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Calibrations of Dipole and Solenoid Magnetic Fields

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Introduction

Alignment of magnetic fields is critical in the compression-shear experiment. It is very important to confirm it before the experiment. Two of the previous works discussed the procedures of the calibration [1,2]. However, only the dipole magnetic field was calibrated in [1] and one power supply (there are two power supplies in the center) was used to calibrate dipole and solenoid fields [2]. The purpose of this work is to make a systematic calibration of the magnetic field system.

Calibration facilities and method

There are two types of power supplies (500A and 250A). We used two standard fixtures which are similar to those of previous [2]. The first one is long Lucite fixture which is shown in Fig.1. This fixture is used to check the axis position of target hold. The second one is target-mounted fixture which is shown in Fig.2. This fixture is more important since it will be mounted at the same position of the target. We used this fixture to check the orientations of the magnetic fields.

As shown in Fig. 1 and 2, three hall probes were mounted in three directions (top, side and back) on the fixtures. When we calibrate dipole field, we should have maximum reading in the top probe and minimum readings in the side and back probes. In the similar way, we should have maximum reading in the back probe and minimum readings in the top and side probes when we calibrate solenoid field.

Calibration procedures

1. Calibration of the alignment by long Lucite projectile fixture.

The main purpose of this step is to confirm the position of Z axis (the axis of the gun). Since solenoid field is quite uniform in the Z axis, we used dipole magnetic field to calibrate, which is sensitive to the miss-alignment in Z direction. 500A source supply was used to the coil of the dipole magnetic field. The standard long Lucite projectile fixture was positioned at different z. The calibration results are given in Table 1.

Table 1. Position calibration

position (") (z)	dipole current (A)	hall current (mA)	VHtop (mV)	VHside (mV)	VHback (mV)
-1/2	401	100.09	81.5	1.4	-0.4
-1/4	404	100.09	81.2	1.5	-0.4
0	403	100.09	82.2	1.5	-0.3
1/4	401	100.10	81.7	1.5	-0.3
1/2	403	100.10	81.4	1.5	-0.3

It is shown in this Table that the best position for the dipole field is Z=0 where a pin was set on the fixture, confirming acceptable alignment of the magentic field. Small reading is found in the side hall probe. The reason will be discussed in the following.

In order to explain the small reading in the side probe, we also measured the relations between the dipole or solenoid coil current and Hall voltages with this long Lucite projectile fixture. 500A source was used for the dipole coil and 250A source was used for the solenoid coil.

1) The relations of hall voltages vs. dipole coil current.

Table 2. Measured Hall voltages vs. dipole coil current
500A source, Lucite Projectile Fixture.
Hall current is 100.00 mA

dipole coil current (A)	HVtop (mV)	VHside (mV)	VHback (mV)
0	-0.4	-0.1	-0.2
93	-46.5	+0.2	-0.3
195	-59.0	+1.0	-0.3
302	-64.3	+1.0	-0.3
402	-82.0	+1.4	-0.3
521	-98.5	+1.9	-0.4

2) The relations of hall voltages vs. solenoid coil current. The results are given in Table 3.

Table 3. Measured Hall voltages vs. solenoid coil current
250A source, Lucite Projectile Fixture
Hall current is 100.00 mA

solenoid coil current (A)	VHtop (mV)	VHside (mV)	VHback (mV)
0	-0.4	-0.1	-0.1
-59.1	-0.4	-0.1	12.9
-100.7	-0.3	-0.1	22.1
-151.8	-0.3	-0.1	33.3
-201.7	-0.3	-0.2	44.4
-242.3	-0.2	-0.2	53.5

Both Table 1 and Table 2 show smaller readings in the side hall probe when the dipole magnetic field is supplied. When the solenoid magnetic field is supplied(see Table 3), the readings in the side probe are very small, showing the acceptable alignment in this direction. We conclude that the standard long Lucite projectile fixture has a small intrinsic angle which has been previously calibrated to be 0.8 ° in [2]. This small angle makes small readings in the side probe when the dipole field is supplied. However, this small angle has no contribution to the side probe when the solenoid field is supplied since the solenoid magnetic field is parallel to the hall probe. Eventually, as we stated before, the main purpose of this step is to confirm the alignment of positions in Z axis. This small angle don't effect our calibration. We are going to calibrate the orientation of the magnetic field in the following steps in which another target-mount fixture will be used.

In summary of this procedure, we confirmed that Z=0 is the best place in the Z axis. The small intrinsic angle is in the long Lucite fixture. However, this angle don't effect our calibration.

2. Calibrations of hall probes.

Before calibrating the orientations of the magnetic fields with the target mounted fixture, we calibrated 3 hall probes by two standard magnetic fields. The results are given in Table 4.

Table 4. Calibration of the hall probes

Hall current is 100.02 mA

gage	magnet field (kGs)	voltage of gages (mV)	KH (Gs/mV)
top	2.95	91.0	32.42
		-91.0	32.42
	2.99	92.4	32.36
		-92.4	32.36
			average 32.39
side	2.95	91.9	32.10
		-92.2	32.00
	2.99	93.3	32.05
		-93.0	32.15
			average 32.075
back	2.95	87.3	33.79
		-87.4	33.75
	2.99	88.6	33.75
		-88.7	33.71
			average 33.75

3. Calibration of the magnetic fields with the target-mounted fixture.

This procedure is more important. The target-mounted fixture is mounted at where the real target will be mounted. The calibration is not only for the positions but also for the orientations.

1) Measurements of relation of the dipole coil current vs. magnetic field

We used the three calibrated hall probes and mounted them on the target-mounted fixture. 500A source and 250A source were used separately. Table 5 gives the results measured by 500A source. Table 6 shows the results measured by 250A source.

Table 5. Calibrated magnetic field vs. dipole coil current
500A source (Results are also given in Fig.3)

Dipole coil current (A)	VHtop (mV)	VHside (mV)	VHback (mV)	MF(Gs)	Corrected MF(Gs)
0	0.3	-0.1	0.1	9.717	0
198	41.2	0.2	-0.1	1334.468	1324.751
244	50.9	0.2	-0.1	1648.651	1638.934
295	60.5	0.2	-0.1	1959.595	1949.878
354	71.3	0.2	-0.1	2309.407	2299.69
404	79.3	0.3	-0.1	2568.527	2558.81
452	86.2	0.3	-0.1	2792.018	2782.301
514	94.7	0.3	-0.1	3067.333	3057.616

The relation between the readings of the dipole coil current and the hall probe (top) can be fitted by (see the data in Fig. 3)

$$V_H = 3.39511 + 0.18482*I \qquad (1)$$

Table 6. Calibrated magnetic field vs. dipole coil current
250A source (The results are also given in Fig.4)

Dipole coil current (A)	VHtop (mV)	VHside (mV)	VHback (mV)	MF(Gs)	Corrected MF(Gs)
0	-0.2	-0.1	-0.1	-6.478	0
-58	-6.6	0	0	-213.774	-207.296
-99.1	-18.7	0	-0.1	-605.693	-599.215
-155	-29.1	0	-0.1	-942.549	-936.071
-203.4	-38.2	0.1	-0.1	-1237.298	-1230.82
-242.2	-45.4	0.1	-0.1	-1470.506	-1464.028

The relation between the readings of the dipole coil current and the hall probe (top) can be fitted by (see the data in Fig. 4)

$$V_H = -1.65880 + 0.19395*I \qquad (2)$$

Some results have been obtained immediately from these measurements. I) Small readings are in side and back hall probes no matter the 500A or 250A power supplies are used. This means that our alignment is acceptable. II) It is clear from the Tables 5-6 that V_H readings with the 500A source and 250A source are different. For the same coil current reading, V_H with the 500A source is greater than that with the 250A source about 10%.

2). Measurements of relation of solenoid coil current vs. magnetic field.

We used the three calibrated hall probes which mounted on the target-mounted fixture to do this procedure. The 500A source and 250A source were used separately. Table 7 gives the results measured by the 500A source. Table 8 shows the results measured by the 250A source.

Table 7. Calibrated magnetic field vs. solenoid coil current
500A source (The results are also given in Fig. 5)

Sol. coil current (A)	VHtop (mV)	VHside (mV)	VHback (mV)	MF(Gs)	Corrected MF(Gs)
0	-0.2	-0.1	-0.1	-3.375	0
58	-0.4	-0.1	-12.5	-421.875	-418.5
109	-0.6	-0.2	-23.5	-793.125	-789.75
185	-0.9	-0.2	-40.2	-1356.75	-1353.38
202	-0.9	-0.2	-44.8	-1512	-1508.63
250	-1.1	-0.3	-54.4	-1836	-1832.63
252	-1.1	-0.3	-54.7	-1846.13	-1842.75
300	-1.2	-0.3	-65.3	-2203.88	-2200.5
347	-1.4	-0.4	-75.7	-2554.88	-2551.5
400	-1.5	-0.4	-87.5	-2953.13	-2949.75
450	-1.7	-0.5	-98.6	-3327.75	-3324.38
503	-1.9	-0.5	-110.6	-3732.75	-3729.38

The relation between the readings of the solenoid coil current and the hall probe (back) can be fitted by (see the data in Fig. 6)

$$V_H = -0.33297 + 0.21947*I \qquad (3)$$

Table 8. Calibrated magnetic field vs. solenoid coil current
250A source (The results are also given in Fig.6)

Sol. coil current (A)	VHtop (mV)	VHside (mV)	VH back (mV)	MF(Gs)	Corrected MF(Gs)
0	-0.2	-0.1	0.1	3.375	0
50.3	-0.4	-0.1	9.9	334.125	330.75
100.7	-0.6	-0.2	19.9	671.625	668.25
150	-0.7	-0.2	29.6	999	995.625
205.8	-0.9	-0.2	40.6	1370.25	1366.875
251.9	-1.0	-0.2	49.7	1677.375	1674

The relation between the readings of the solenoid coil current and the hall probe (back) can be fitted by (see the data in Fig. 6)

$$V_H = -0.06725 + 0.19732*I \qquad (4)$$

Small readings are in the top and side hall probes, regarding acceptable solenoid field alignment. Same discrepancy (10%) has been found in use of different type of sources.

Conclusions.

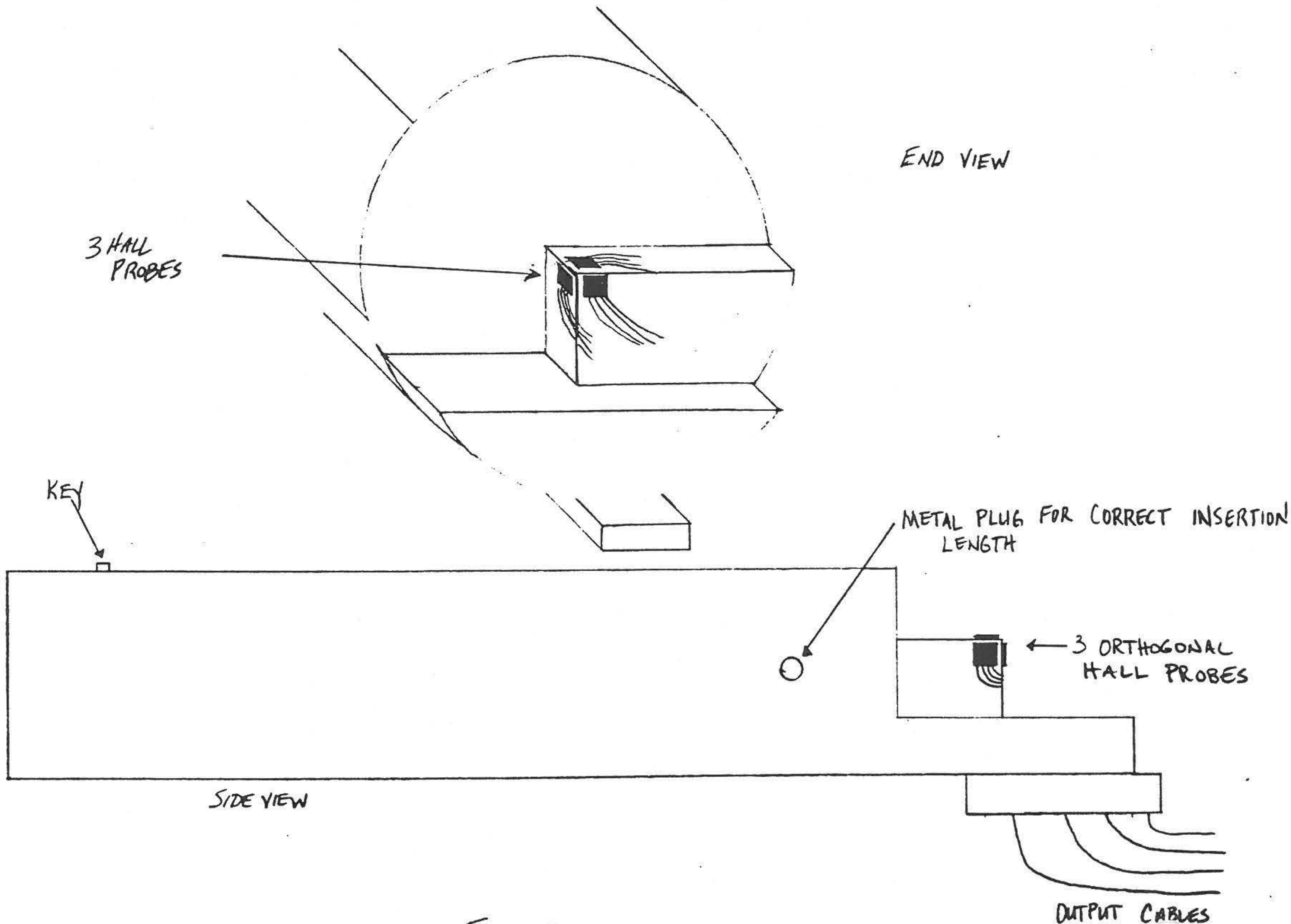
With the calibration procedures we used above, we can get suitable alignments of the magnetic fields. The solenoid coil is more stable than dipole coil. The readings of coil current has been found 10% discrepancy with using 500A power supply and 250A power supply. However, the transformation from the hall probe readings to magnetic field (Table 4) is correct. The calibration curves depend on which power supplies were used. One can not transfer the coil current to magnetic field directly. The calibration procedures must be divided into two steps. The first step is to use the calibration curves to transfer the coil current to the V_H in the hall probes. For example, Fig. 3-4 and Equ. 1-2 are for the dipole field, and Fig. 5-6 and Equ. 3-4 are for solenoid field. The second step is to transfer V_H of hall probes to magnetic field by use of Table 4.

Reference

[1] S.C. Gupta, Magnetic field versus coil current for the dipole magnet, Internal report SDL-91-01

[2] R. Brumback, Dipole and solenoid magnetic field calibrations, SDL-1993.

STANDARD LUCITE FIXTURE



FIGURE

TARGET-MOUNTED HALL PROBE FIXTURE

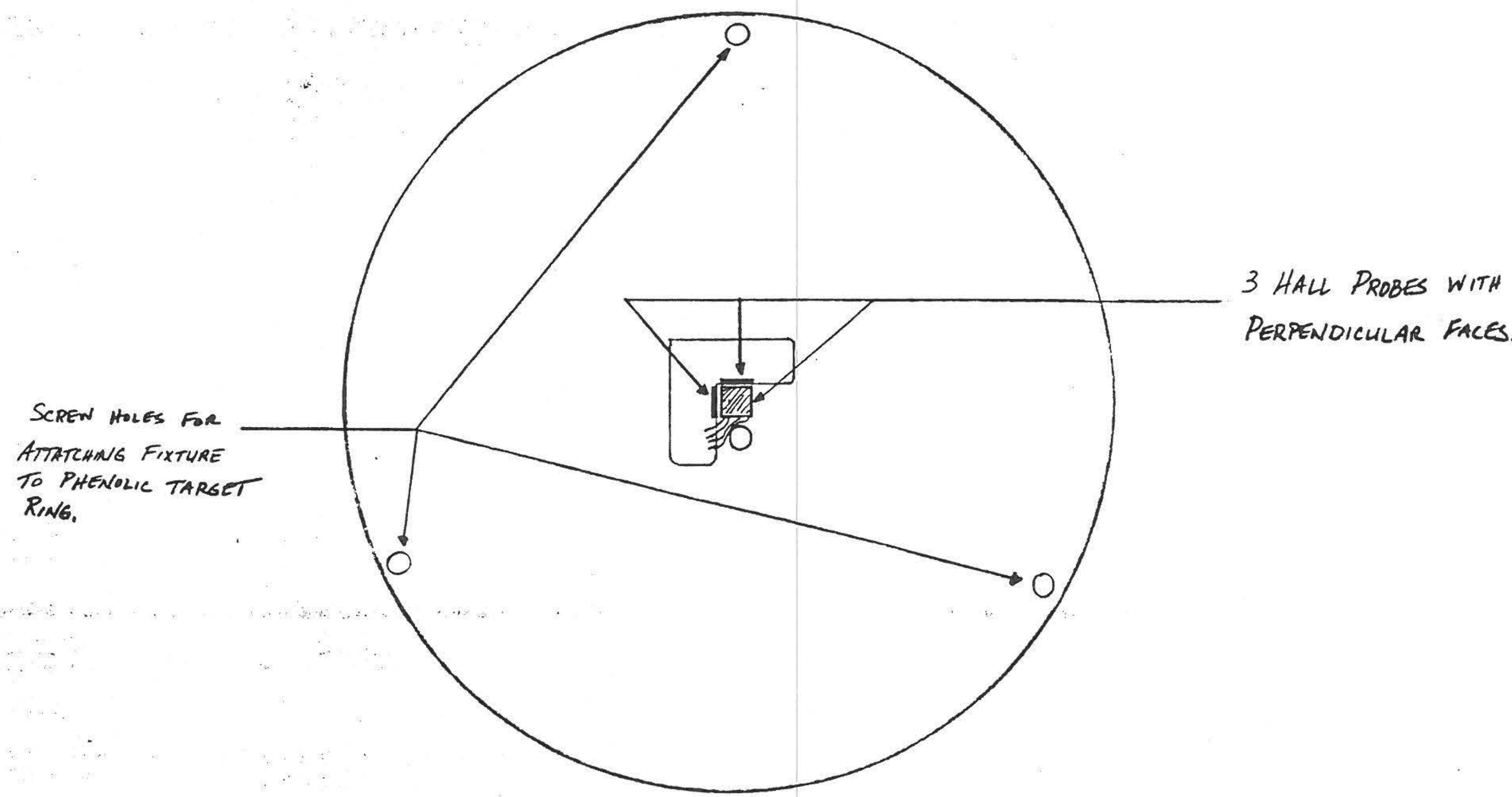


FIG 2

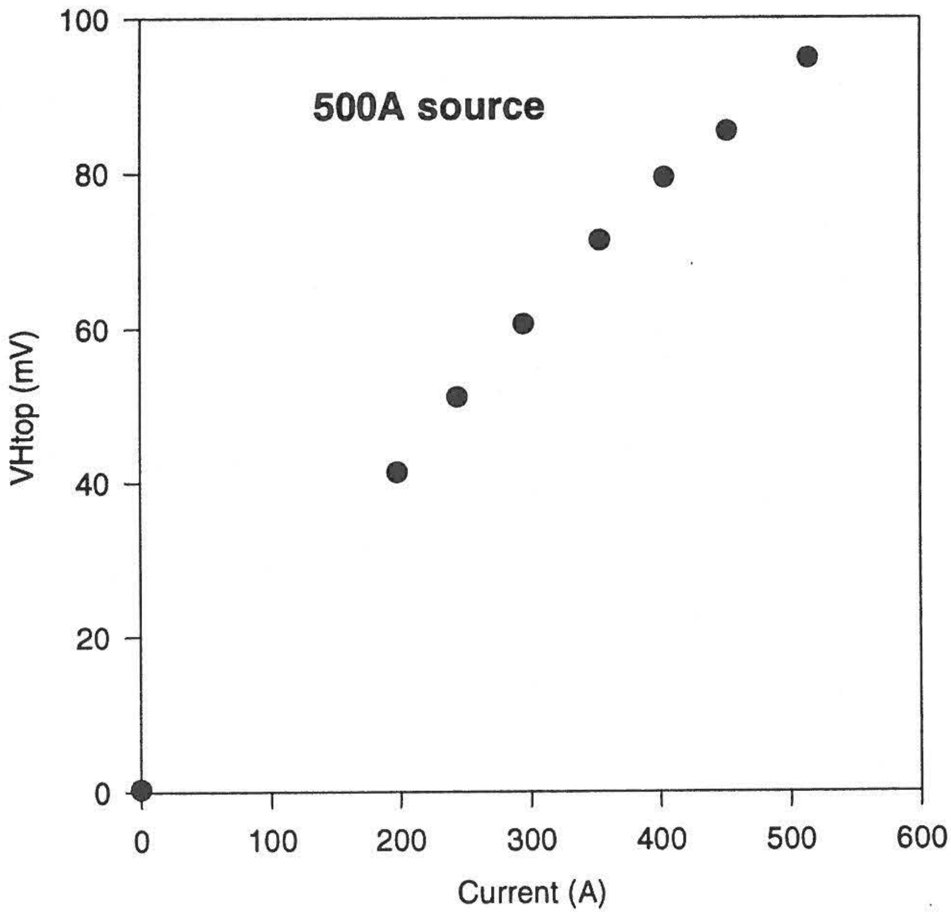

500A source
VHtop (mV)
0
20
40
60
80
100
Current (A)
0
100
200
300
400
500
600

Fig. 3

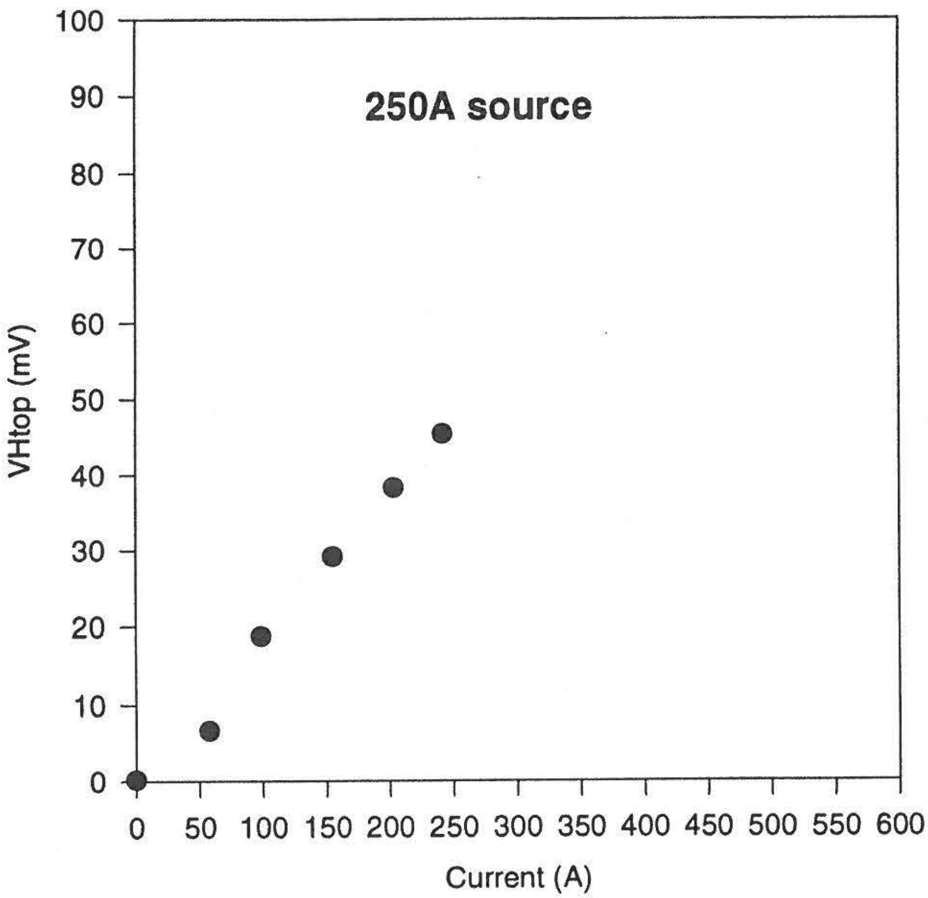

250A source
VHtop (mV)
100
90
80
70
60
50
40
30
20
10
0
0 50 100 150 200 250 300 350 400 450 500 550 600
Current (A)

Fig. 4

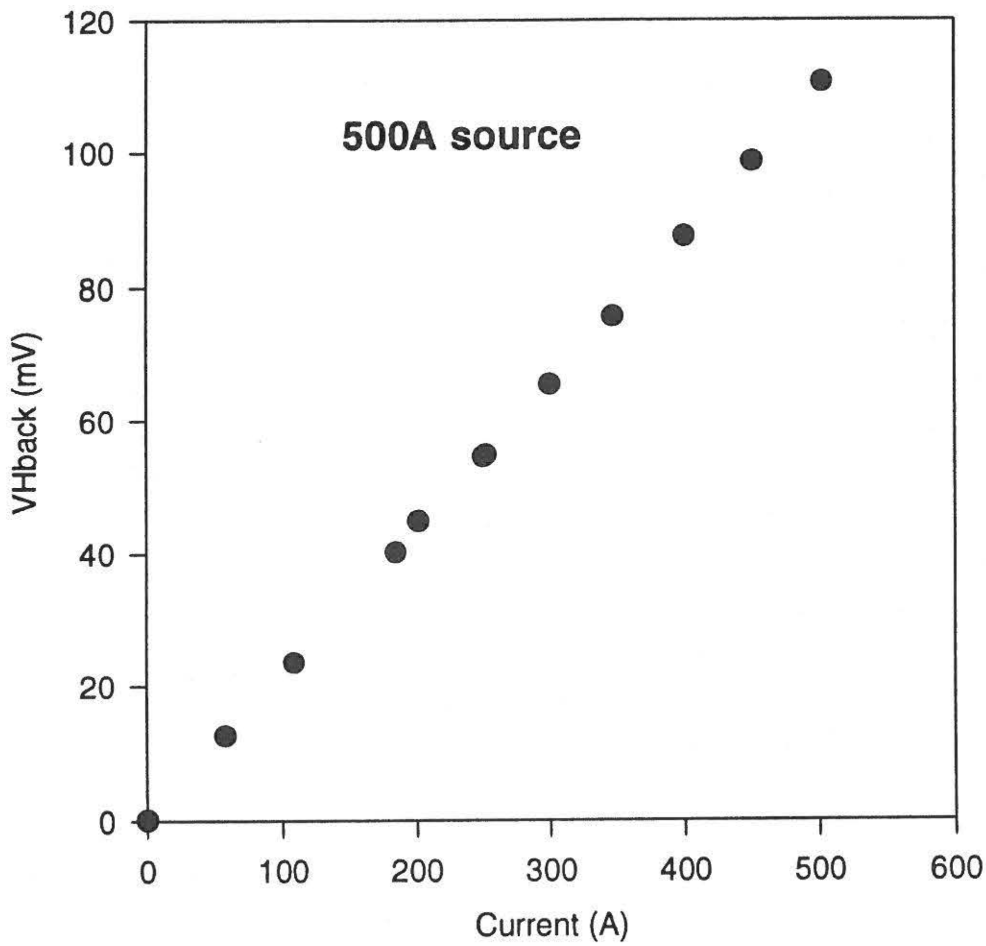

500A source
VHback (mV)
Current (A)
0
20
40
60
80
100
120
0
100
200
300
400
500
600

Fig. 5.

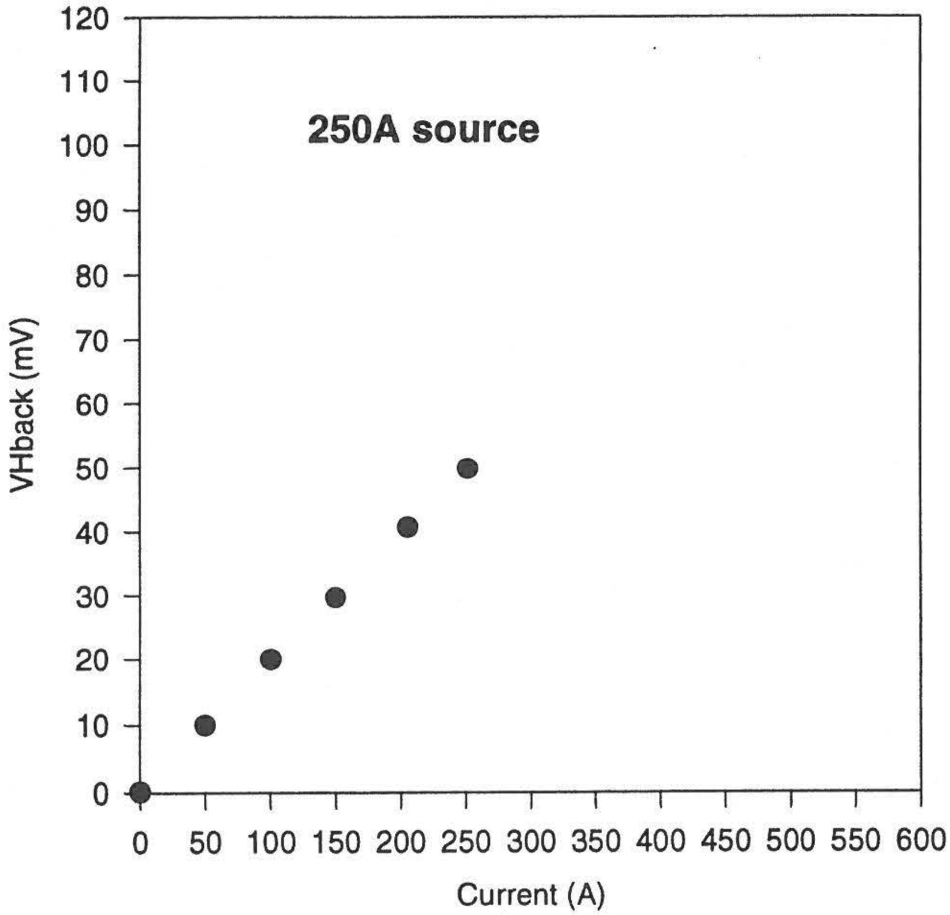

250A source
VHback (mV)
Current (A)
0
10
20
30
40
50
60
70
80
90
100
110
120
0 50 100 150 200 250 300 350 400 450 500 550 600

Fig. 6