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ABSTRACT

This report describes a 20-channel "stepper" magnet assembly designed to cause the incoming Bevatron particle beam to scan across the 72-inch hydrogen bubble chamber in discrete steps. The purpose of this device is to avoid superimposing tracks. Stepping was triggered by an "events" counter placed in the beam. The system was built with low-voltage silicon-controlled rectifiers. Magnet pulsing was accomplished in two parts: rapid rise of field was produced by a fast circuit; pulse length was maintained by a slow circuit. Cost was approximately $15,000, exclusive of the surplus components.

INTRODUCTION

A need existed for the incoming particle beam to be swept across the 72-inch hydrogen bubble chamber so as to prevent superimposed tracks. Uniform spacing of tracks would make the photographs clearer and would simplify automation of the track scanning system. It was proposed to do this scanning by a pulsed magnet, using either a simple sinusoidal sweep or a stepped sweep triggered by an "events" counter. The counter-triggered system with a maximum of 20 steps was selected because it was more compatible with a random time distribution of incident particles.

A second choice had to be made between a high-voltage system using ignitrons or a low-voltage system employing silicon-controlled rectifiers. The CERN system used ignitrons.[1] We chose the SCR system because it cost less.[2]

OBJECTIVE

The objective was to build a pulsed magnet that would move the beam laterally after the arrival of each particle in a beam spill containing as many as 20 particles (Fig. 1). The Bevatron was to spill the beam for 200 μsec once every 5 seconds. The magnet was to be made in 20 segments, each providing a deflection of 6000 gauss-inches. We had hoped to achieve a rise-time and electronic delay of 2 μsec, but because of modifications to increase reliability, the total time was stretched to 6 μsec. Electronic delay was held to less than 1 μsec. The magnet aperture required was 1-inch wide by 1/2-inch high. The magnets were prebiased at one side of their B-H loops so that the scan would be symmetrical with respect to the center line of the beam.

We also wanted to keep cost low by using existing or surplus components whenever possible. Final cost of the stepper magnet system was approximately $15,000, exclusive of the surplus magnet cores and power supply.

DESCRIPTION OF APPARATUS

General

Each of the 20 magnet segments was driven by a fast circuit to achieve a short rise time and a slow circuit to achieve a long fall time. Figure 2 shows the relation of the fields due to the fast and slow windings. The individual fast and slow circuits were built on removable boards to simplify maintenance. Figure 3 shows the box that contains the fast circuit boards and the assembly of 20 magnets. This box was mounted on the beam line and the remaining electronic equipment was located remotely in a double 6-foot rack.

Figure 4 is a block diagram of the electronic circuits of the stepper-magnet system.

Figure 5 is a timing diagram for the various parts of the system.

MAGNET CORE AND WINDINGS

Each magnet consisted of two cores taken from surplus radar pulse transformers (Fig. 6). These were tape-wound toroids of moly-permalloy 1-mil thick and 1/2-inch wide, and built up to 1 inch. The outside core diameter was 6 inches. Cores and windings were potted in epoxy resin and a 1-by-1/2 inch aperture was machined in one side.

There were three windings in each potted magnet unit. The fast winding consisted on a one-turn copper sheet surrounding the aperture and pole-tip area. Leads to this winding were of copper sheet, closely spaced to minimize inductance. The slow winding contained 14 turns with 7 above and 7 below the aperture. The bias winding for each magnet contained 20 turns and was connected in series with the bias windings of the other magnets. By prebiasing the magnets in one direction and then reversing the field at the time of triggering, the iron was used more efficiently and approximately equal positive and negative deflections were achieved. A fourth "winding" consisted of a one-turn shielded monitor loop inserted into the aperture area of the complete 20-magnet assembly. A break in the shield prevented a shorted turn from forming.

FAST CIRCUIT BOARD

Each fast winding was driven by a fast circuit board (Figs. 7 and 8). This board consisted of four similar circuits with outputs in parallel. Each section contained approximately 1000 μF charged to 230 V. Capacitors consisting of parallel electrolytic and Mylar units were separated into 1000-μF blocks to minimize and localize damage in case of failure.[3,4] The capacitors were discharged through eight SCR's in parallel, each with a 0.5-ohm limiting resistor of low inductance. To minimize series inductance, the fast circuits were built in stripline fashion and the interconnecting leads kept short. The relatively high voltage per turn caused the field to build up rapidly (approximately 5 μsec).

SLOW CIRCUIT BOARD

Each slow winding was driven by a slow circuit board that contained approximately 2000 μF charged to 230 V (Fig. 8). The capacitors were discharged through three SCR's in parallel, each with a 1.5-ohm limiting resistor. Diodes in series with the output lead blocked the high induced voltage when the fast circuit was fired. After the high voltage decayed, the slow circuit supplied ampere turns so that field remained approximately constant during the 200 μsec of beam spill. Actual decay time constant of the field was between 1 and 2 msec. Figure 2 shows the overlapping of fields due to slow and fast circuits.

COMMON BIAS CIRCUIT

The common bias winding was pulsed through a high-voltage blocking inductor by an ignitron. The ignitron discharged 18,000 μF charged to 230 V, reaching maximum current in about 8 msec. Timing circuits were adjusted so that the current peaked simultaneously with beam spill.

POWER SUPPLY

The power supply consisted of a pair of 400-V 5-A units. Charging current was limited by reactors in the primary circuits. Timing and simple regulation were controlled by a back-to-back SCR contactor. When the magnets were pulsed, the power supply was turned off for 0.8 sec during which time a small negative voltage was applied to all SCR anodes. This reverse voltage overcame "soakage" effects in the electrolytic capacitors and ensured SCR turnoff.

SCALER AND LOGIC

At the entrance window of the bubble chamber a pair of coincidence counters with an associated 20:1 scaler and logic circuit provided "event" triggers for each of the 20 magnet circuits in sequence. After the "event" signal passed through the scaler and logic device, the unit waited 800 μsec for other events and then "cleared" remaining unused circuits by firing them in sequence at 3-μsec intervals. Finally, the scaler reset itself to zero. In case no events occurred, a delayed "no events" trigger started the "clearing" cycle. The output signals of the logic chassis passed to the reed-relay gating unit so that the magnets were not triggered unless the common bias circuit was on.

OPERATING EXPERIENCE

Figure 9 shows the effect of the stepper magnet in spreading out beam over most of the bubble chamber's sensitive area. Particle tracks are not precisely spaced because of the relatively large statistical width of the undeflected beam shown in the upper photograph.

Figure 10 shows a "staircase" of field produced by triggering magnets at 13-μsec intervals.

During the month the stepper magnet has been in use at the Bevatron, some 200,000 pictures have been taken. Sixteen magnets are being used, with four kept as spares. With this arrangement, we can carry the experiment through until the weekly maintenance day. Reliability is increasing with time as shakedown-type troubles are eliminated. Troubles to date have been confined mainly to the fast board circuits.[5]

ACKNOWLEDGMENTS

We thank Dr. William Chinowsky for initiating the stepper-magnet program, Percy H. Cutler for his work in coordinating and guiding the construction of the apparatus, and John A. Saarloos for designing the twenty-channel scaler and logic circuit.

FOOTNOTES AND REFERENCES

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

1. E. Chesi and G. Petrucci, A Ferrite Step-Magnet for Bubble Chamber Experiments, CERN/TC/200 65-9, June 5, 1965.
2. K. Aaland, Silicon Controlled Rectifiers (SCR) Destructive Pulse Tests, Lawrence Radiation Laboratory Internal Report LER 442-2, March 1962 (unpublished).
3. D. Hopkins, Electrolytic Capacitor Banks, Lawrence Radiation Laboratory Report UCRL-16263, July 1965 (unpublished).
4. D. Hopkins and P. Pellissier, A High-Voltage Electrolytic Capacitor Bank, Lawrence Radiation Laboratory Report UCRL-9968, December 1961 (unpublished).
5. J. Barale and A. Faltens, Description and Instructions for Multiple Deflector Magnet 10Y2725, Lawrence Radiation Laboratory Internal Report 10Y3451, March 1966 (unpublished).

FIGURE CAPTIONS

Fig. 1. Simplified block diagram of stepper-magnet system and bubble chamber.

Fig. 2. Combined field due to fast and slow circuits.

Fig. 3. Above, fast-board circuit assembly. Below, magnet assembly (center of picture above terminal strips).

Fig. 4. Block diagram of electronic circuits in the stepper-magnet system.

Fig. 5. Timing diagram of the electronic circuits.

Fig. 6. Sketch of the magnet core.

Fig. 7. One side of fast board circuit, with trigger amplifier at center. The other side of the board is similar but does not have a trigger amplifier.

Fig. 8. Simplified circuit of fast and slow circuit boards and connections to magnet.

Fig. 9. Bubble chamber tracks; (above) stepper magnet off, (below) stepper magnet on.

Fig. 10. "Staircase" of field. Magnets triggered in sequence every 13 μsec. Sweep speed is 100 μsec per cm.

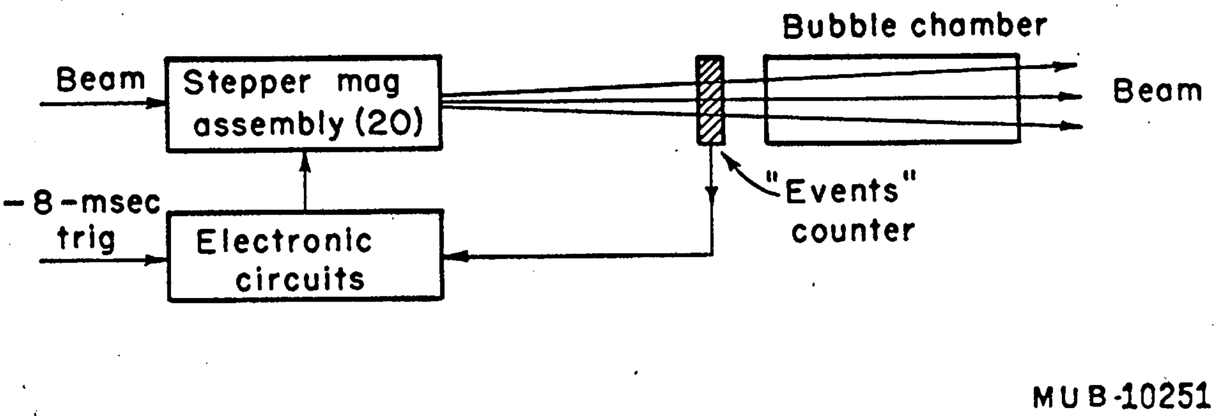

Bubble chamber
Beam
Stepper mag assembly (20)
Beam
-8-msec trig
Electronic circuits
"Events" counter
MUB-10251

Fig. 1

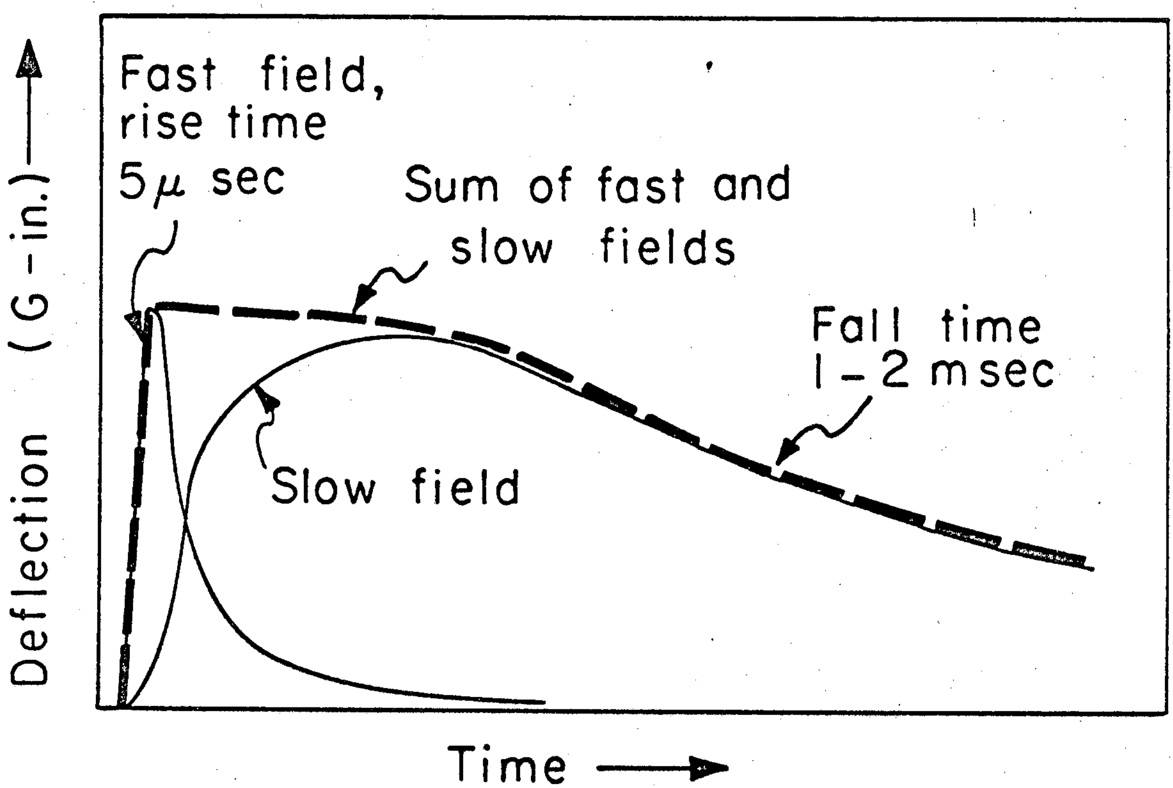
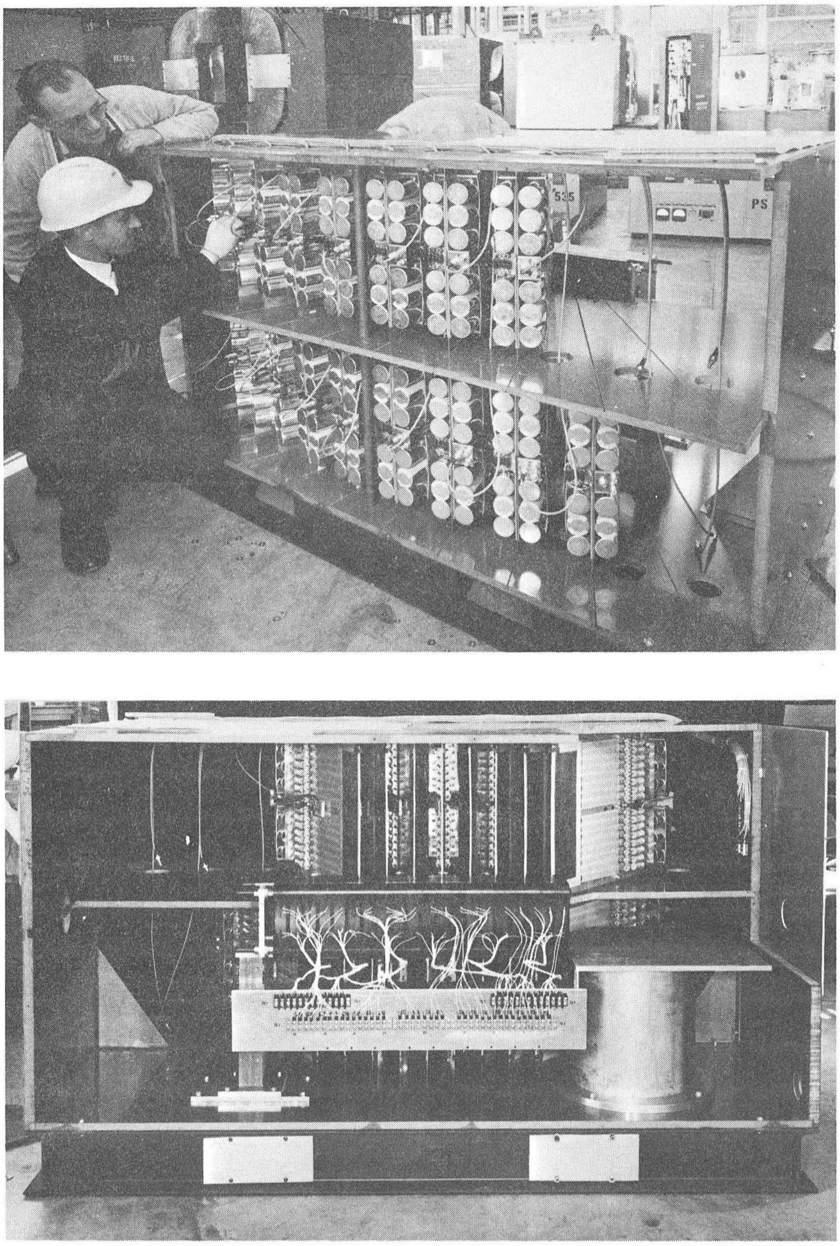

Fast field,
rise time
5μ sec
Sum of fast and
slow fields
Fall time
1 - 2 msec
Slow field
Deflection (G - in.)
Time
MUB-10539

Fig. 2



ZN-5509

Fig. 3

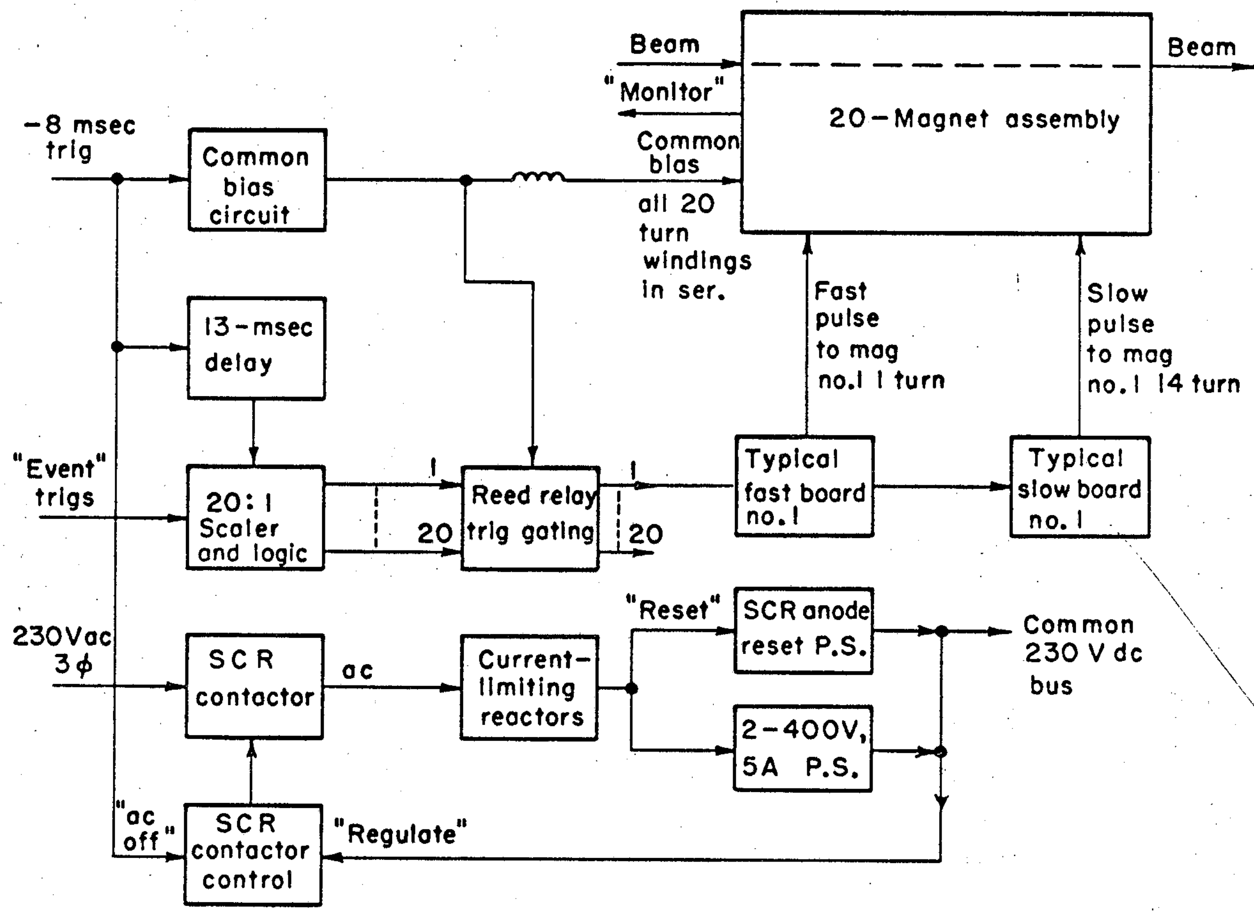

Beam
"Monitor"
Common bias
all 20 turn windings in ser.
20-Magnet assembly
Beam
-8 msec trig
Common bias circuit
13-msec delay
"Event" trigs
20:1 Scaler and logic
1
20
Reed relay trig gating
1
20
Fast pulse to mag no.1 1 turn
Slow pulse to mag no.1 14 turn
Typical fast board no.1
Typical slow board no.1
230Vac 3φ
SCR contactor
ac
Current-limiting reactors
"Reset"
SCR anode reset P.S.
2-400V, 5A P.S.
Common 230 V dc bus
"ac off"
SCR contactor control
"Regulate"
MUB-10252

Fig. 4

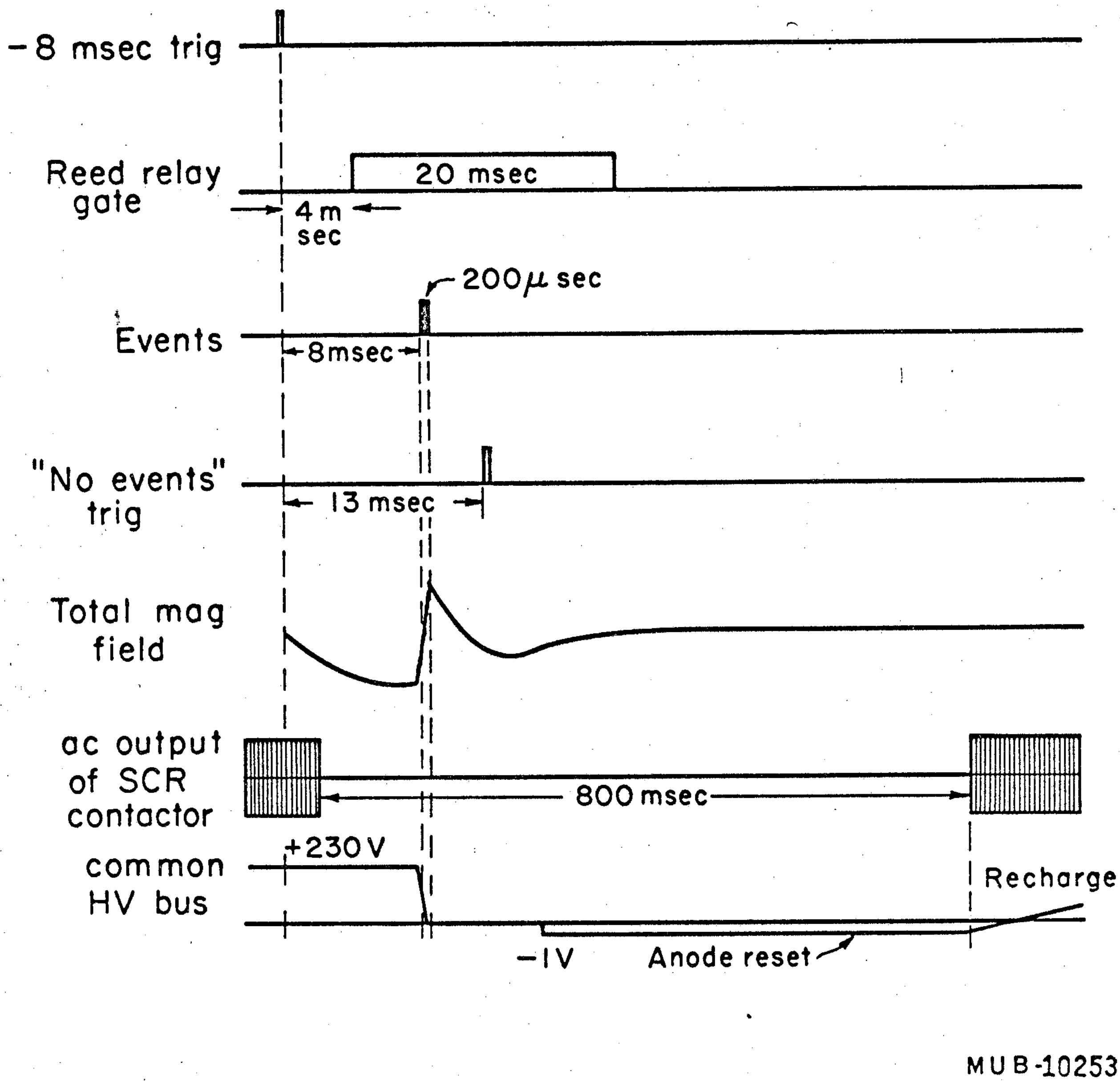

-8 msec trig
Reed relay gate
20 msec
4 m sec
200μ sec
Events
8msec
"No events" trig
13 msec
Total mag field
ac output of SCR contactor
800 msec
+230V
common HV bus
Recharge
-1V
Anode reset
MUB-10253

Fig. 5

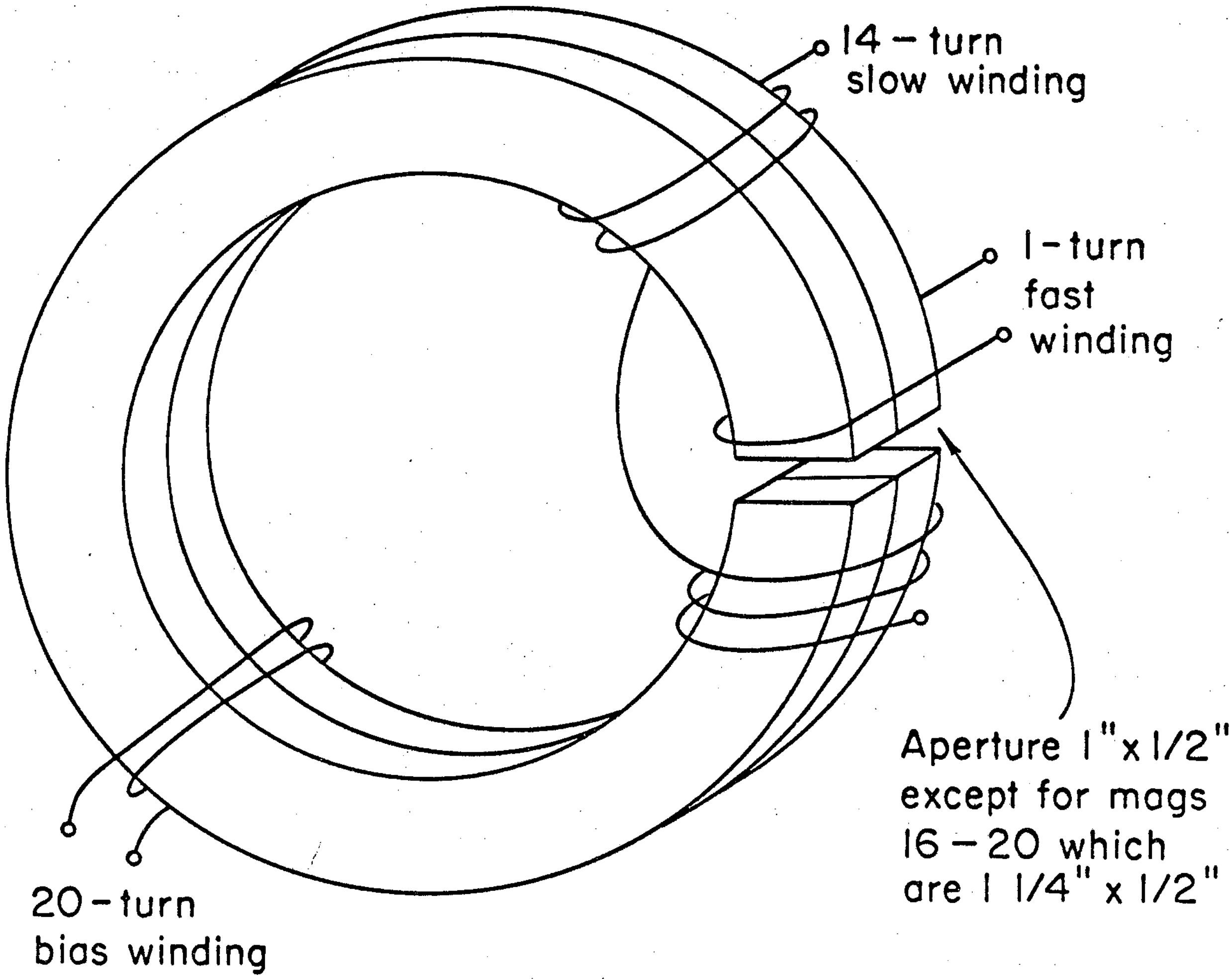
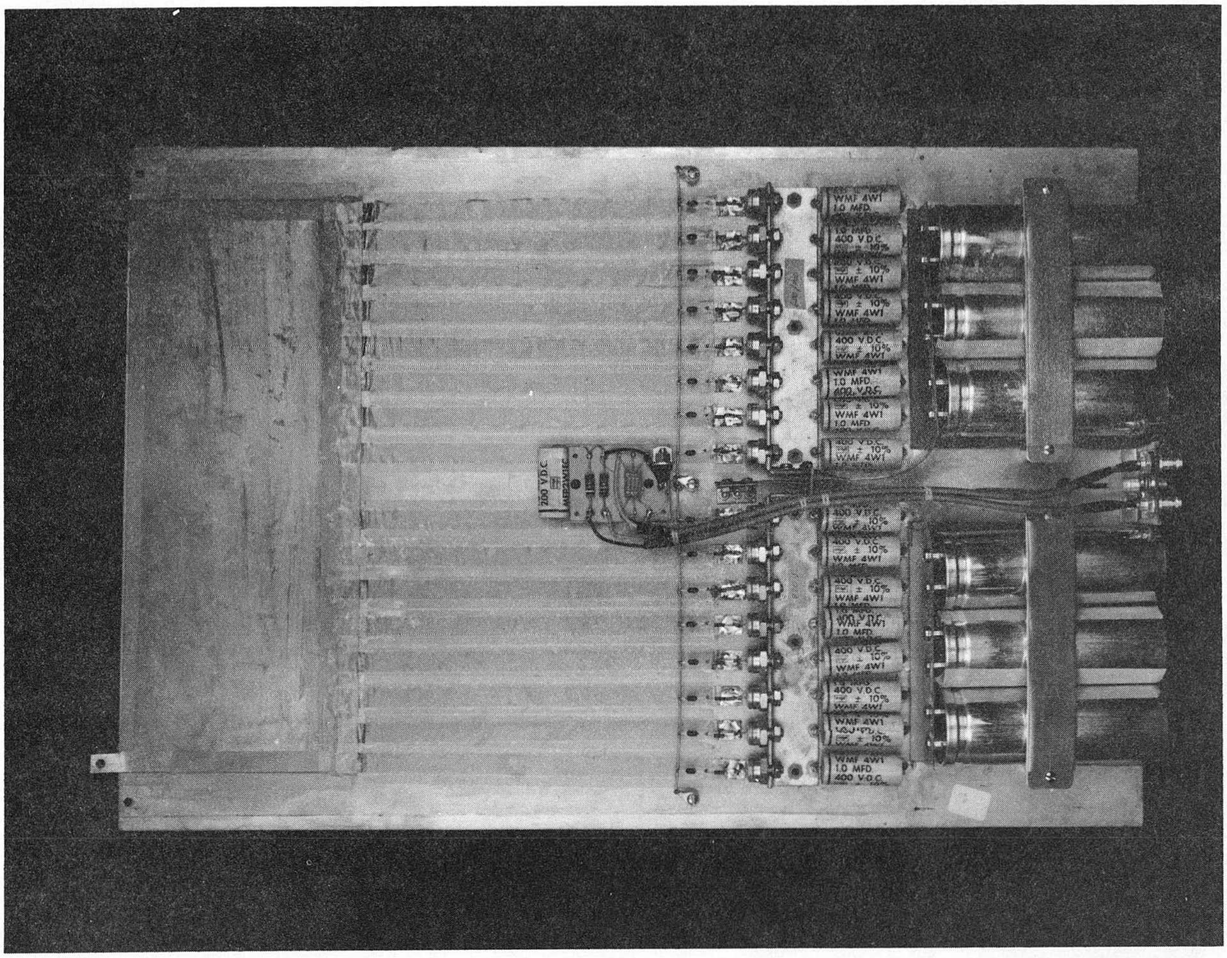
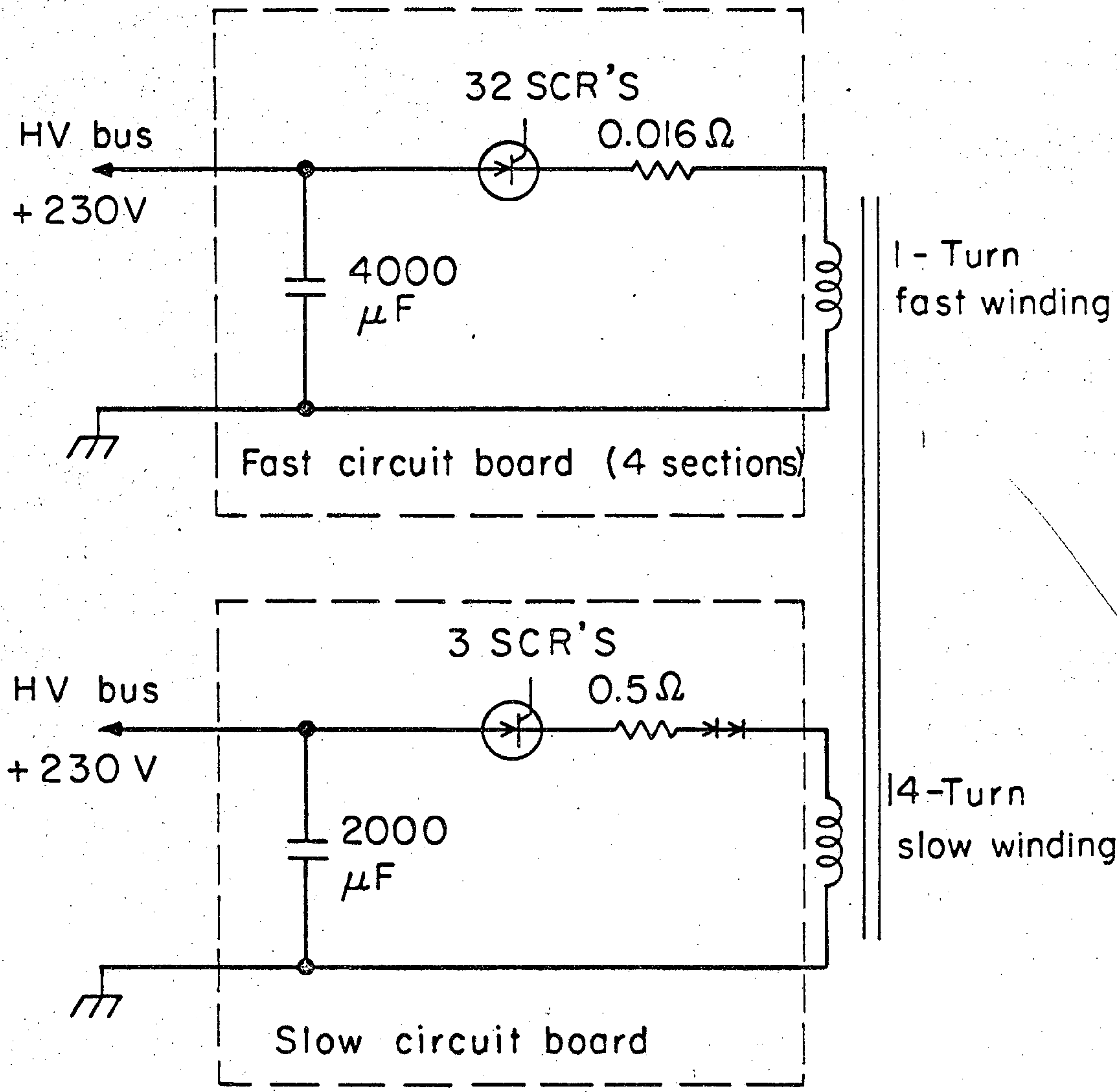

14 - turn
slow winding
I - turn
fast
winding
Aperture I"x I/2"
except for mags
16 - 20 which
are I I/4" x I/2"
20 - turn
bias winding
MUB-10254

Fig. 6



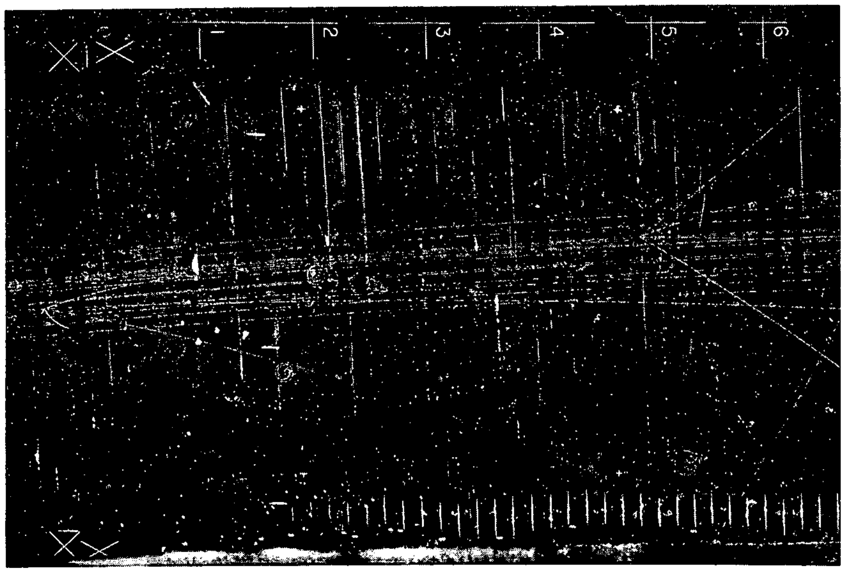
ZN-5510

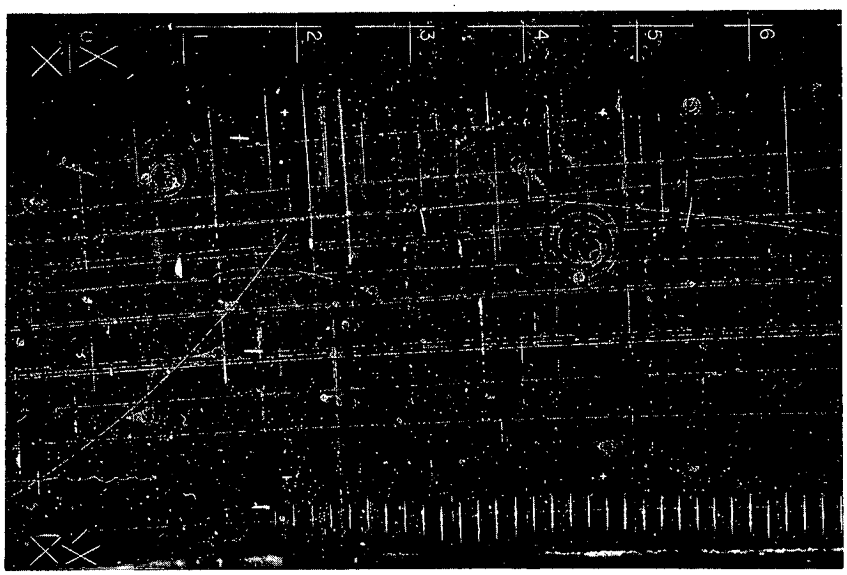
Fig. 7



MUB-10540

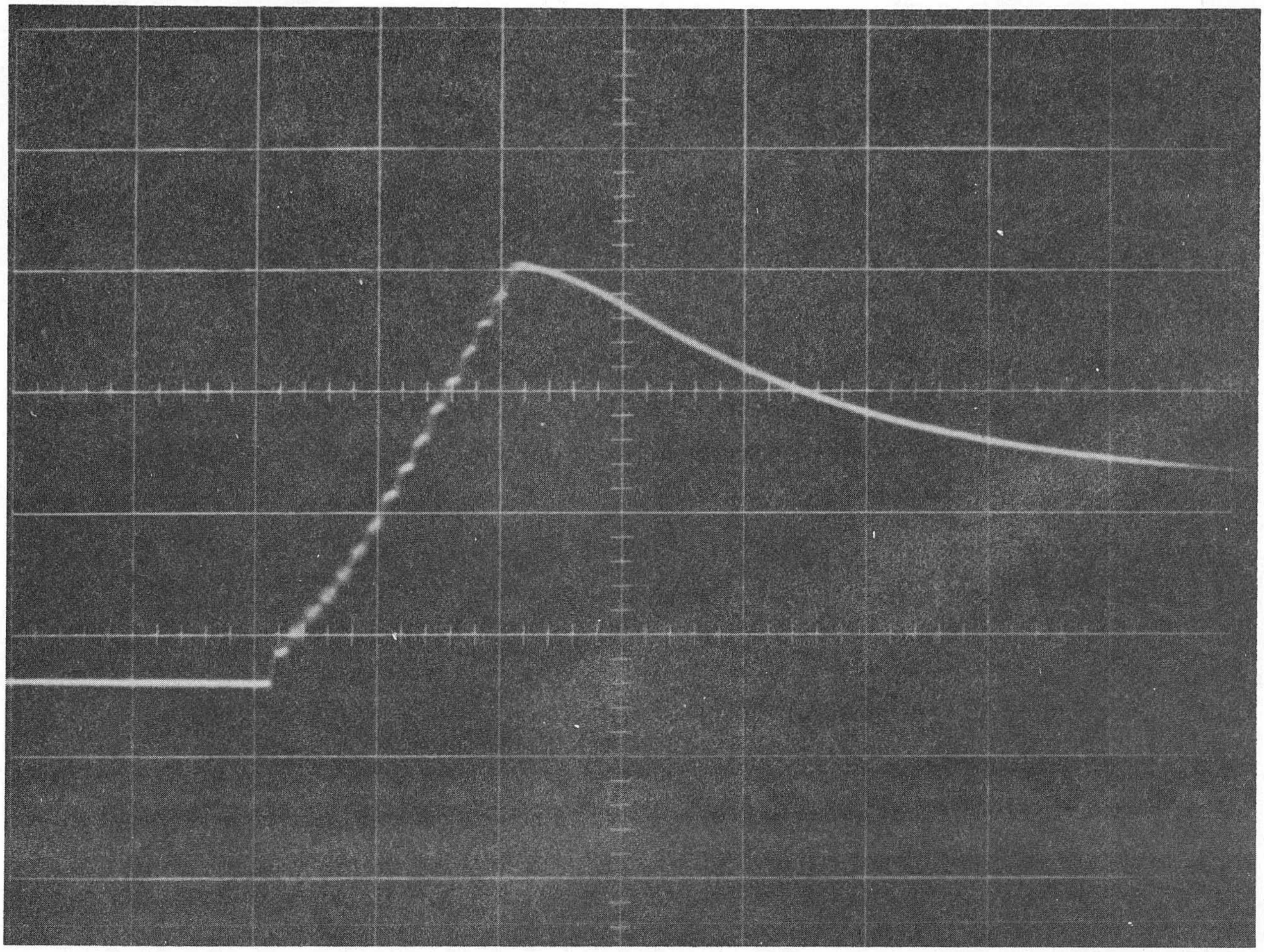
Fig. 8





ZN-5511

Fig. 9



ZN-5512

Fig. ~~11~~ 10