BNL-104608-2014-TECH

AGS/AD/Tech Note No. 180;BNL-104608-2014-IR

EDDY CURRENT EFFECTS OF SEPTUM-BACKLEG SPRINGS I N THE H-10 MAGNET

E. S. Rodger

March 1982

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

AGS TECHNICAL NOTE
No. 180

EDDY CURRENT EFFECTS OF SEPTUM-BACKLEG SPRINGS IN THE H-10 MAGNET

E. S. Rodger

March 9, 1982

Summary

This study predicts the field perturbation effects of a proposed spring element in an improved H-10 magnet and concludes its effect to be negligible.

Introduction

Construction difficulty and cost of half sine wave pulsed magnets can be significantly reduced and reliability improved if the septum and backleg can be inserted transversely from the front of the aperture and held apart with a spring "can" as shown below in Fig. 1

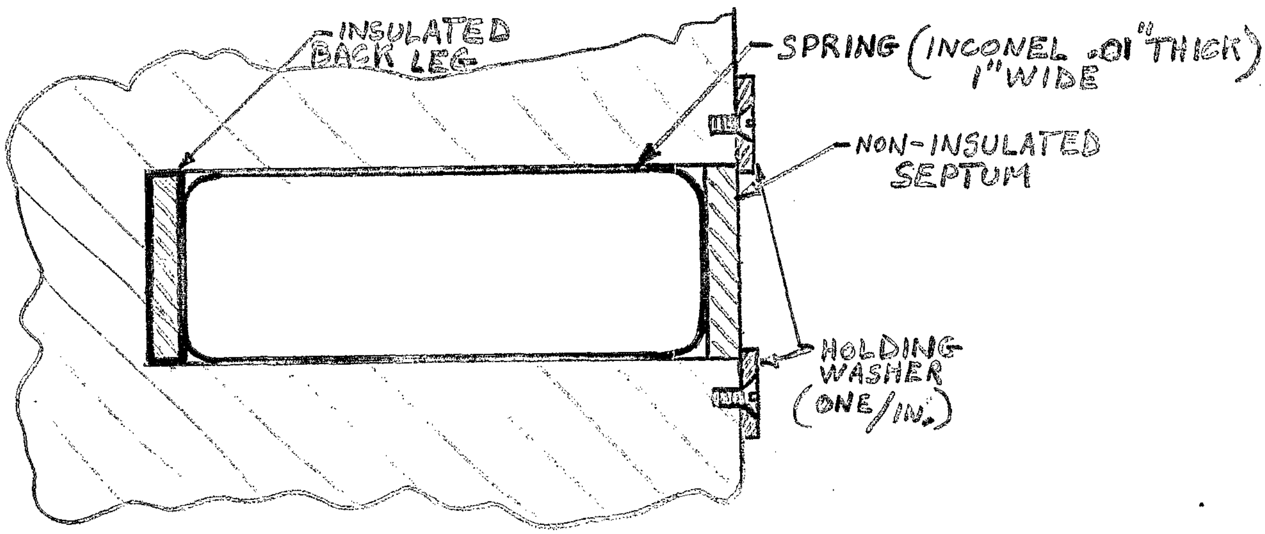

Fig. 1

This construction is feasible if the eddy current effects of the spring are acceptably low. Fig. 2 shows the eddy currents in the spring.

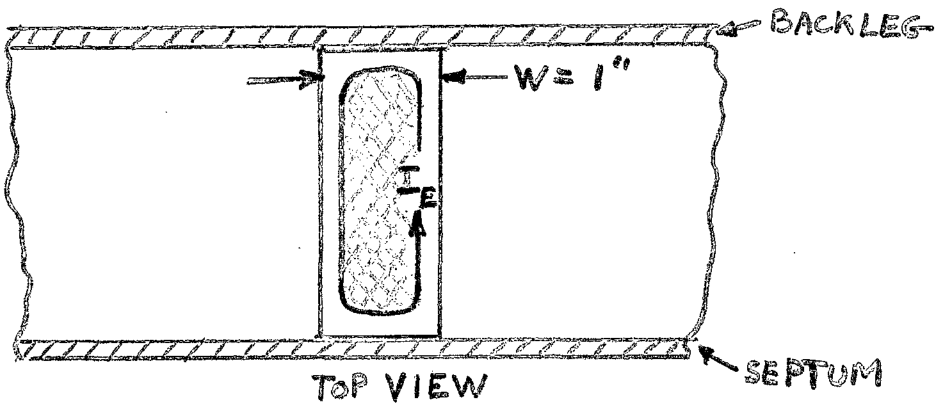

Fig. 2

Assumptions:

1. The main field is altered only in the shaded area of Fig. 2 within the boundary of the eddy currents.
2. The applied field over the aperture is uniform.
3. The spring is equivalent to a flat plate of thickness equal to twice the spring thickness.
4. The ends of the spring have little resistance compared to the resistance along the long axis of the spring.
5. The eddy currents are not sufficiently large to significantly reduce the main field that is they are a perturbation on the main field.

Calculations on the eddy current field.

B = a sin ωT

$\dot{B}$ = main field rate of rise = a ω cos ωT = 2.9×10^7 gauss/sec

where a = 13000 gauss

$$\omega = \frac{1}{2t} 2\pi = 2244 \text{ RAD/sec}$$

ρ = resistivity of inconel = 125×10^{-6} Ω cm

t = equivalent plate thickness = 2(.01") 2.54 = .05cm

W = spring short dimension = 1" = 2.54cm

$$I_E = \frac{\dot{B}tW^2}{8\rho} 10^{-8} = 94 \text{ amps*}$$

$$B_E = \frac{4\pi \times 10^{-3} N I_E}{G} = 48 \text{ gauss}$$

where N = 1 turn
G = .025 meters

*AGS TN #49 Herrera

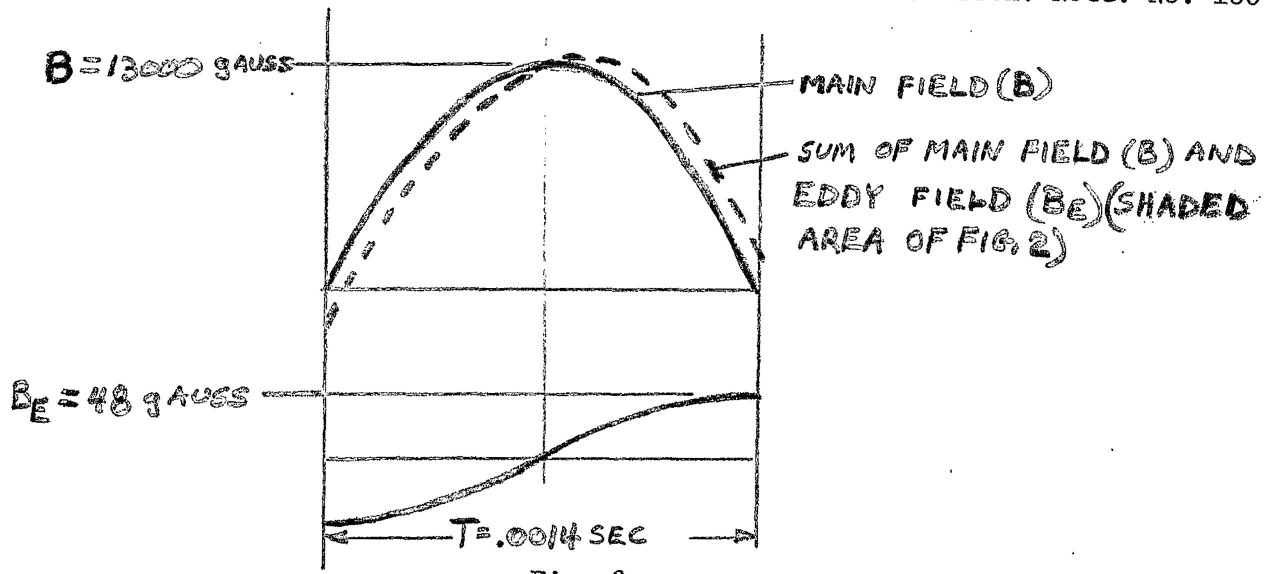

Fig. 3

The fields add as follows $\sin\theta + a\cos\theta \simeq \sin(\theta + a)$

$$\text{where } a = \frac{48}{13000} = .0037 \text{ RAD}$$

The beam pulse lasts about 2.6×10^{-6} sec. If the middle of the pulse were timed exactly on $\dot{B} = 0$ the leading and trailing edges would pass through the magnet at 1.3×10^{-6} sec from this time. The difference in the two field regions would then be

$$B = 48 \text{ gauss} \cos\left\{\frac{\pi}{2}\left[1 + \frac{2\,(1.3 \times 10^{-6})}{.0014}\right]\right\} = .14 \text{ gauss}$$

or about 10.8 parts in 10^6 near the spring. This would be no problem.

A more serious effect arises from the fact that the beam sometimes passes through H-10 40 or so micro seconds from $\dot{B} = 0$ as seen in Fig. 4 where the lower trace is the output from U/165 and the upper is the H-10 current wave form taken 3/2/82.

This would cause a field non uniformity of 3.2 parts in 10^4 near the spring or <u>1.6 parts per 10^4</u> over the magnet length as the springs occupy 1/2 the length of the magnet.

The given criteria for this magnet for injection into ISA is 5 parts in 10^4. Therefore the springs as presently envisioned appear to have negligible effect.

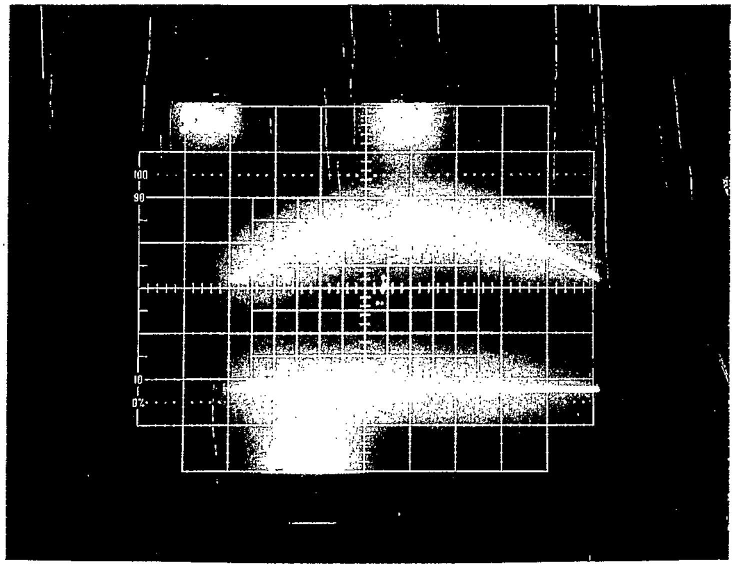

Fig. 4

It is interesting to compare the eddy current effects of the H-10 magnet laminations to those of the proposed spring. Fig. 5 shows the H-10 1/2 scale cross section and the path chosen to represent the thickness "t" in the eddy current formula. The "W" dimension corresponds to lamination thickness of .018" = .046cm.

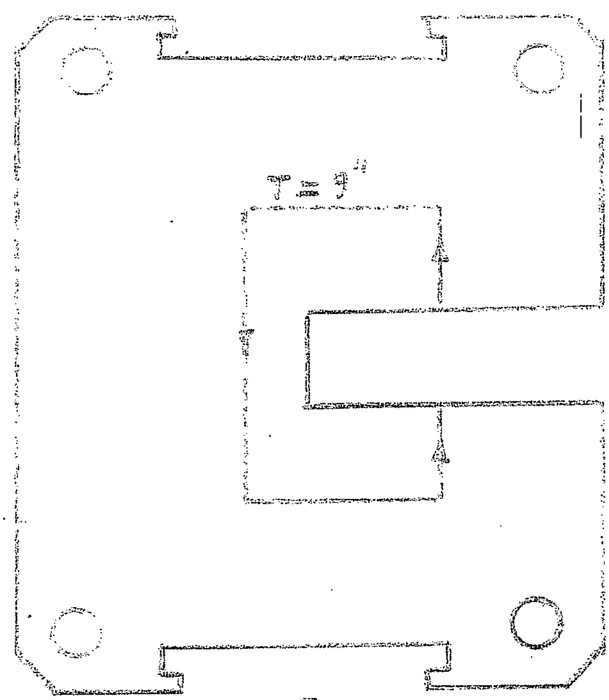

FIG. 5

$$I_{EL} = \frac{\dot{B} t W^2 \times 10^{-8}}{8\rho}$$

$$I_{EL} = 40 \text{ amps}$$

where $\dot{B} = 2.92 \times 10^7$ g/sec
$t = 9'' = 22.86$cm
$W = .018'' = .046$cm
$\rho = 44 \times 10^{-6}$ $\Omega\cdot$cm (M-36 Steel)

This current (I_{EL} = 40 amps) should be multiplied by 2 in comparing its effect on the beam since it acts continuously along the magnet where the spring current I_E acts on half the length. With this in mind we see that the effect of the laminations is about .85 times that of the springs.

My thanks to Howard Weisberg, Bill Weng and Woody Glenn for their help in this study.