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FIELD RAMPING IN SOLID CORE BENDING MAGNETS

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Experiment #396, a collaboration between Virginia Polytechnic Institute, the University of Wisconsin, and Collin's Group at BNL, will make use of a beam of essentially full energy protons scattered from the "A" target in the slow external proton beam. Variation in momentum of the SEPB by about 1% over the 1/2 sec flat top would lead to an unacceptable dispersion of the diffracted proton image at its momentum defining slit. It has been proposed that this be compensated by "ramping" the current in the bending magnets of this beam. This note describes some magnetic measurements carried out in order to ascertain whether this could be done satisfactorily in the presence of the eddy currents which would be induced in the solid core 18D72 and 18C72 magnets involved.

I. Reference Voltage Pulser

To modulate the magnet current, a pulse generator was constructed in order to inject a programmed voltage change into the reference source of the power supply regulator. For testing, a trapezoidal form of pulse was employed. The duration of the linearly rising portion of the pulse could be varied from 10 msec to 500 msec. The flat top duration had a range of 10 μsec to 1.0 sec. A third control determined the amplitude of this pulse. This pulser was employed as a function generator in conjunction with a programmable reference source which was substituted for the power supply's standard fixed source. This programmable source may be used with most commercial function generators. With this combination, the power supply reference could be pulsed over a range of 0.5% to 5.0%.

II. Test Location

Although intended for eventual use on the 72-in. magnets, it was convenient to carry out the test on another type already connected to power and water. The charged particle test beam to the 7-ft bubble chamber has two 18D36 magnets (#613 and #614) connected in series to a 300 kW supply of the mag-amp type (#316). It seemed sensible to go ahead with magnetic measurements on one of these magnets (#613 was used) and try to estimate the effect of the longer 72-in. magnet based on the data obtained.

III. Apparatus

Since dynamic effects were of interest here, search coils connected to an integrator were employed in order to get good sensitivity to small changes of field. Two coils were used. A point coil, furnished by the Magnetic Measurements Group, had an area of 4260 cm^2. The other was a long coil of 10 turns, 100 cm long, with an area of 2650 cm^2 wound on a simple wooden form. A Type O Tektronix operational amplifier was used as an integrator, its output appearing on an oscilloscope. A high gain, Type W plug-in, with a built-in bucking voltage was used for observation of the current pulse signal from the main shunt in the power supply. A polaroid camera was used to photograph the oscilloscope traces.

IV. Measured Data

Measurements were made initially with the power supply in the Voltage Regulation Mode to confirm that observable field changes could be produced. Later, the reference pulse was applied as a current reference with the supply in the Current Regulation Mode. Using a relatively long pulse (1.2 sec), the current was observed to reach an assymptotic change of -3.6%. Presumably, the voltage change (which was not observed directly due to the large ripple content) must also have reached the value

$$\Delta v/\Delta = 3.6\%$$

The magnetic field change was found by first calibrating the coil in use by flipping it through 90°, thus producing an integrated output from the amplifier proportional to the full magnetic field in the gap. The pulsed field change could then be measured in terms of the full field. In this way, the integrated magnetic field, as measured by the long coil, was found to change by

$$\Delta B/B = 0.99\% \text{ in } \Delta t = 1.18 \text{ sec.}$$

Therefore, the time constant for the magnetic field with respect to an applied voltage change is

$$\gamma = -\Delta t/\log\left(1-\frac{\Delta B/B}{\Delta V/V}\right) = 3.55 \text{ sec.}$$

This increase can be compared to the calculated low frequency time constant (i.e., neglecting eddy currents) of 2.6 sec.

At a dc current of 1750 amp a repetition period of 2.4 sec was set up, and the pulse shape adjusted to provide a crudely linear field change for 0.5 sec. The reference pulse is shown in Fig. 1. The resulting current behaviour is illustrated in Fig. 2, which shows a peak change of 62.8A or

$$\Delta I/I = 3.59\%$$

Figure 3 is a picture of the output of the long coil, which integrates the magnetic field from its center out to a point 21.4 in. outside the steel edge of the gap. The trace illustrates the rough linear change in field over 0.5 sec, reaching a peak value of

$$\frac{\Delta\int Bdz}{\int Bdz} = 0.90\%$$

Point measurements of the field gave the following results

Position	Center	6" inside edge	at edge	6" outside
$\Delta B/B_o$	-1.12%	-1.19%	-0.66%	-0.15%

When plotted, the integrated field change is estimated to be

$$\frac{\Delta \int Bdz}{\int Bdz} = \int \frac{\Delta B \ dz}{B_o L_{eff}} = 1.02\%$$

which agrees with the long coil result within the rather rough accuracies of the magnetic and geometrical measurements.

The magnet voltage swing necessary for this field modulation is about 9 to 10%.

V. Recommendation

These measurements indicate that it is feasible to ramp the bending magnet fields for Exp. #396. The 72-in. magnets involved will have a longer time constant, which we may expect to be proportional to the increase in length, or about

$$\tau_{72} = \tau_{36}\left(\frac{78''}{42''}\right) = 6.6 \text{ sec.}$$

The required voltage swing must therefore be correspondingly greater to reach the same ΔB during the flat top.

In order to secure a more linear variation in field, the reference pulse should probably be modified to that shown in Fig. 4.

By continuing to drive the current downward during the spill period of the SEPB it should be possible to make $\Delta \int Bdz$ more linear than it is in Fig. 3. The amplitude ranges should be such as to allow a maximum field change of 1.5% in 0.5 sec which apparently would require a current swing of about 6% and a voltage swing of about 30%. The present tests did not go to this great a voltage excursion, and it is not known yet if any stability problems will arise. A current stability check should be made using a prototype of the final pulser design.

Pulsers such as this, modified as required to suit the various power supplies used, should be available for the following magnets.

A2D4	18C72-3
A2D5	18C72-4
A2D6	18C72-2
A2D7	18D72-#737
A2D8	18D72-#738

There is yet another magnet in this beam to be considered, which represents a somewhat different case. This is 15C30-2 which follows A1D1 and A1D2, the two 18D72's in the 0^{o} charged secondary beam from "A" target. They bend the 28.5 Gev/c protons through a total of 4.325^{o}. The 15C30 is required to operate near zero field, but must be ramped to compensate for about 1% of this angle. Again providing a 50% over-range to 1.5%, the 15C30 field pulse should deflect up to 0.065^{o} or 1.1 mrad, which corresponds to 42.4 kG-in. at 28.5 Gev/c. Therefore, another pulser and power supply are needed which can pulse this magnet to about 1.3 kGauss or 180 amp from a quiescent value not exceeding 70 G or ~ 10 amp. This will keep the beam centered in the long channel through the big stopper to within 1/16".

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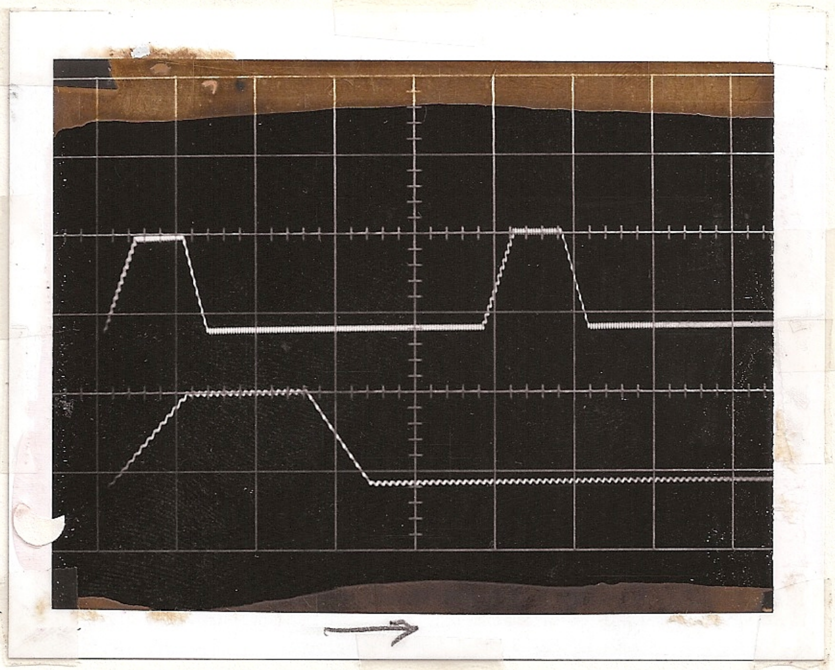
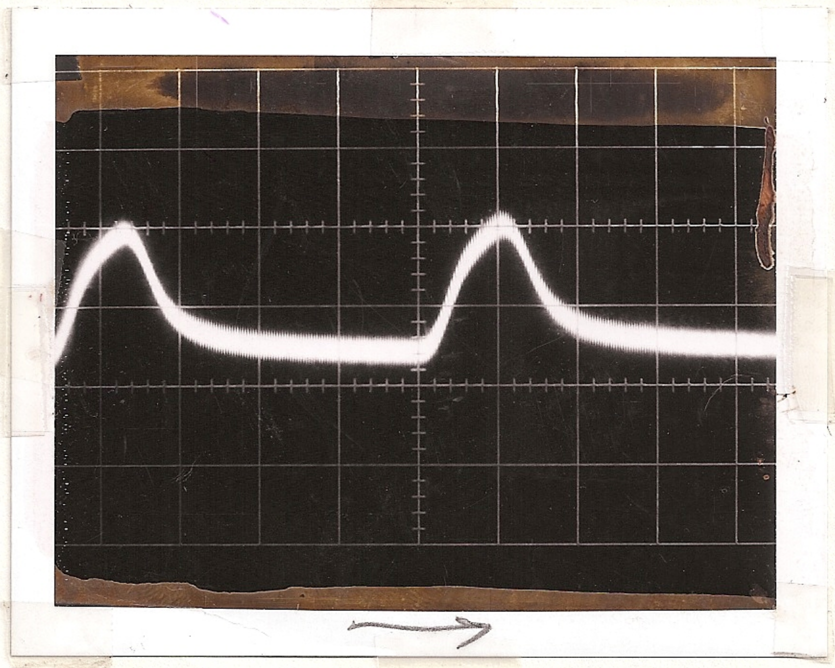
FIG. 1.



Current Reference Pulse
Upper Trace: 0.5 sec/cm., 5 V/cm.
Lower Trace: 0.2 sec/cm., 5V/cm.

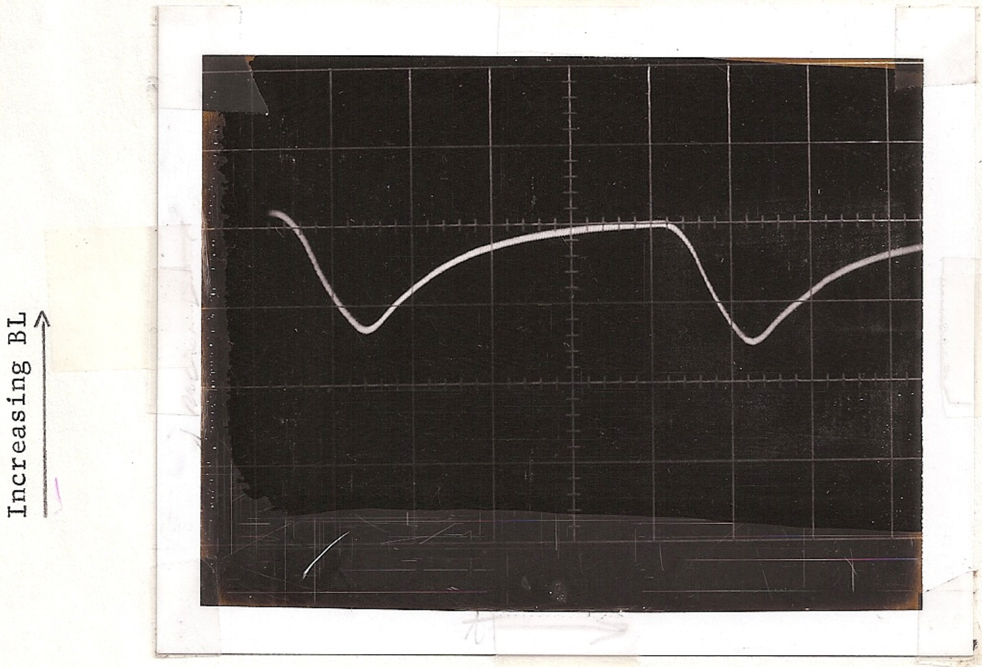
FIG. 2

Increasing I



Current Pulse
Vertical: 40A/cm
Horizontal: 0.5 sec/cm.
I_{dc} = 1750 A.
ΔI = -62.8A

FIG. 3



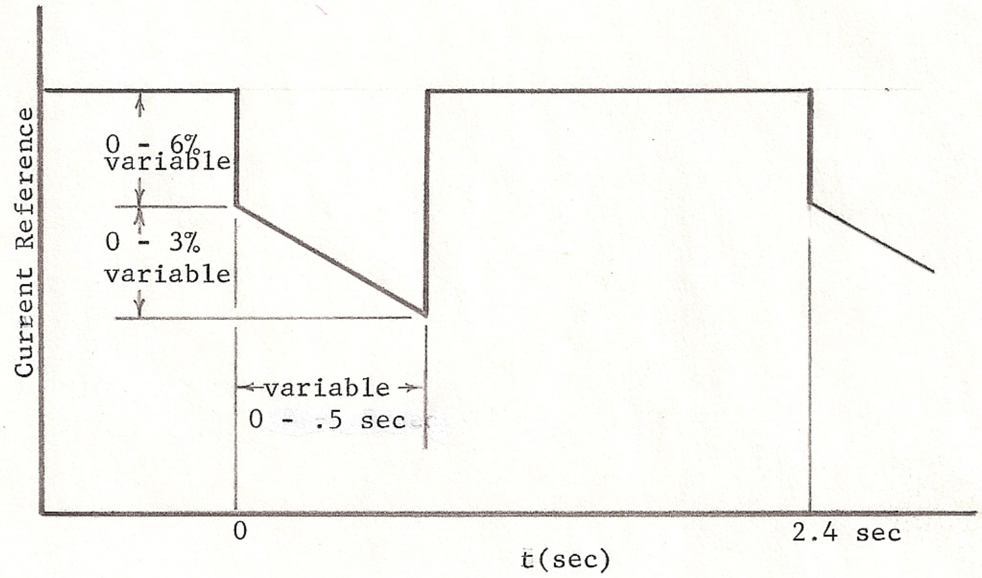
Integrated Field Pulse: $\int_{\frac{1}{2}} \Delta B \, dz$

Vertical: 2.15 kG-in/cm.
Horizontal: 0.5 sec/cm.

$$\left(\int_{\frac{1}{2}} \Delta B \, dz \right) = 3.07 \text{ kG-in.}$$

$$\left(\int_{\frac{1}{2}} B \, dz \right)_{dc} = 341.4 \text{ kG-in.}$$

FIG. 4



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