



MAGNETIC FIELD MEASUREMENT ON THREE-WAY SPLIT MAGNET

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Magnetic measurements of proton's three-way split magnet #1 were completed on March 20, 1975.

The magnet has a 10-ft long core with three apertures for the beam; see Figures 1 and 2. The central aperture is 1.24 in high and 1.75 in wide and is used to pass beam without any deflection. The other two apertures lie one on each side of the central hole. Each of these apertures are 1.24 in high and 3.2 in wide and are oppositely offset horizontally from the magnet center by .6 in. The magnet has two separate coil and water systems, one for the top gap and one for the bottom gap. Each coil system consists of 16 turns.

Various measurements were made with both coils energized, top coil energized only, and bottom coil energized only. In all cases the power leads were connected with a polarity such that the magnetic field for each gap was directed towards the center.

The probe consisted of one loop of 4 mil diameter tungsten wire stretched around two .4997 in diameter crystals. For field shape measurements, a bucking coil was used to compensate for any power supply instabilities.

Measuring system parameters:

R integrator = 30,130 $\Omega$  (9949 $\Omega$  for field shape)

C integrator = 1.0 $\mu$ f ( $\pm$ .1%)

R probe = 82 $\Omega$

R bucking coil = 2 $\Omega$

Excitation

Excitation values were obtained by turning the power supply on then off and using the integrated voltage to find  $\int B(x=0)dl$ . Excitation values were also obtained by using a Hall Probe located approximately 18 inches inside the magnet. Field direction was chosen as shown in Figure 2.  $\int B(x=0)dl$  data is given below and is plotted in Figure 3.

Excitation Data ( $\int B[x=0]dl$ )

	Current (amperes)	$\int Bdl$ (kG-m) Both Coils Energized	$\int Bdl$ (kG-m) Top Coil Energized	$\int Bdl$ (kG-m) Bottom Coil Energized
Top Gap				
	200	3.839	3.872	-.010
	400	7.783	7.807	-.020
	600	11.689	11.713	-.028
	800	15.617	15.653	-.037
	1000	19.458	19.494	-.053
	1100	21.310	21.461	-.059
Bottom Gap				
	200	3.870	-.010	3.892
	400	7.805	-.019	7.812
	600	11.711	-.028	11.740
	800	15.638	-.037	15.682
	1000	19.453	-.054	19.551
	1100	21.324	-.057	21.447

Excitation Data (Hall Probe approximately 18 in inside magnet)

Current (amperes)	Field (kG) Both Coils Energized	Field (kG) Top Coil Energized	Field (kG) Bottom Coil Energized
Top Gap			
0	.011	.009	.004
200	1.263	1.265	-----
400	2.529	2.529	-----
600	3.799	3.802	.002
800	5.063	5.065	-----
1000	6.314	6.330	-----
1100	6.923	6.959	.001
Bottom Gap			
0	.012	.011	.016
200	1.272	.009	1.277
400	2.543	.008	2.540
600	3.810	.009	3.806
800	5.080	.009	5.069
1000	6.329	.008	6.333
1100	6.942	.007	6.963

Field Shape (Percent difference from center)

Note: For brevity, symbolism such as P=T+B indicates that power was supplied to both top and bottom coils. Field shape measurements were made at the midplane of the gap at currents of 600 and 1100 amperes.

Field shape measurements were obtained by moving the stretched wire probe across the gap and noting the change in voltage at different positions using a bucking coil to compensate for power supply fluctuations. This change in voltage was then divided by the central

(x=0) voltage (induced by turning off the power supply) hence yielding the percent change in the field. Note that the large percent changes are associated with the small fields obtained by measuring one gap and energizing the opposite gap. See Figures 4 and 5 for graphical presentation of the data below.

x =	1.00 %	.75 %	.50 %	.25 %	.00 %	-.25 %	-.50 %	-.75 %	-1.00 %	$\int B(x=$ dl kG-m
<u>Top Gap</u>										
I=600 P=T+B	.054	.032	.026	.016	.000	-.014	-.032	-.051	-.060	11.6
I=1100 P=T+B	.093	.058	.046	.027	.000	-.023	-.043	-.065	-.075	21.3
I=600 P=T	.001	-.011	.000	.004	.000	-.011	-.024	-.049	-.069	11.7
I=1100 P=T	.015	.001	.007	.007	.000	-.008	-.020	-.039	-.050	21.4
I=600 P=B	-20.514	-15.107	-9.356	-4.120	.000	4.893	7.468	9.013	10.729	-0
I=1100 P=B	-16.550	-13.256	-8.892	-4.611	.000	4.693	8.234	11.445	14.162	-0
<u>Bottom Gap</u>										
I=600 P=T+B	-.074	-.063	-.038	-.018	.000	.018	.031	.037	.060	11.7
I=1100 P=T+B	-----	-----	-.048	-.023	.000	.025	.046	.059	.090	21.3
I=600 P=T	7.458	6.937	4.769	1.908	.000	-2.255	-5.116	-8.759	-12.574	-.0
I=1100 P=T	14.076	11.595	8.482	4.241	.000	-4.557	-9.610	-14.708	-20.347	-.0
I=600 P=B	-.071	-.058	-.030	-.012	.000	.015	.021	.016	-.198	11.7
I=1100 P=B	-.052	-.049	-.030	-.014	.000	.014	.023	.020	-.216	21.4

$\int Bdl$  Off Midplane

$\int Bdl$  and field shape measurements were made with the stretched wire probe in the top gap on a plane .15 in from the surface of the gap (surface near center of magnet). Only the top coils were energized.

The values given for field shape were measured without a bucking coil, since the distance between the probe and the gap surface was too small to accommodate the bucking coil. Graphical representation of this data is given in Figure 6.

Top Gap

Excitation

Current (amperes)	$\int B(x=0)dl$ (kG-m)
200	3.884
400	7.790
600	11.703
800	15.624
1000	19.508
1100	21.436

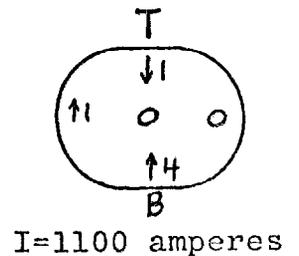
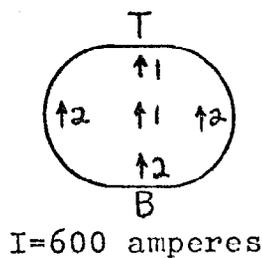
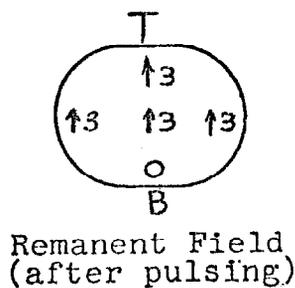
Field Shape (Percent difference from center)

x =	1.00 %	.75 %	.50 %	.25 %	.00 %	-.25 %	-.50 %	-.75 %	-1.00 %
I=600 P=T	-.139	-.055	-.013	.001	.000	-.006	-.027	-.078	-.166
I=1100 P=T	-.118	-.042	-.009	.001	.000	-.013	-.036	-.078	-.147

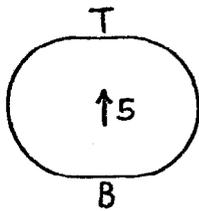
Hole Measurements

Quick field measurements of the central aperture were made with a Hall Probe approximately 18 in inside the magnet for various bus configurations and currents. Fields shown are in gauss.

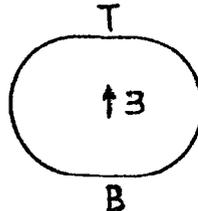
Both Coils Energized



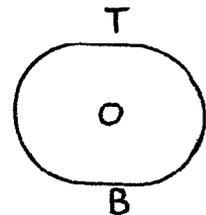
Top Coil Energized



Remanent Field  
(after pulsing)

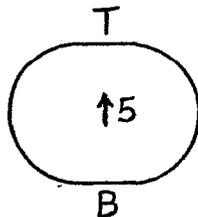


I=600 amperes

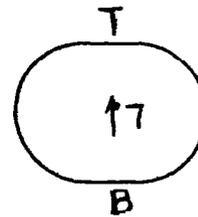


I=1100 amperes

Bottom Coil Energized



I=600 amperes



I=1100 amperes

Inductance

Inductance was measured at 50 and 1000 Hertz for the top coil and for the bottom coil.

Top Coil

$$50 \text{ Hz} \begin{cases} L_s = 4.11 \text{ mh} \\ Q = 6.45 \end{cases}$$

$$1\text{k Hz} \begin{cases} L_s = 2.86 \text{ mh} \\ Q = 5.00 \end{cases}$$

Bottom Coil

$$50 \text{ Hz} \begin{cases} L_s = 4.17 \text{ mh} \\ Q = 6.50 \end{cases}$$

$$1\text{k Hz} \begin{cases} L_s = 2.87 \text{ mh} \\ Q = 4.97 \end{cases}$$

Water Flow

The top and bottom cooling systems were connected in parallel. At 160 p.s.i. the flow rate was 5.4 gallons per minute.

Equipment Used

Dana Model 5900 D.V.M. Fermilab #12837

Dana Model 5500 D.V.M. Fermilab #2435

General Radio Inductance Bridge, Model 1633-A, serial #826

Varian Model 620i Computer Fermilab #2448

Philbrick Integrator

F.W. Bell Model 811 Gaussmeter Fermilab #10864

F.W. Bell Hall Probe Model HTL8-0618 (.25%)



NATIONAL ACCELERATOR LABORATORY  
**ENGINEERING NOTE**

SECTION: PROTON 1 1/1  
0621.000

SUBJECT: 3-Way Split Magnet (1.24X3X120)  
NAME: SCS/CTM/EBT  
DATE: 5/22/74  
REVISION DATE:

MAGNETIC FIELD

CENTRAL FIELD 7.0  
GOOD FIELD 2.8" x 1.125"  
FIELD QUALITY ±.15%

POWER:

Dc Power 23.3kW/gap  
Current 1100A/gap  
Voltage 21.1V/gap  
Copper Temp. Ave.  
Resist @ Temp. .0192Ω/gap  
Time Constant ~~5.3mH/gap~~  
Inductance 5.3mH/gap

COOLING:

Water Temp. Rise 11.2°  
Total Flow 2.6 GPM  
Pressure Drop 200 psi

COIL DATA:

Conductor O.D. 0.46" x 0.46"  
Hole Diameter 0.23"  
Turns 16/gap  
Water Paths 2/gap  
Ave. Turn Length 260'

WEIGHTS: (est.)

Coil & Insul. 445 lb  
Core 6250 lb  
Support 200 lb  
Total Magnet Assembly 6900 lb

ALCULATION CONSTANTS:

B<sub>kg</sub> =  
θ<sub>mr</sub> =

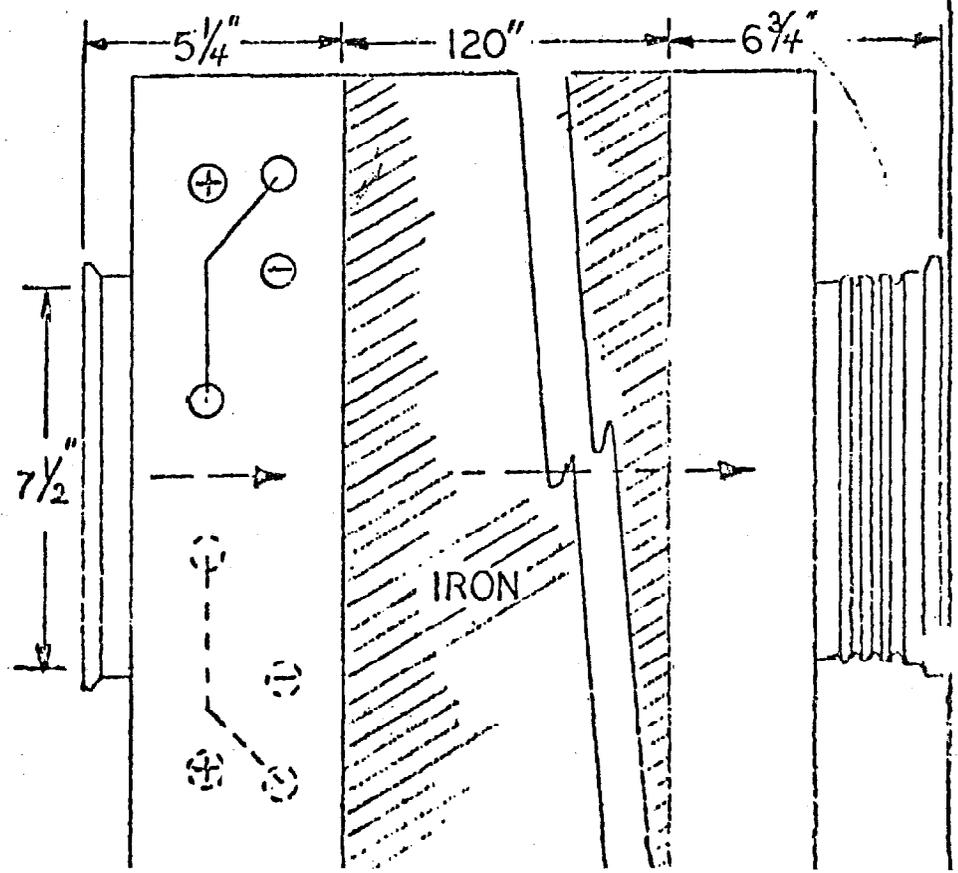
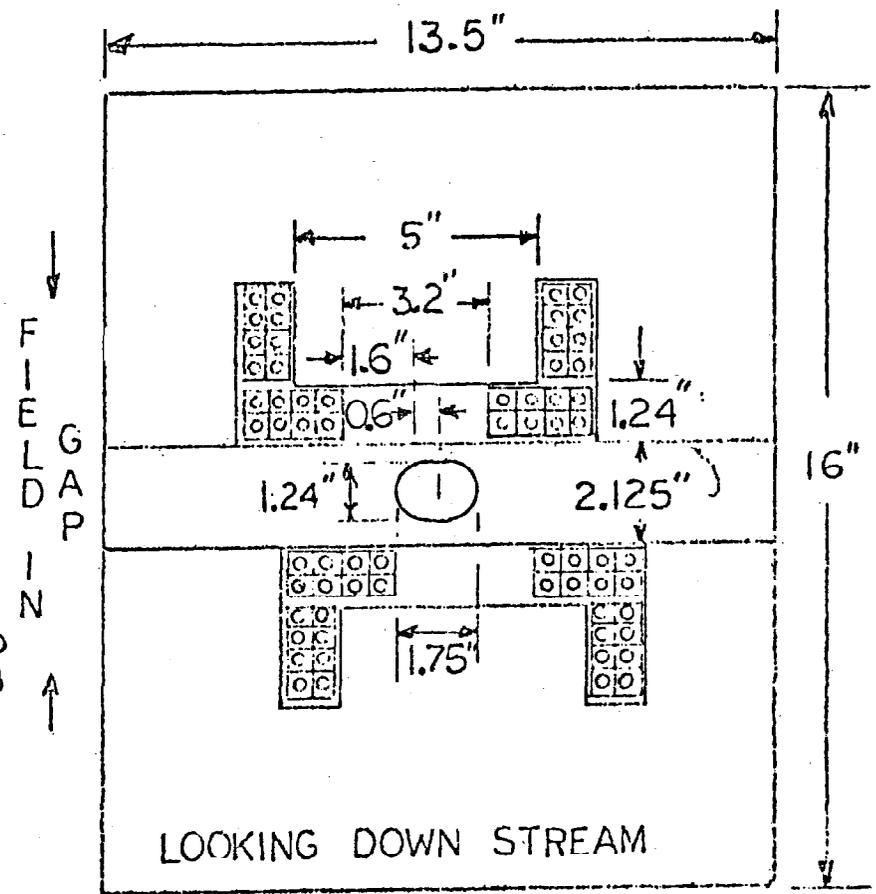


Figure 1

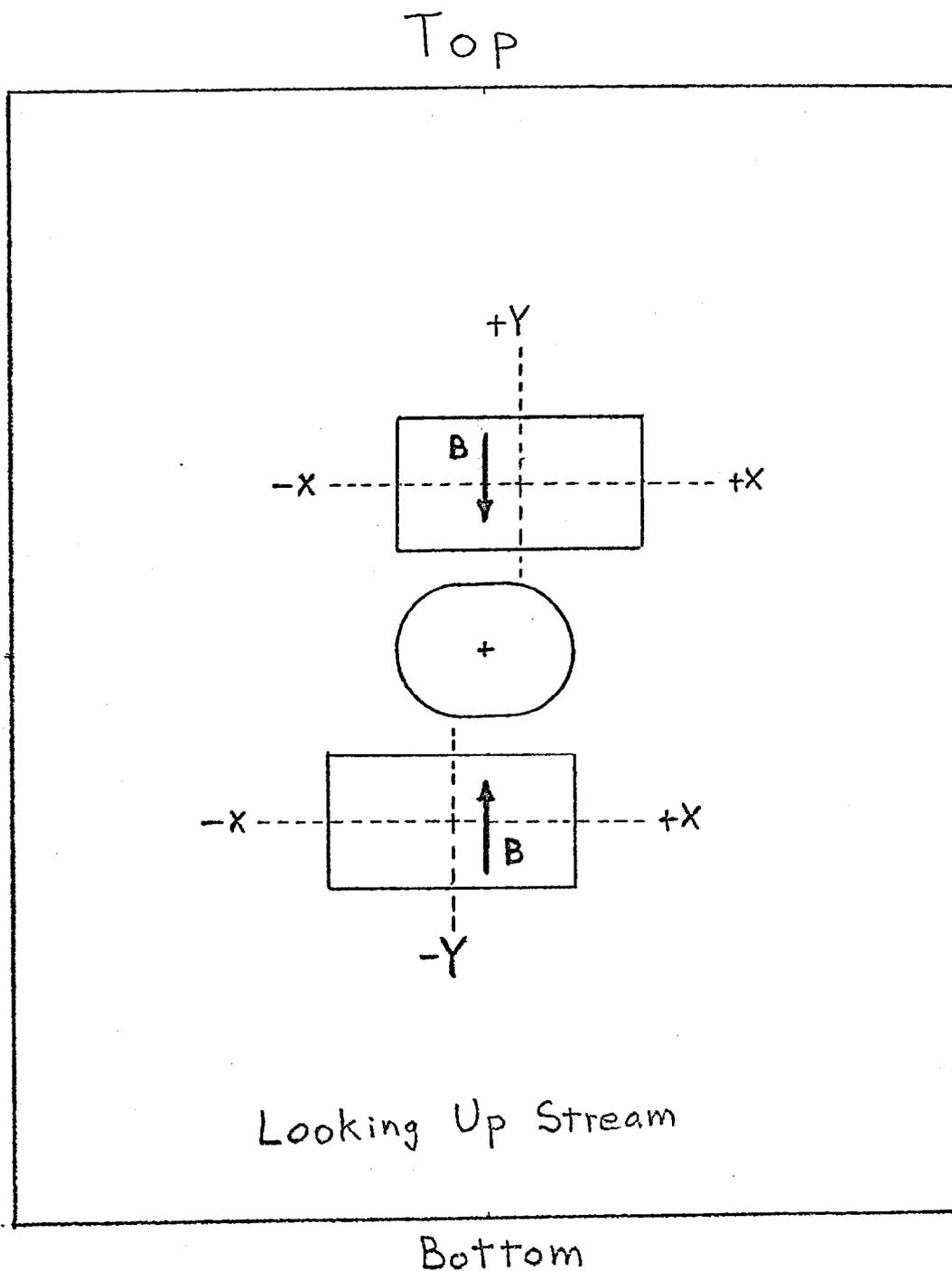


Figure 2. X-Y Axis Orientations Used in Measurements of 3-Way Split Magnet #1

# Excitation Curve For 3-Way Split Magnet #1 (Top Gap)

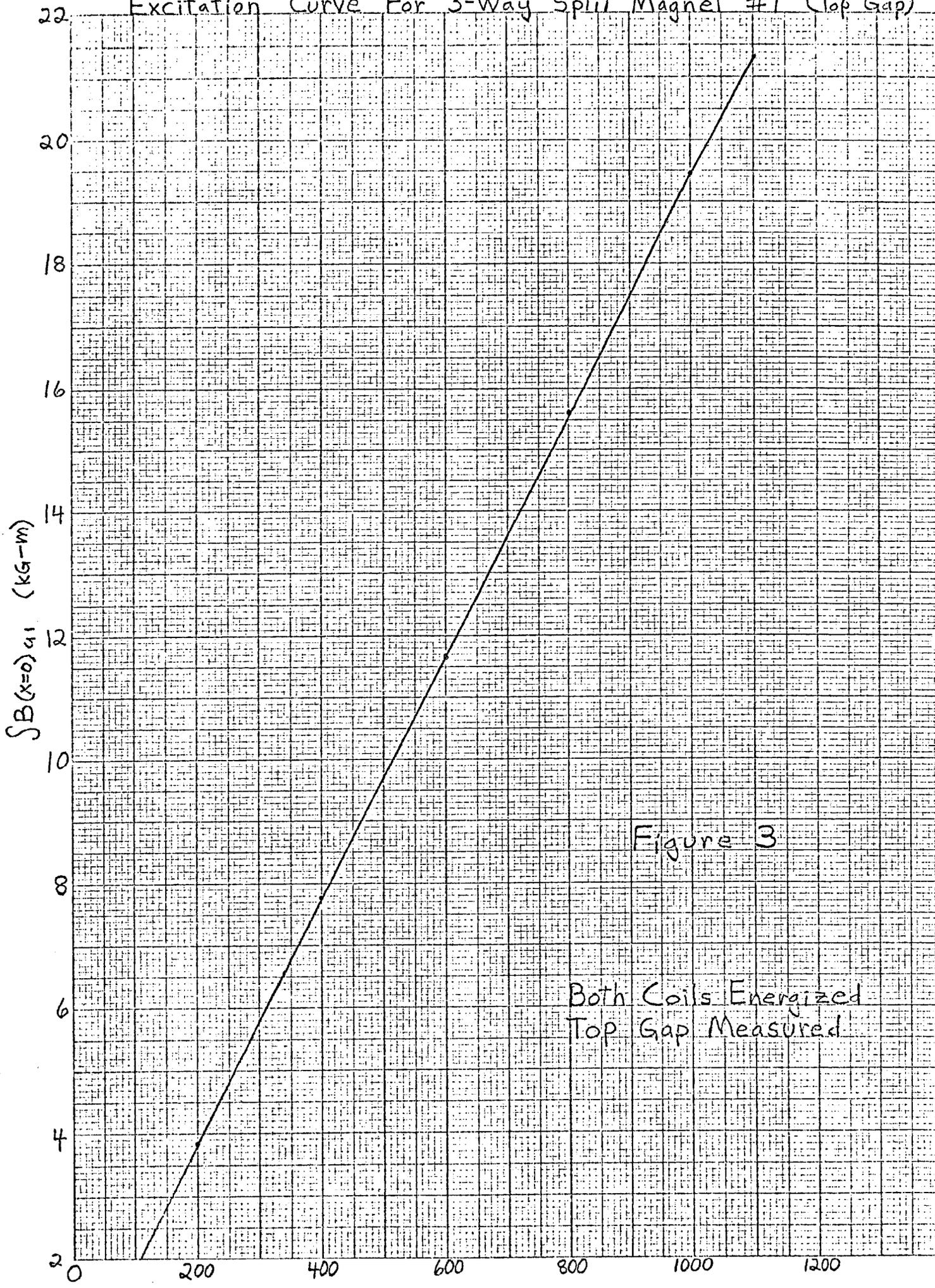
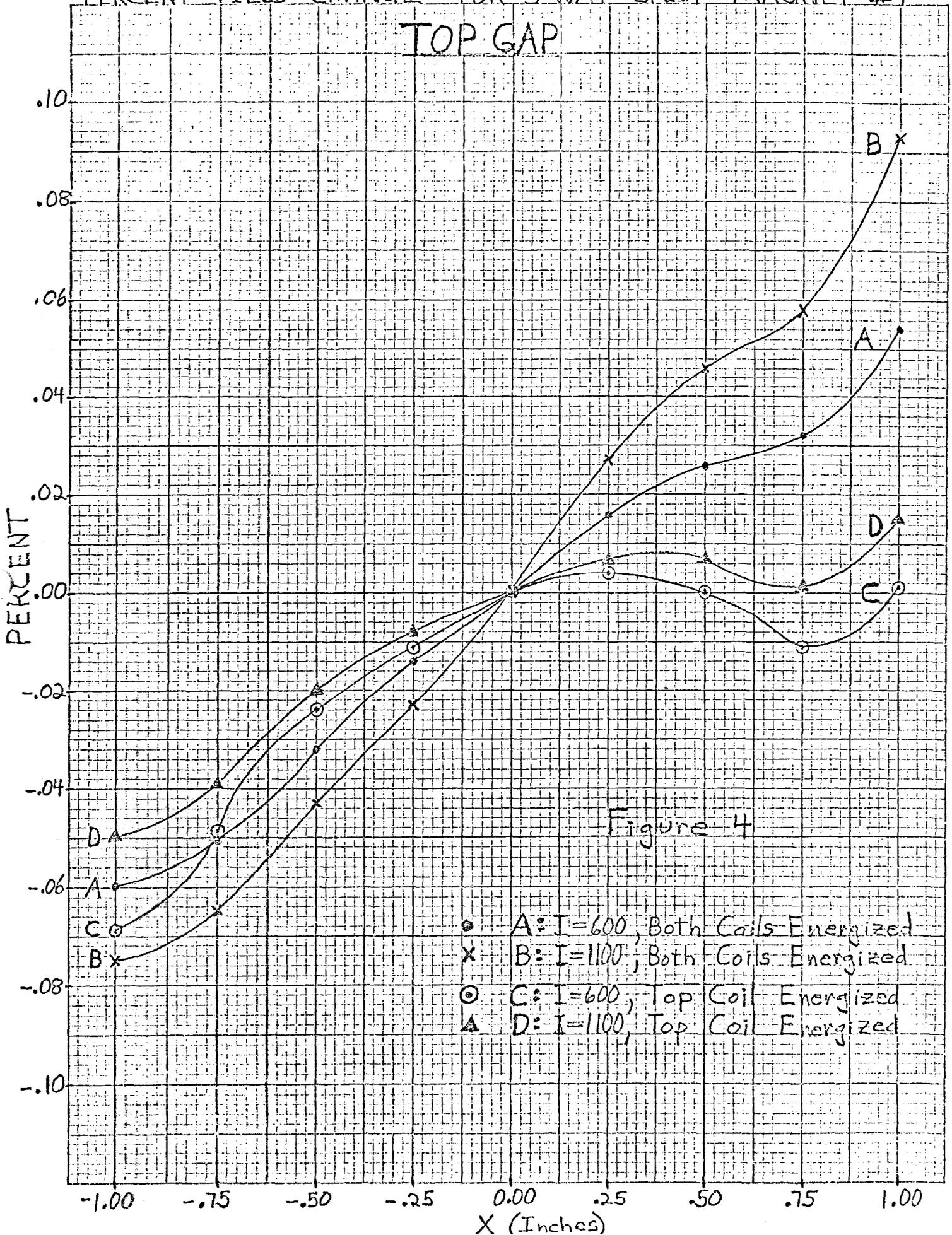


Figure 3

Both Coils Energized  
Top Gap Measured

PERCENT FIELD CHANGE FOR 3-WAY SPLIT MAGNET #1

TOP GAP



# PERCENT FIELD CHANGE FOR 3-WAY SPLIT MAGNET #1

## BOTTOM GAP

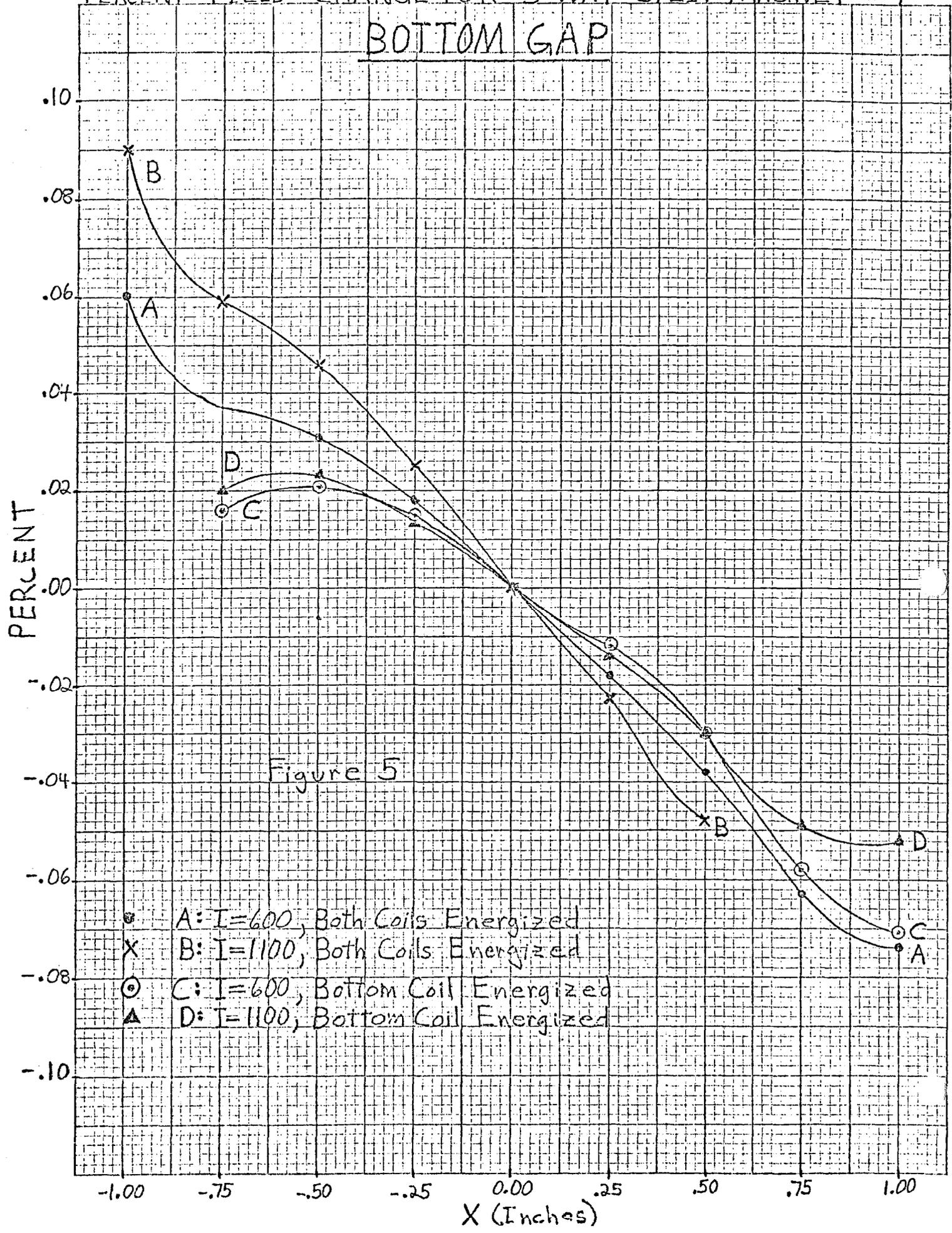


Figure 5

- A: I=600, Both Coils Energized
- X B: I=1100, Both Coils Energized
- ⊙ C: I=600, Bottom Coil Energized
- ▲ D: I=1100, Bottom Coil Energized

PERCENT FIELD CHANGE FOR 3-WAY SPLIT MAGNET #1

TOP GAP (.15" above surface)

Top Coil Energized

o = 600 amperes

x = 1100 amperes

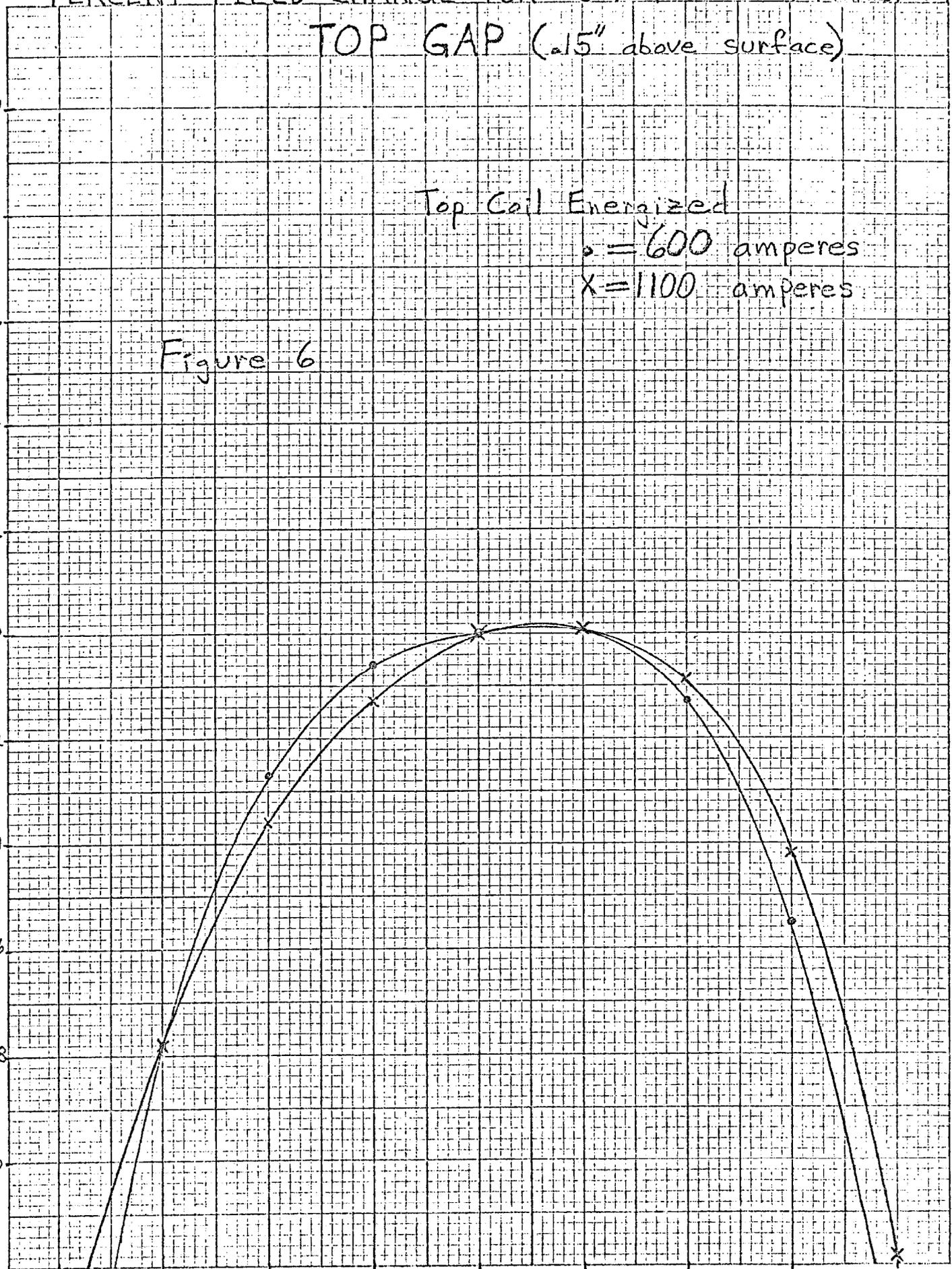
Figure 6

PERCENT

.10  
.08  
.06  
.04  
.02  
.00  
-.02  
-.04  
-.06  
-.08  
-.10

-1.00 -0.75 -0.50 -0.25 .00 .25 .50 .75 1.00

X (Inches)



-1.00 -0.75 -0.50 -0.25 .00 .25 .50 .75 1.00