. From this the focal lengths $F$ were calculated.

$$F_0 = \frac{f_0}{f_1 + f_0}$$

Then the effective length $L$ of the quadrupole can be determined from

$$F_0 = \left( \frac{\sqrt{dB/dR}}{L} B^1 \right)^{-1} \text{ or}$$

approximately $F_0 = \frac{B^2}{L dB/dr}$.
From the horizontal coordinates, the convergent \(fi\) was calculated, and from the \(y\) coordinates, the divergent \(fi\) was calculated.

The results of the measurements of focal length are tabulated on page 3 of this note.

The aberration in focus was maximum and measurable in the \(y = 0\) plane. In other horizontal planes the focus varied only slightly. At \(y = \pm 3/4\) aberration at the limits of the aperture was least and unmeasurable.

In the \(x = 0\) plane no aberration was detected within the experimental error. With divergent rays, the paths cannot approach the limits of the aperture where convergent aberration does occur.

The aberration for \(y = 0\) was expressed as the distance \(\Delta x\) that the trajectory missed the focal point of the central rays, as a function of where the trajectory intersected the plane \(z = h\). [An actual trajectory is curved for about 5 inches from center and the actual value of \(x2 = 0\) is about equal to the straight line value at \(z = 2\frac{1}{2}\). The projected value of \(x2 = h\) is only 1% less than \(x2 = 0\)]. The results are graphed on page 8.
Magnetic Measurements of a Single \( \frac{1}{4} \) in. long Quadripole with \( \frac{1}{4} \) in. bore. Summary of tests made from 5-5-55 to 5-10-55.

Assembly dia. 5A 3686-3 Cells dia. 5A 3576

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date (1955)</td>
<td>5/5</td>
<td>5/6</td>
<td>5/6</td>
<td>5/10</td>
<td>5/10</td>
<td>5/10</td>
</tr>
<tr>
<td>Wire Current (amps)</td>
<td>1.753</td>
<td>1.818</td>
<td>1.096</td>
<td>1.594</td>
<td>1.390</td>
<td>2.100</td>
</tr>
<tr>
<td>( B_\phi ) ( (10^6 ) gauss-inches)</td>
<td>2.59</td>
<td>2.30</td>
<td>1.775</td>
<td>1.15</td>
<td>1.40</td>
<td>0.927</td>
</tr>
<tr>
<td>Proton Mev</td>
<td>1250</td>
<td>1050</td>
<td>710</td>
<td>350</td>
<td>190</td>
<td>240</td>
</tr>
<tr>
<td>Deuteron Mev</td>
<td>850</td>
<td>700</td>
<td>430</td>
<td>190</td>
<td>280</td>
<td>130</td>
</tr>
<tr>
<td>( dB/dR ) (gauss/inch)</td>
<td>3080</td>
<td>3195</td>
<td>2490</td>
<td>1589</td>
<td>1947</td>
<td>1291</td>
</tr>
<tr>
<td>( F_c ) measured (inches)</td>
<td>89.14</td>
<td>75.65</td>
<td>75.05</td>
<td>75.37</td>
<td>76.51</td>
<td>75.30</td>
</tr>
<tr>
<td>( F_d ) measured (inches)</td>
<td>73.6</td>
<td>72.7</td>
<td>71.9</td>
<td>96.8%</td>
<td>96.8%</td>
<td>95.4% See note (2)</td>
</tr>
<tr>
<td>( F_d/F_c \times 100% )</td>
<td>96.8%</td>
<td>96.8%</td>
<td>95.4% See note (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( L_{\text{theoretical}} )</td>
<td>9.81</td>
<td>9.73</td>
<td>9.69</td>
<td>9.81</td>
<td>9.61</td>
<td>9.74→av. 9.70</td>
</tr>
<tr>
<td>( \phi ) theor. approx. formula</td>
<td>9.83</td>
<td>9.52</td>
<td>9.50</td>
<td>9.60</td>
<td>9.40</td>
<td>9.53→av. 9.50</td>
</tr>
</tbody>
</table>

(1) Note: The above information applies in the range measured \( 75^\circ < F_c < 90^\circ \)

(2) Note: From theory \( F_d/F_c \approx \frac{\sin \phi}{\sin \phi} \). Within the experimental error this

agrees with actual measurements. For \( \phi = .37 \) (which is in

the range observed) \( F_d/F_c \approx \frac{\sin \phi}{\sin \phi} = \frac{.3616}{.3785} = 95.5\% \)

\[ \phi = L \sqrt{\frac{dB}{dR} \frac{1}{B_\phi}} \]
Magnetic Measurements of a Single 8" long Quadripole with 4" bore. Summary of tests made from 5-5-55 to 5-10-55.
8" Assembly dwg. 5A 3686-1. Coils dwg. 5A 3576

POLE TIP #1

POLE TIP #2

POLE TIP #3

POLE TIP #4
MAGNET TESTING GROUP

MAGNET CURRENT: 100 AMPS.

The dashed lines connect points of varying radius.

R = Also the field of symmetry between the poles.

\[ \text{magnet current} = 100 \text{ amps} \]

\[ \text{radius} \]

\[ \text{magnetic field} \ (\text{magnitudes}) \]

\[ \text{points at} \ (R, B) \]

\[ \text{points along the tip contours for above surfaces} \]
ABERRATION IN Y = 0 PLANE

\[ dx \text{ at } z = z_1 \text{ vs. } y \text{ at } z = 1 \text{ in.} \]

1 in. BORE BY 8 IN. LONG QUADRIPOLE MAGNET

DRAWN: No. 54 1656-1

DATE: 5-6-55

DRAWN BY: LOR

5-10-55

BOOK NO. 197

for the inner curve

\[ I = 220, I_0 = I_1 = 150 \text{ inches} \]

for the outer curve

\[ I = 55, I_0 = I_1 = 150 \text{ inches} \]

\[ I = \text{Magnet current (amperes)} \]

\[ px \text{ position at } z = 4 \text{ in. (inches)} \]

\[ dx \text{ is the radius of the "circle of confusion"} \]

\[ z = 0 \text{ is the center of the magnet} \]

The \( y = 0 \) plane is the \( z = 0 \) plane and is the plane of symmetry between two adjacent poles.

These curves are from interpolations of measurements of the positions of flexible wire "rays".