Hall Effect

หนังสืออ้างอิงสำหรับเขียนทฤษฎีและเพื่อค้นคว้าทั่วไป

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HALL EFFECT

1. INTRODUCTION

The Hall Effect Probe is a semiconductor device used to demonstrate the "Hall effect," and to develop and measure the "Hall voltage." By measuring the Hall voltage, it is possible to measure the strength of a magnetic field without using a fluxmeter. Due to its compactness, the probe is ideal for making measurements even in the narrow gap between the pole pieces of a magnet.

In addition to laboratory demonstrations, the probe can be used industrially in many types of instrument and analog computer applications.

2. DESCRIPTION

2.1 General: The Hall Effect Probe consists of a 0.15 mm, or 0.006-inch, thick slab of indium arsenide compound cemented to a 3-5/8-inch long printed circuit element. A 70-inch conductor cable carries four leads to the circuit element, which terminates in the Hall Generator. The printed circuit board is encapsulated in epoxy resin to protect the Hall Generator and to prevent shorting of the leads. The slab is mounted on a 6-inch long bakelite handle. The arrangement of the circuit and its leads is shown in Fig. 1.

An optional Control Unit, Cenco No. P67847, is available for use with the Hall Effect Probe. The control unit incorporates the circuitry and power supply necessary for operation of the probe.

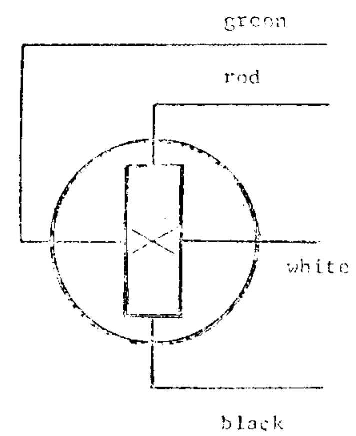


FIG. 1 - CIRCUIT OF THE HALL GENERATOR

2.2 Electrical Characteristics

Control Current, maximum at 25°C, mA.	500
Nominal Working Current, mA.	300
internal Resistance, Ohm	1
Hall Constant, min.	100
Hall Null Voltage, millivolts	10
Flux Density Range, Kilogauss	0-I0
Load Resistance for maximum linearity, ohms	I0
Load Resistance for maximum power transfer, ohms	2
Frequency Response, megacycle	I

The Hall Effect Probe is suited for operation at ambient temperatures ranging from -65 to + 75° c.

3. THEORY

Because the Hall coefficient is directly related to the mobility of current carrying (electrons)- a phenomenon which has played an important role in our understanding of electrical conductivity in semiconductors - a study of the "Hall effect" become of paramount importance.

Hall Effect

If a current-carrying conductor placed in a magnetic field is positioned so that the direction of the magnetic field is perpendicular to the direction of the current flow, a transverse electric potential (Hall Voltage) and a gradient electric field (Hall Field) will be developed across the conductor. This is known as the Hall Effect, from the scientist who discovered it first in 1879.

The Hall voltage will appear between the sides of the conductor; and the Hall field will be proportional to the product of the current density and the magnetic field.

The Hall voltage arises from the deflection (by the applied magnetic field) of electrical charge carriers moving toward the sides of the conductor. The mobility or the charge carriers, the carrier density, and the thickness of the conducting mate are three variables affecting the magnitude of the Hall voltage -- the higher the carrier mobility and the thinner the strip, the higher will be the Hall voltage. The other variables are the magnetic field and the control current.

In the equilibrium state, the electric-field intensity **E**, due to the Hall effect, must exert a force on the carrier which just balances the magnetic force, or

$$eE = Bev \qquad (1)$$

where **e** is the magnitude of the charge on the carrier, **B** is the intensity of the magnetic field, and **v** is the drift speed.

The electric field intensity times distance equals the potential difference between the Hall voltage probes. This potential is the Hall voltage.

Therefore,
$$E = \frac{V_H}{d} \qquad (2)$$

where E = field intensity, V_H = Hall voltage, d = distance between Hall voltage probes.

Also,
$$J = \rho v = \frac{I}{dw}, \quad v = \frac{I}{\rho\, dw} \qquad (3)$$

where **J** is the current density, ρ is the charge density, **w** is the width of the specimen in the direction of the magnetic field, and **I** is the total current value. Combining these relationships (1), (2), (3) we find

$$V_H = Ed = Bvd = \frac{BI}{\rho\, w} \qquad (4)$$

Thus, the Hall voltage is directly proportional to the magnetic field intensity and to the total current value applied to the specimen, and inversely proportional to the charge density and the thickness of the specimen.

The Hall Effect Probe can be calibrated to read directly the magnetic field intensity. Solving for B, we find that

$$B = \frac{V_H\, w\rho}{I} \qquad (5)$$

4. SETUP

Connect the Hall Effect probe to its current source and to an electronic millivoltmeter, Cenco No.82430, as shown in Fig. 2. A Student Potentiometer, Cenco No. 83411, may be used in place of the millivoltmeter for voltage measurements. The Hall voltage is best measured when no current is being drawn from the Hall terminals. Set a 30-ohm rheostat to its highest resistance and make the final connections. Adjust the current value so as not to exceed 500 mA. For best results, the recommended working current should be around 300 mA. Use of the Cenco Control Unit (P67847) would greatly facilitate the setting up and use of the Hall Effect Probe.

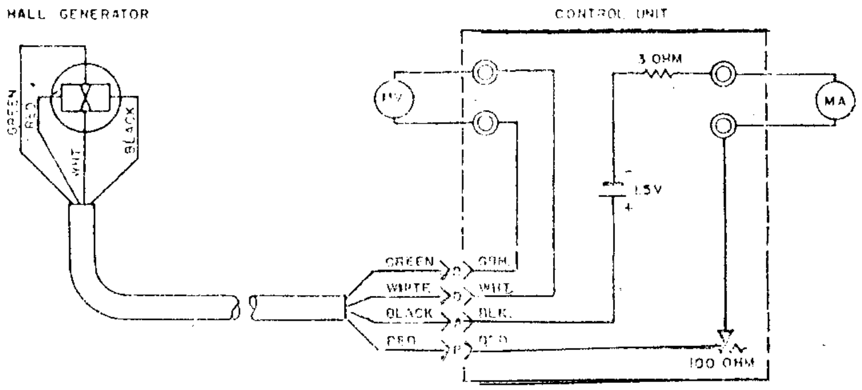


FIG. 2 - WIRING DIAGRAM FOR THE HALL EFFECT PROBE SETUP

5. OPERATION

In operation, the Hall Effect Probe multiplies the current flowing through it and the magnetic field perpendicular to it to provide a voltage output proportional to the product of the two electrical quantities.

However, a voltage sometimes appears when the control current is flowing even without applied magnetic field. In Fig. 3, A and B represent probes for measuring the Hall voltage. With no magnetic field applied, the equipotentials are lines perpendicular to the lines of current flow. If A and B are not on the same equipotential, a potential will be measured between them, giving a constant error to the Hall voltage measured. This effect is sometimes referred to as the "IR drop." It appears that there will always be some error due to the IR drop because of the difficulty in exactly aligning the probes.

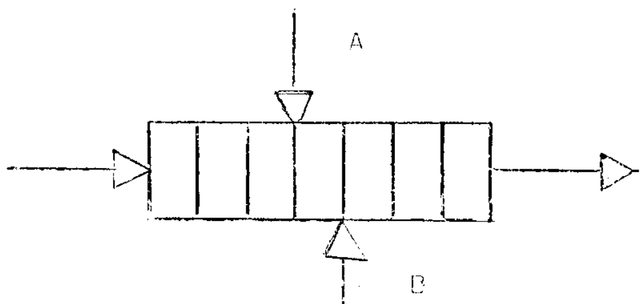


FIG. 3 - MEASURING THE HALL VOLTAGE

6. EXPERIMENTS

No. 1 - Magnetic Field Measurement

Object : To measure the magnetic field strength of an electromagnet.

Procedure : Place the Hall Effect Probe, connected as shown in Fig. 2 between the poles of the electromagnet so that the face is perpendicular to the magnetic field lines. Plot the electromagnet current vs ths Hall voltage for a single control current.

The Magnetic field strength of the electromagnet may be found using a flip coil magnetometer or a test coil with a ballistic galvanometer or fluxmeter. Thus a graph of current vs measured magnetic field can be plotted for the electromagnet, and the Hall Effect probe can than be calibrated to read directly in magnetic field strength. One such set of curves is included as an illustration.

No. 2 - Relation of Hall Voltage to Magnetic Field and Control Current

Object : To show that the Hall voltage is proportional to the product of the magnetic field and the control current.

Procedure : Same setup as for the Magnetic Field Measurement.

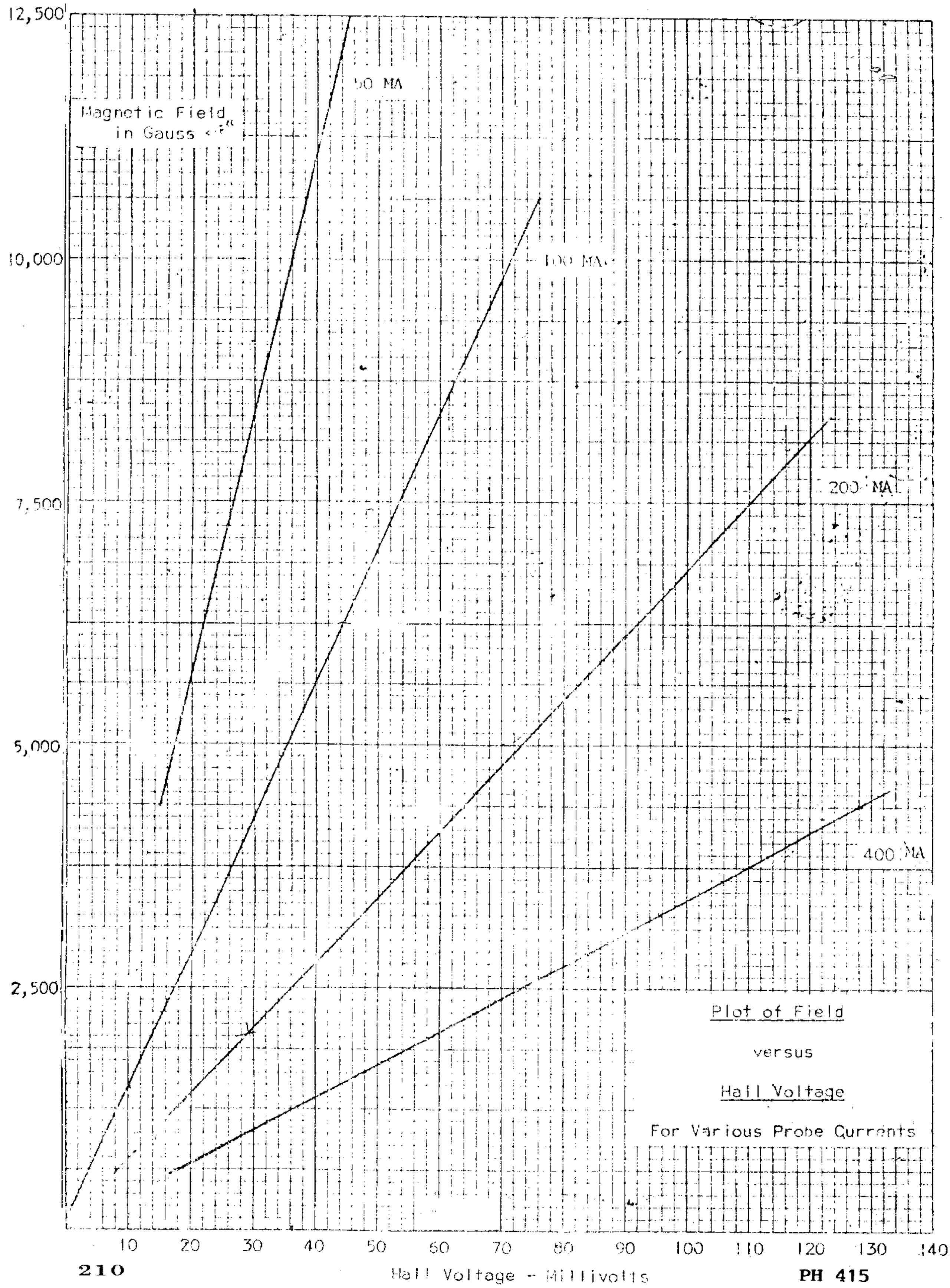
Using the data from the first experiment, plot the electromagnet current vs the Hall voltage for various control currents. Do not exceed a control current of 400 mA.

Any of these curves may be used as the curve for magnetic field measurements as outlined in the first experiment. The curves illustrate the dependence of the Hall voltage on the product of the control current and magnetic field. From this it, can be seen how two electrical quantities may be multiplied directly in an analog computer.

The Hall voltages obtained in the experiment will come close to being linearly dependent upon the product of the magnetic field and the control current. It is assumed here that the permeability of the iron used in the electromagnet is constant and therefore causes the magnetic field to become a linear function of the current.

No. 3 - Rotary Position Indicator

Object : To measure the Hall voltage when the Hall probe is at various angles other than 90° to the applied magnetic field.


12,500
10,000
7,500
5,000
2,500
Magnetic Field in Gauss
50 MA
100 MA
200 MA
400 MA
Plot of Field
versus
Hall Voltage
For Various Probe Currents
10 20 30 40 50 60 70 80 90 100 110 120 130 140
Hall Voltage - Millivolts

Procedure : Using the setup indicated in Fig. 3, rotate the probe through the magnetic lines of force at various angles.

Plot the angle that the probe makes with the field vs the Hall voltage. Notice that the polarity reverses when the probe is rotated through different quadrants.

If the Hall generator cuts the magnetic lines at angles other than 90°, the Hall voltage is a product of the magnetic field times the cosine of the angle that the probe makes with the magnetic field.

No. 4 - Linear Position Indicator

Object : To show how the Hall Effect probe can be used to indicate linear position.

Procedure : Connect the Hall Effect Probe and vary its distance from the magnetic field of a bar magnet; record the Hall voltage for various distances.

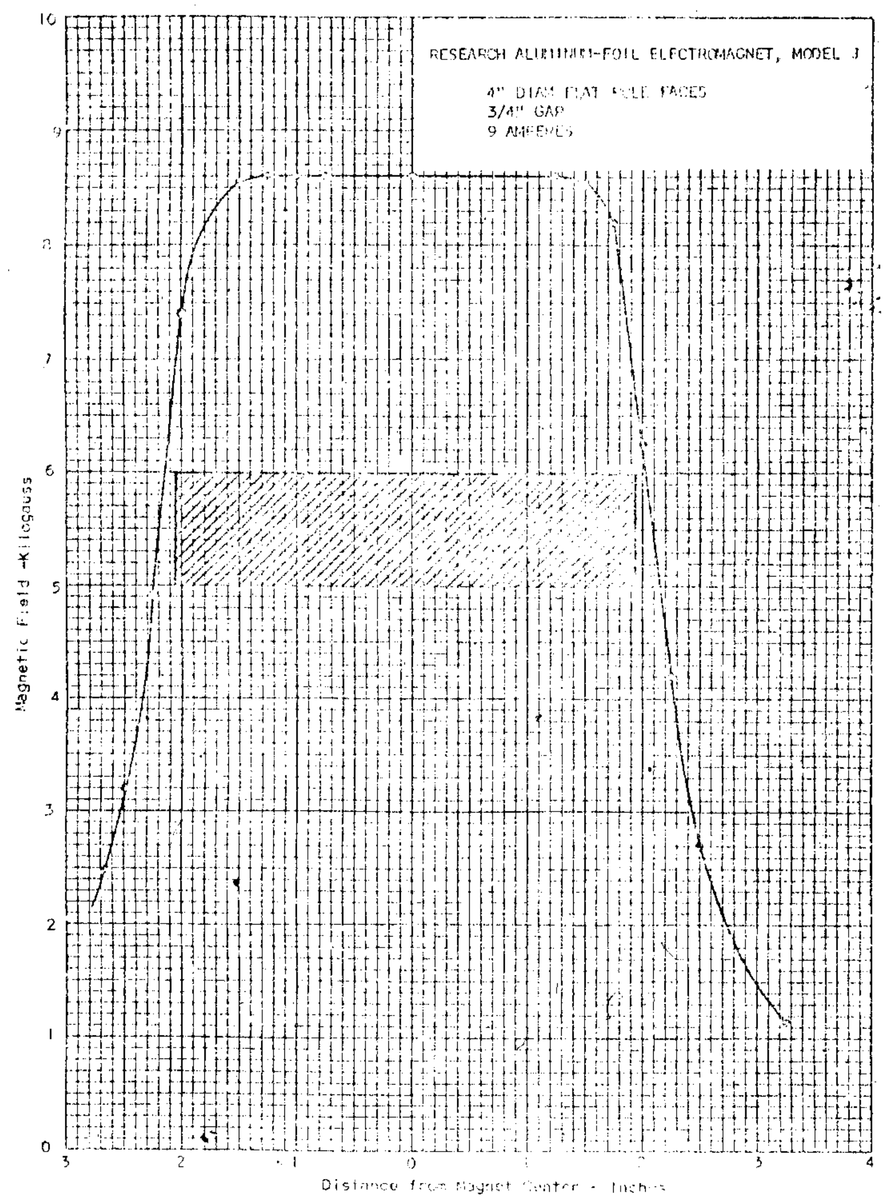
Since the magnetic field strength is a function of distance from a magnetic pole, the Hall voltage can indicate the distance between the probe and the magnet.

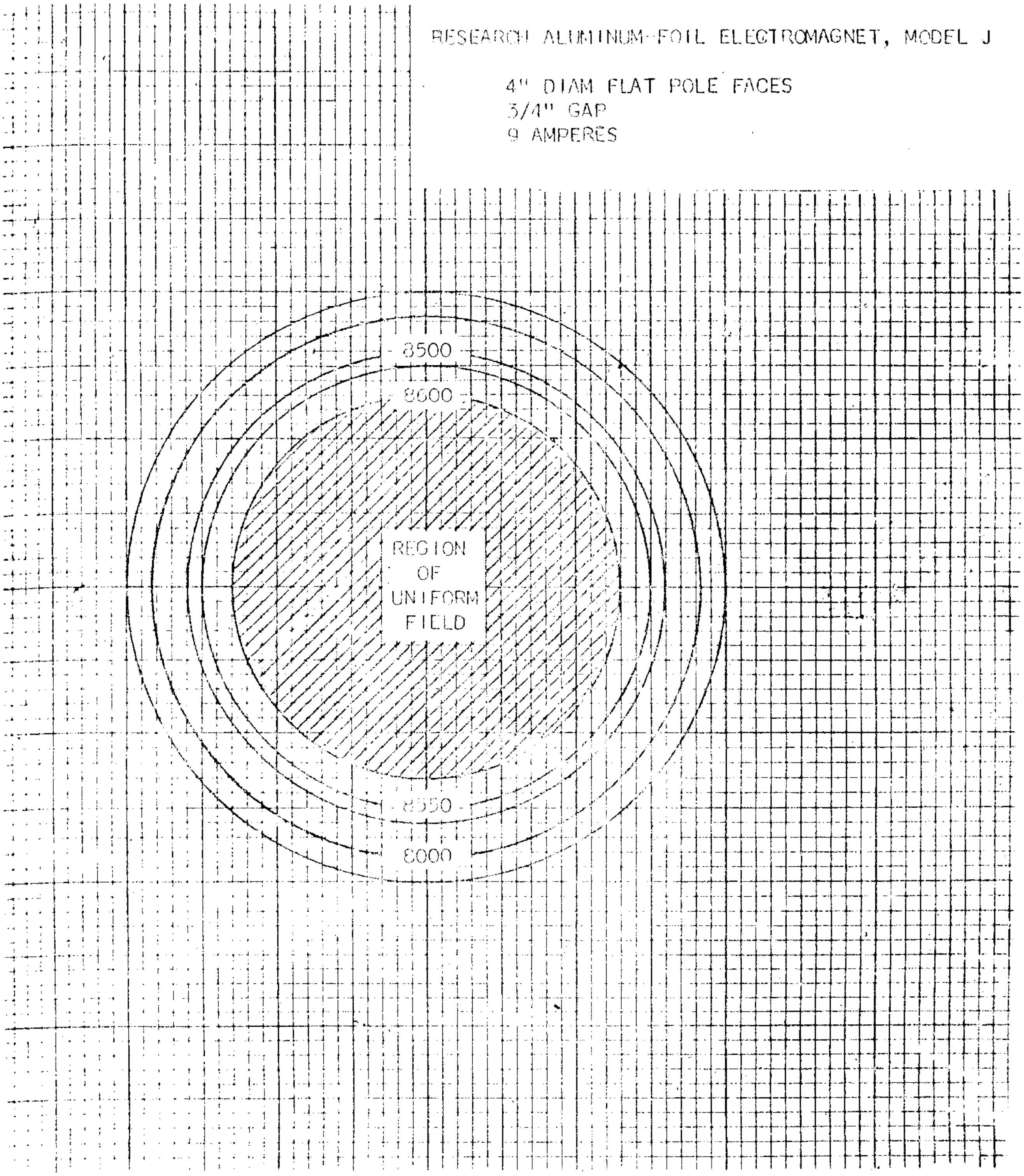
Determine the functional relationship between distance and magnetic field strength.

Experiment 5: Mapping a Magnetic Field

In order to map the magnetic field of a magnet with respect to position in the gap it is necessary to provide a means for accurately locating the Hall Effect Probe in the gap. This may be done by taping a (non-magnetic) scale to the probe handle and clamping the handle of the probe to a support stand. Attach to the magnet a pointer which comes close to the scale. Then the probe can be manipulated in and out of the gap and its position correlated with each reading of the Hall voltage. After one pass through the gap the probe can be raised, or lowered, by a known distance and the procedure repeated.

Data obtained from this method may be displayed in either of two ways. Individual passes can be plotted separately to obtain a series or profieles, or all the data can be combined on one map, with points or equal intensity connected by lines to form a contour representation. The following graphs illustrate these two alternatives.


RESEARCH ALUMINUM-FOIL ELECTROMAGNET, MODEL J
3/4" GAP
9 AMPERES
10
9
8
7
6
5
4
3
2
1
0
3
2
1
0
1
2
3
4


RESEARCH ALUMINUM-FOIL ELECTROMAGNET, MODEL J
4" DIAM FLAT POLE FACES
3/4" GAP
9 AMPERES
8500
8600
REGION OF UNIFORM FIELD
8550
8000

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