www.kirton-dbo.co.uk
E: info@kirtonhealthcare.co.uk
T: +44 (0)1440 705352
F: +44 (0)1440 706199

Final Report

Magnetic Flux Density Measurements Surrounding Holding Magnets

For The DBO Patient Chair
By Kirton Healthcare Group

Dr. Geoffrey Hilton
9 March 2010

Introduction

This report is concerned with the measurement of static magnetic fields associated with permanent magnet fixtures.

Eleven sets of holding magnets were supplied by Kirton Healthcare Group. Each set of holding magnets was labelled. The two halves of the holding magnet were separated by spacers supplied by Kirton. The spacers were constructed from the materials that would be used for the chair construction.

Tests were carried out to establish the distance from the holding magnet that the magnetic flux density generated by the magnet reduced to a value less than 3Gs (3mT) as stipulated in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for the exposure to static magnetic fields.

Research carried out indicates that low level static magnetic fields do not affect solid metallic implants such as artificial joints. Research on the use of cardiac pacemakers indicates that in early models the pacemaker could be changed into different modes of operation by placing a permanent magnet near the implanted pacemaker. This causes a magnetic relay in the device to switch. This may be activated by ambient static magnetic fields emanating from permanent magnet devices in the environment. General information from References given at the end of this report contains data that the minimum recommended ambient static magnetic field should not exceed 0.5 mT (5Gs).

All the holding magnets have been tested between 12 October and 25 October 2009. Each set was measured using the test procedures outlined below.

Test Apparatus.

Each holding magnet was placed on a horizontal surface. An axial Hall probe was mounted on an X:Y:Z venire system. This probe was connected to a Bell 9640 gaussmeter. The output of the gaussmeter was connected to a calibrated digital volt meter. See Fig 1.

For each test procedure given below the probe was positioned using the X:Y:Z venire, for each test position the probe was positioned such that it was touching the surface of the holding magnet. (Note the active element of the Hall probe is not at the surface of the probe. For the probe used the specification for the distance between the tip of the probe and the position of the active element is 0.381mm ± 0.254 mm.) The probe was then moved in the directions indicated in the test procedures until the magnetic flux density reading was below the 3 Gs value. For the first two sets of holding magnets the magnetic flux density was recorded with distance from the surface until the value reduced to below 3 Gs. For subsequent holding magnet sets only the distance for the magnetic flux density to reduce to below 3Gs was recorded.

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Test Procedures.

The following tests were taken to evaluate the magnetic fields surrounding the holding magnets: -

Test 1 Axial magnetic flux density measurements for one half of a holding magnet

One half of each of the magnet pairs in turn was mounted horizontally on a nonmagnetic base. The poles of the holding magnet were upward. (See Fig 2.)

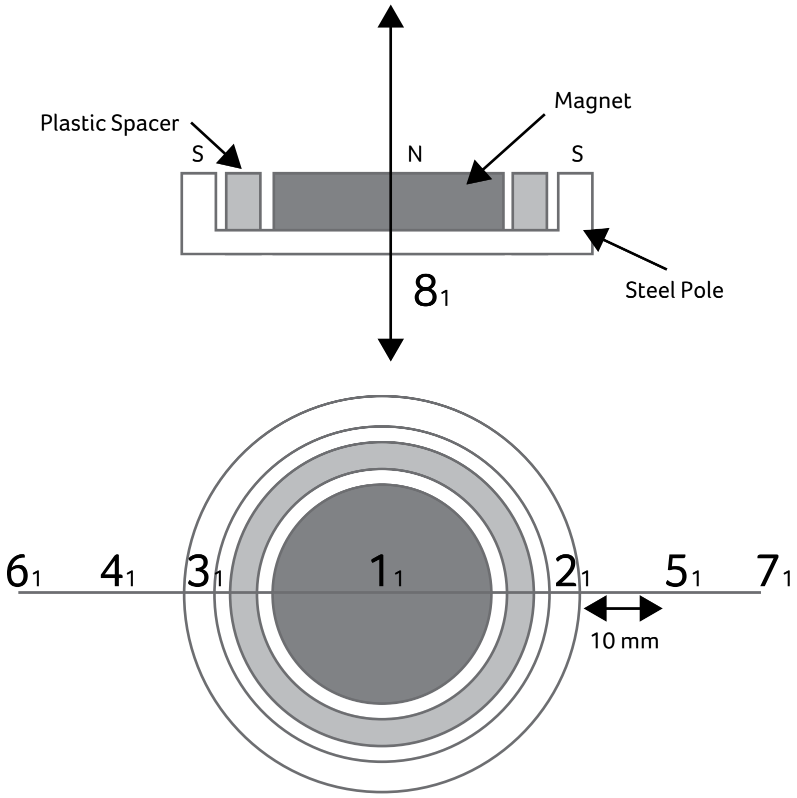


Figure 2. Axial Measurements of Magnetic Flux Density for One Half of a Pair of Holding Magnets.

Using a calibrated Axial Hall probe mounted in a precision X: Y: Z venire system, the magnetic flux density was measured starting at the points indicated in Fig 2. The measurements were taken as follows: -

(i) The Hall probe was moved along the axial direction of the geometric centre of the magnet, position 11 indicated in Fig. 2.
(ii) The Hall probe was moved along the axial direction of the magnetic centre of the outer poles, position 21 and 31 along the line indicated in Fig 2.
(iii) The Hall probe was displaced 10 mm from the magnetic centre position of the outer poles and was then moved along the axial direction parallel to the magnet axis at positions 41, 51, 61 and 71
(iv) The Hall probe was moved along the reverse axial direction indicated by 81 in Fig. 2.

The results are given below.

Test 2 Axial measurement of magnetic flux density for a holding magnet with spacers between poles

Each pair of holding magnets was assembled together with the spacers provided between the poles. The holding magnet was then again mounted horizontally on a nonmagnetic base as shown in Fig. 3.

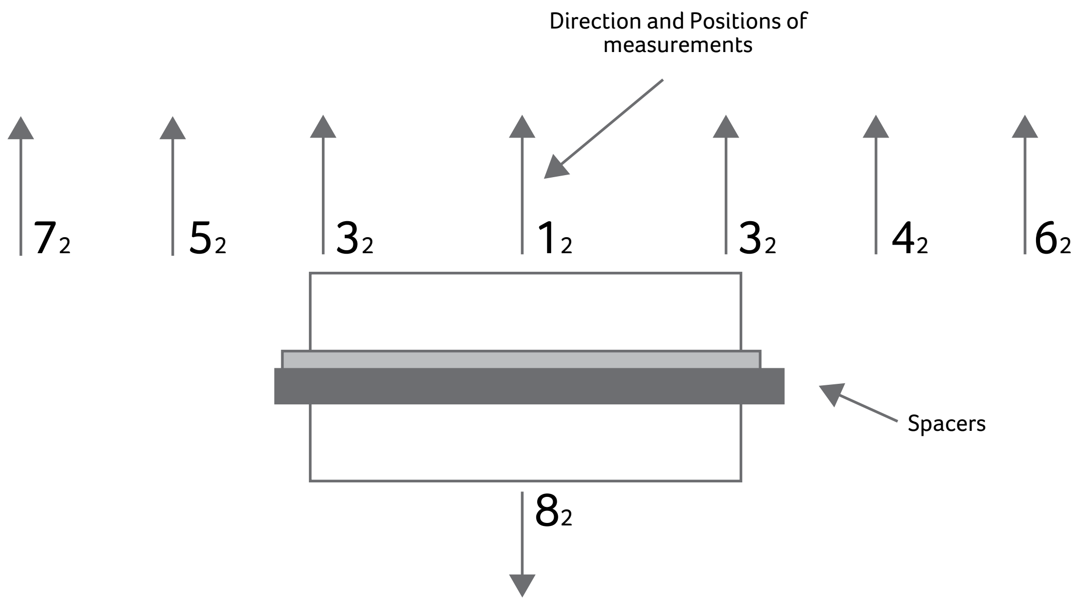


Figure 3 Axial Measurements of Magnetic Flux Density for a Pair of Holding Magnets Together With the Spacers Between the Poles.

Using the Axial Hall probe and venire system measurements were taken as follows: -

(i) At the magnetic centre of the back of one half of the holding magnet, position 12 in Fig. 3, the Hall probe was moved along the axis of the system as indicated in Fig. 3.
(ii) The Hall probe was moved horizontally to maximum flux density values at position 22 and 32 indicated in Fig. 2. For each position the Hall probe was then moved axially.
(iii) The Hall Probe was then moved from positions 22 and 32 in turn 10 mm at a time horizontally to positions 42, 52, 62, and 72. The Hall probe was then moved axially.
(iv) At the magnetic centre of the back of the other half of the holding magnet, position 82 in Fig. 2 the Hall probe was moved along the axis of the system as indicated in Fig. 2. This was to check the symmetry of the system.

The results are given below.

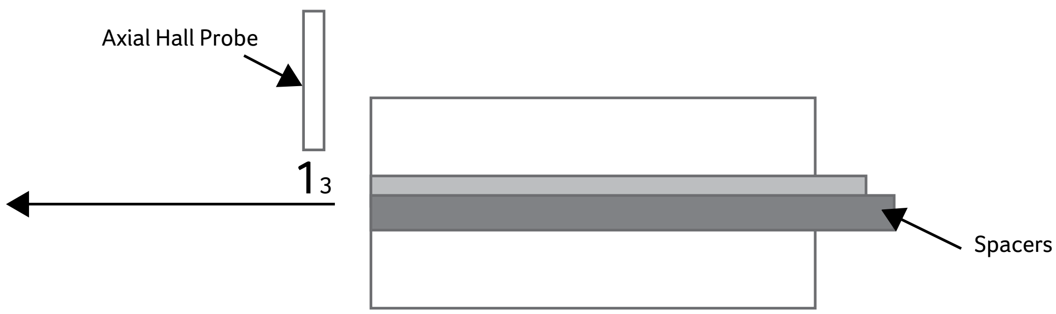


Figure 4 Horizontal Magnetic Flux Density Measurements from Edge Pole

Results.

The results are for the following magnet sets sent on the dates given: -

Magnet Reference	Date tested	Magnet size	Comment	Results Table
A	12/10/2009	Large		1, 3 and 4
B	12/10/2009	Large		2 and 5
C	20/10/2009	Large	5mm outer pole	3 and 6
D	20/10/2009	Large	7.5mm outer pole	3 and 6
E	20/10/2009	Large	10 mm outer pole	3 and 6
F	4/11/2009	Large	5mm outer pole	3 and 6
G	4/11/2009	Large	3mm outer pole	3 and 6
H	4/11/2009	Small	5mm outer pole	3 and 6
I	4/11/2009	Small	3mm outer pole	3 and 6
J	25/11/2009	Large	1mm outer pole	3 and 6
K	25/11/2009	Large	2mm outer pole	3 and 6

The dimensions and condition of the magnet holders are given in the following table: -

Batch No	Magnet Reference	Magnet Size (mm)	Holder Size (mm)	Holder Wall Thickness (mm)	Spacer Thickness (mm)	Base Machining Quality
1	A	15 x 4	26 x 7.2	3	1.5mm plus fabric	Poor
	B	15 x 4	24 x 6.2	2	1.5mm plus fabric	Poor
2	C	15 x 4	30 x 9.2	5	1.5mm plus fabric	Poor
	D	15 x 4	35 x 11.2	7.7	1.5mm plus fabric	Poor
	E	15 x 4	40 x 14.2	10	1.5mm plus fabric	Poor
3	F	15 x 4	30 x 9.2	5	1.5mm plus fabric	Flat
	G	15 x 4	26 x 7.2	3	1.5mm plus fabric	Flat
	H	10 x 5	30 x 10.2	5	1.5mm plus fabric	Flat
	I	10 x 5	24 x 8.2	3	1.5mm plus fabric	Flat
4	J	15 x 4	22 x 5.2	1	1mm plus fabric	Flat
	K	15 x 4	24 x 6.2	2	1mm plus fabric	Flat

Test 1

Table 1 Test 1 Magnetic Flux Density Measurements Half of Holding Magnet A, B and D

Distance Moved (mm)	6_1 Flux Density (Gs)	4_1 Flux Density (Gs)	3_1 Flux Density (Gs)	1_1 Flux Density (Gs)	2_1 Flux Density (Gs)	5_1 Flux Density (Gs)	7_1 Flux Density (Gs)	8_1 Flux Density (Gs)
Magnet A								
0	-14.5	-59.9	-1617.0	4016.0	-1738.0	-56.7	-16.1	-78.0
5	-15.3	-58.8	38.0	1557.0	-34.0	-44.7	-13.9	-65.4
10	-11.9	-26.5	113.0	572.0	84.0	-14.8	-9.1	-46.8
15	-7.1	-4.1	81.5	228.0	71.0	2.8	-4.2	-31.2
20	-2.7	6.1	53.8	107.0	49.9	9.9	-0.2	-20.4
25	-0.1	9.0		58.0		11.2	2.1	-13.6
30	1.9	8.9	24.8	34.2	23.5	10.2	3.3	-9.2
35				22.5				-6.3
40	2.9	6.7	12.9	15.5	12.5	7.1	3.7	-4.3
45				11.1				-3.1
50	2.8	4.6	7.9	8.3	7.6	5.0	3.2	-2.0
55				6.4				
60	2.3	3.3	5.3	5.2	5.4	3.5	2.6	
65				4.2				
70	1.9	2.5	4.2	3.7	4.1	2.6	2.0	
75				3.2				
80	1.6	1.9	3.4	2.9	3.3	2.0	1.7	
85				2.6				
90	1.3	1.5	2.9	2.3	2.9	1.6	1.4	
100	1.2	1.3	2.6	2.0	2.6	1.3	1.2	
110	1.0	1.1	2.4	1.8	2.3	1.1	1.0	
120	0.9	1.0	2.2	1.6	2.2	1.0	0.9	
130	0.8	0.9	2.1	1.5	2.1	0.9	0.9	
140	0.8	0.8	2.0	1.4	2.0	0.8	0.8	
150	0.7	0.7	2.0	1.4	2.0	0.8	0.7	
160	0.6	0.7	1.9	1.3	1.9	0.7	0.7	
Magnet B								
0	-21.8	-103.0	-1621.0	3899.0	-1398.0	-64.6	-16.3	-1250.0
5	-21.2	-75.8	22.2	1322.0	74.1	-42.7	-14.2	-96.8
10	-14.2	-21.1	98.0	488.0	120.8	-10.4	-8.8	-63.3
15	-6.8	5.1	74.8	196.0	85.5	7.2	-3.6	-40.2
20	-1.3	12.7	49.6	96.9	55.4	12.8	0.8	-25.7
30	3.3	11.7	22.8	32.1	24.4	11.5	4.0	-12.0
40	3.8	7.8	11.5	14.4	12.4	7.8	4.1	-6.1
50	3.2	5.2	6.5	7.7	7.0	5.3	3.4	-3.4
60	2.6	3.6	4.1	4.7	4.4	3.6	2.7	-2.0
70	2.0	2.6	2.7	3.2	3.0	2.6	2.1	-1.2
80	1.7	1.9	1.9	2.3	2.2	2.0	1.7	-0.7
Magnet D								
0	13.9	49.5	554.0	3991.0	511.0			-30.5
15		2.9						
18	2.9							
21					2.9			
23			2.9					
47								-2.9
75				2.9				

Figure 5 Plot of Magnetic Flux Density against Distance for Half of Holding Magnet A

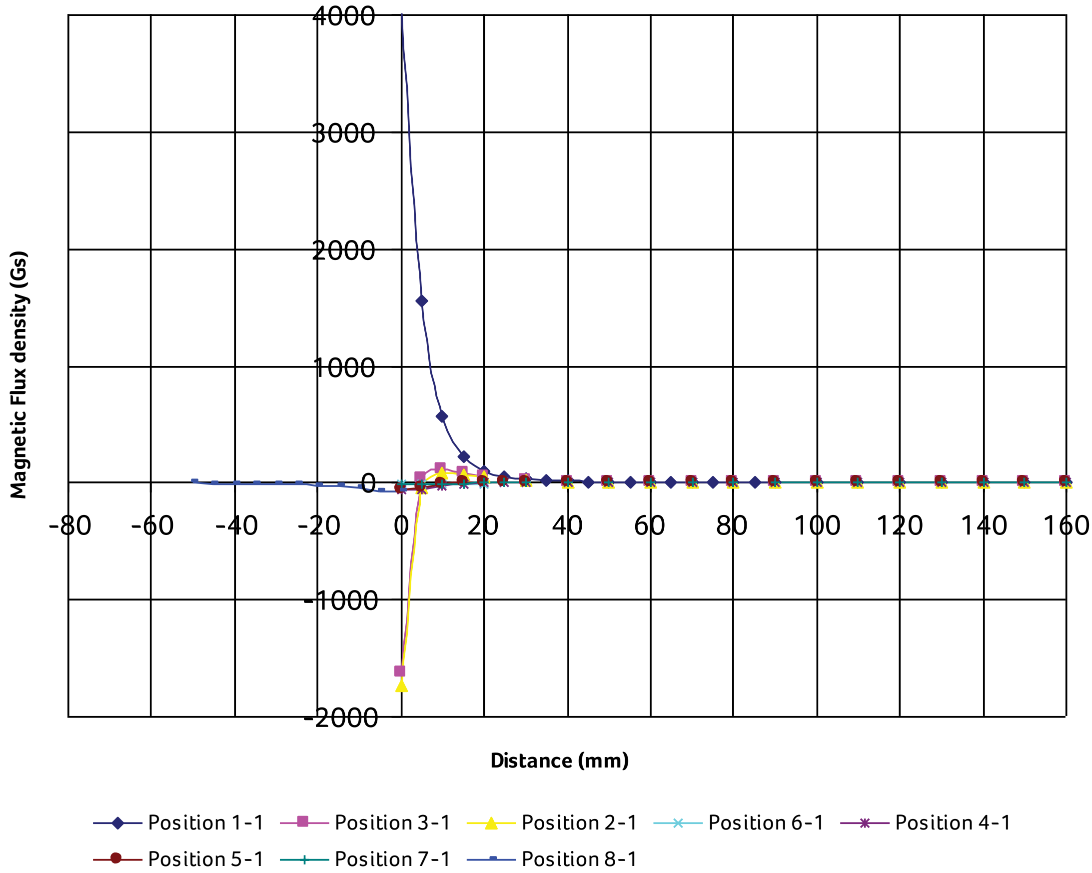


Figure 5A Plot of Magnetic Flux Density Against Distance for Half of Holding Magnet A Expanded Scale

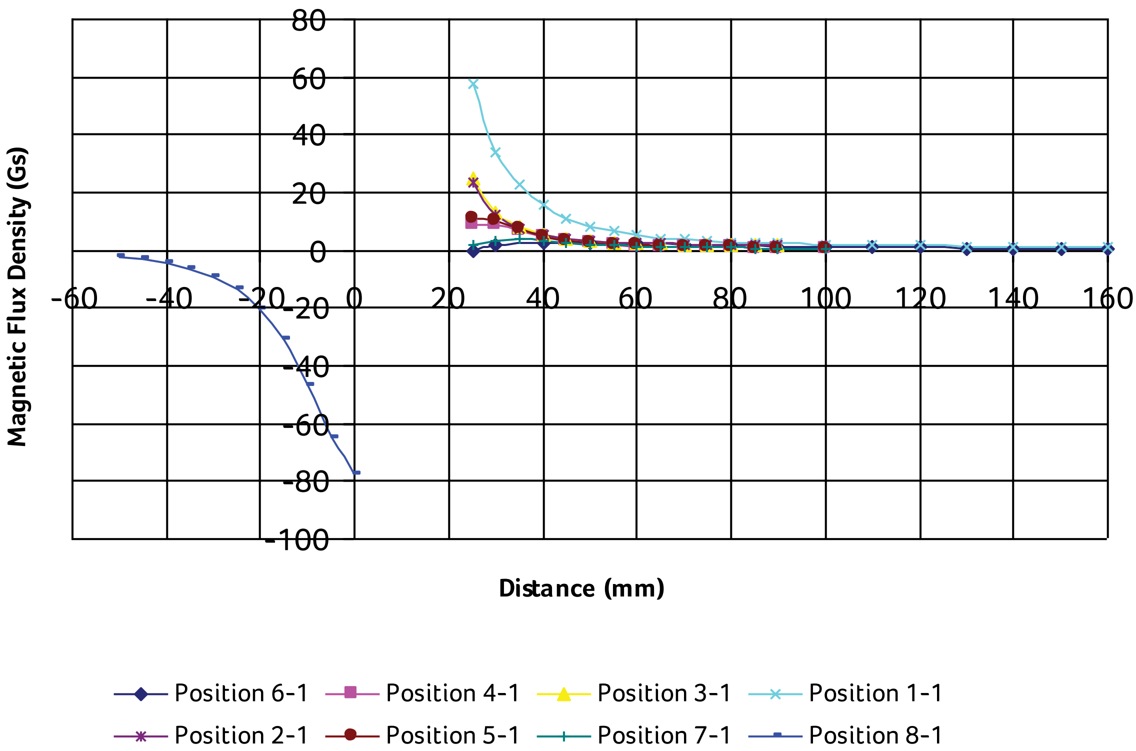


Figure 6 Plot of Magnetic Flux Density against Distance for Half of Holding Magnet B

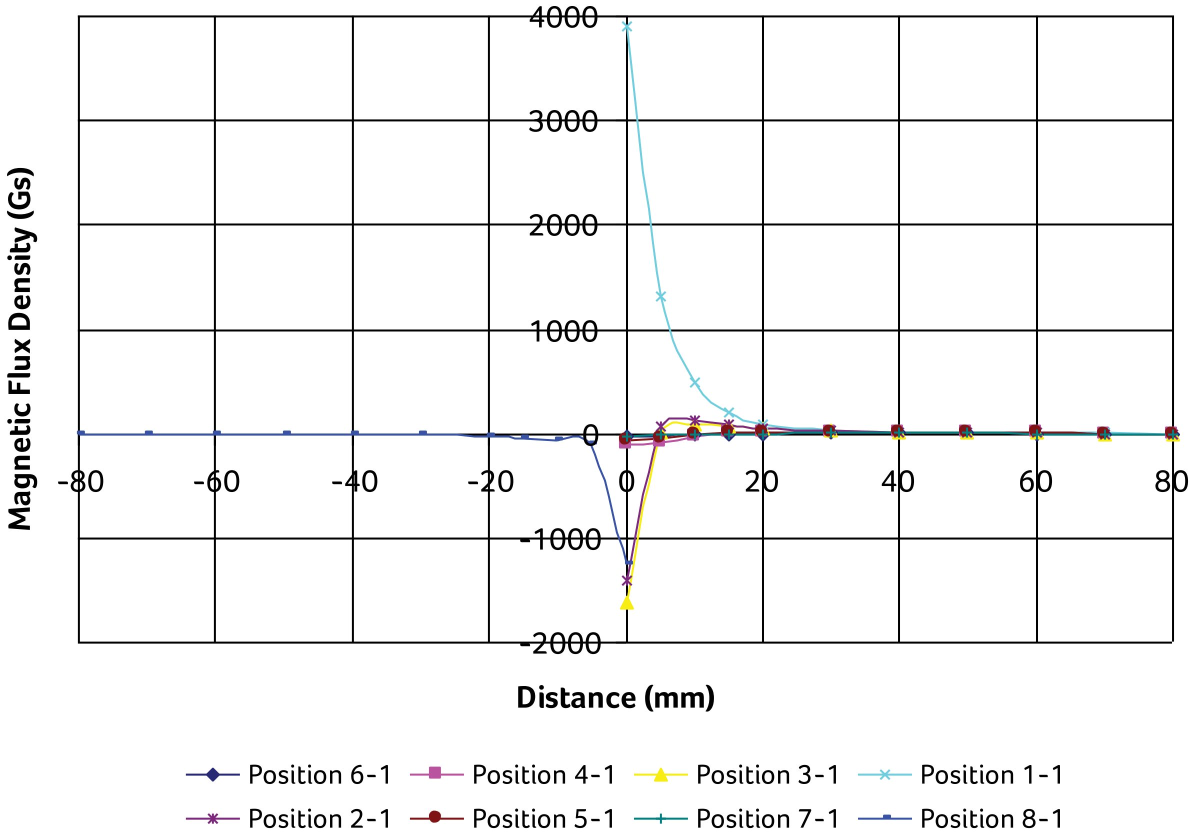
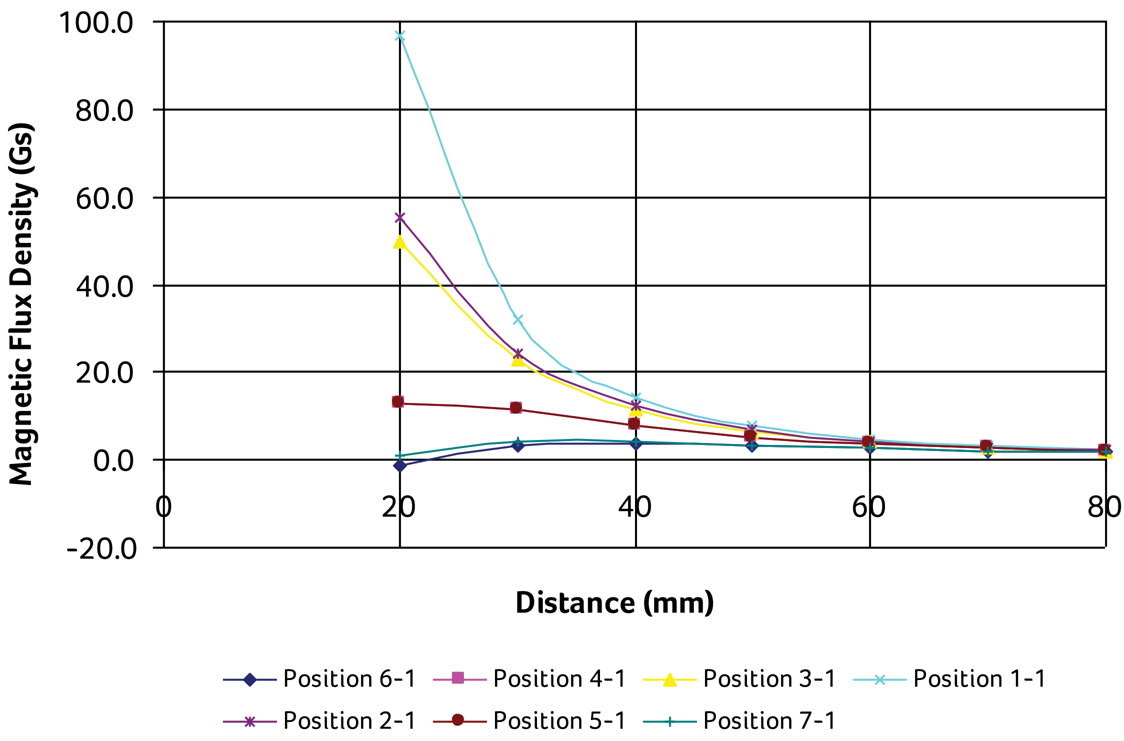


Figure 6A Plot of Magnetic Flux Density Against Distance for Half of Holding Magnet B Expanded Scale



Test 2

Table 1 Test 1 Magnetic Flux Density Measurements Half of Holding Magnet A, B and D

Distance Moved (mm)	1_2 Flux Density (Gs)	2_2 Flux Density (Gs)	3_2 Flux Density (Gs)	4_2 Flux Density (Gs)	5_2 Flux Density (Gs)	6_2 Flux Density (Gs)	7_2 Flux Density (Gs)	8_2 Flux Density (Gs)
Magnet A								
-80								-2.8
-70								-3.8
-60								-5.4
-50								-8.2
-40								-13.0
-30								-23.8
-20								-49.4
-15								-73.0
-10								-110.2
-5								-156.5
0	-25.3	-34.5	409.7	186.5	476.5	-24.8	-16.2	-187.3
5	-11.1	15.5	136.9	155.6	128.8	7.6	-6.7	
10	-1.6	25.0	79.1	111.1	75.6	18.3	0.2	
15	3.6	23.5	51.1	74.6	50.6	19.2	3.8	
20	5.9	19.7	35.3	49.3	35.8	17.1	5.7	
30	6.4	12.9	19.1	24.0	19.0	12.0	6.2	
40	5.4	8.7	11.3	13.2	11.3	8.3	5.2	
50	4.3	6.0	7.1	8.2	7.3	5.8	4.2	
60	3.4	4.3	4.9	5.4	5.0	4.2	3.3	
70	2.7	3.2	3.6	3.8	3.6	3.2	2.7	
80	2.2	2.5	2.7	2.9	2.7	2.5	2.2	
Magnet B								
-80								-1.8
-70								-2.8
-60								-4.5
-50								-7.3
-40								-12.8
-30								-24.6
-20								-54.1
-15								-84.1
-10								-135.2
-5								-204.4
0	-21.5	-47.1	403.1	274.7	583.1	-26.2	-20.1	-276.1
5	-12.0	-6.4	149.0	204.6	174.6	16.5	-7.5	
10	-4.5	10.3	87.2	134.9	99.9	26.6	1.3	
15	0.6	14.9	57.0	85.1	63.8	25.4	5.6	
20	3.3	14.7	39.6	54.9	43.3	21.8	7.4	
30	5.0	11.2	20.6	26.1	21.9	14.3	7.4	
40	4.6	7.9	11.9	14.0	12.5	9.4	6.0	
50	3.9	5.6	7.5	8.3	7.8	6.4	4.6	
60	3.1	4.1	5.0	5.5	5.2	4.5	3.6	
70	2.5	3.1	3.6	3.9	3.7	3.4	2.8	
80	2.1	2.4	2.7	2.9	2.8	2.6	2.3	

Figure 7 *Measurement of Magnetic Flux Density Against Distance For Holding Magnet A with Spacers*

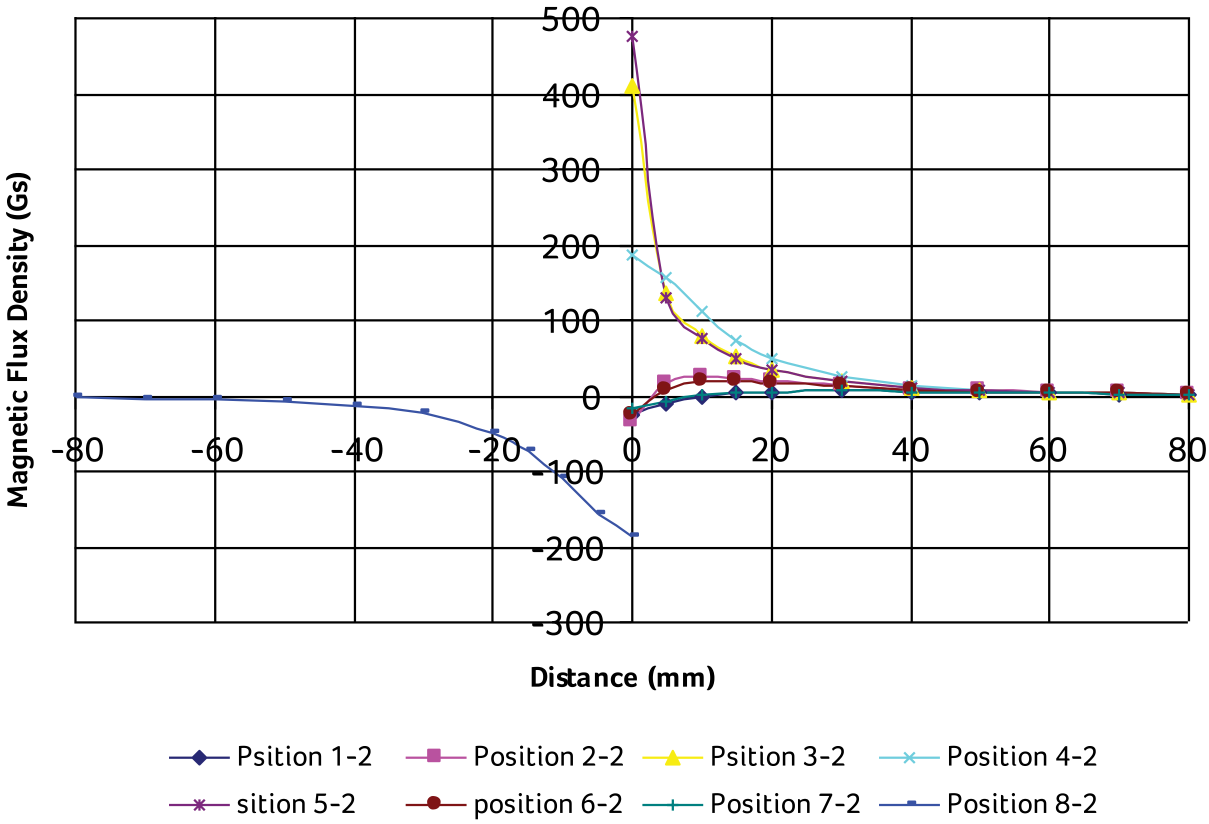


Figure 8 *Measurement of Magnetic Flux Density Against Distance For Holding Magnet B with Spacers*

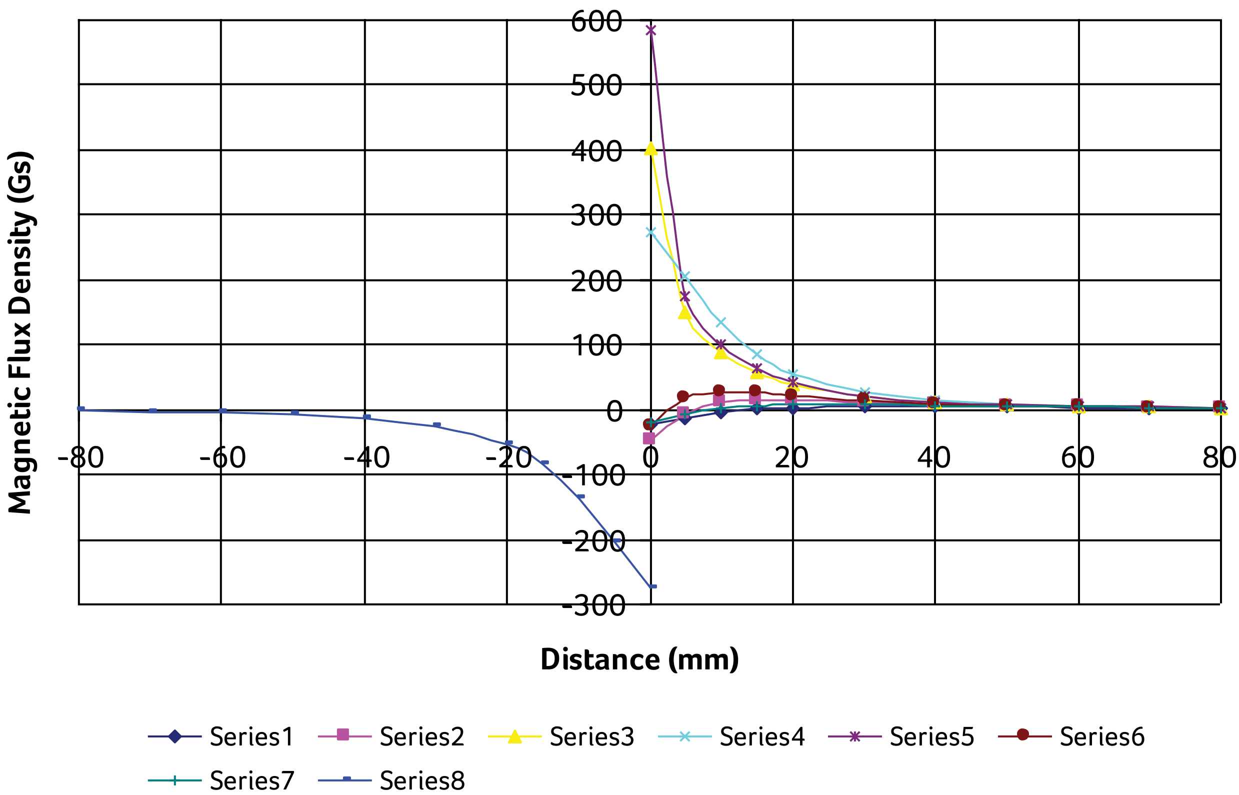


Table 3 Test 2 Magnetic Flux Density Measurements for Magnets F,G,H,I,J and K

Test	Magnet Set	Reference Position	Distance (mm) (mm)	Magnetic Flux Density (Gs)
2	C	12	0	129.0
			78	2.9
		82	0	-125.8
C Magnet set with no spacers inserted and the test repeated				
2	C	12	0	83.4
			51	2.9
		82	50	-2.9
2	D	12	0	74.9
			67	2.9
		22	0	234.3
			64	2.9
		52	0	-2.6*
			59	-2.9*
		72	0	8.1
			5	2.9
		82	0	-77.5
			76	-2.9
2	E	12	0	53.7
			73	2.9
		82	0	-49.5
			65	-2.9
2	F	12	0	92.5
			64	2.9
		82	64	-2.9
2	G	12	0	155.7
			67	2.9
		82	67	-2.9
2	H	12	0	48.4
			48	2.9
		82	48	-2.8
2	I	12	0	85.6
			49	2.9
		82	49	-2.9
I Magnet set displaced Approx 1.5 mm Horizontally and test repeated				
2		12	0	85.1
			51	2.9
		82	51	-2.9
2	J	12	0	950.0
			75	2.9
		82	74	-2.9
2	K	12	0	219.5
			69	2.9
		82	69	-2.9

Table 4 Test 3 Horizontal Flux Density Measurements Along the Horizontal Plane From the Side of Holding Magnet A with Spacers.

Distance (mm)	Flux Density (Gs)
0	512.7
5	146.3
10	64.6
15	33.8
20	20.4
25	12.9
30	8.8
40	4.5
50	2.5

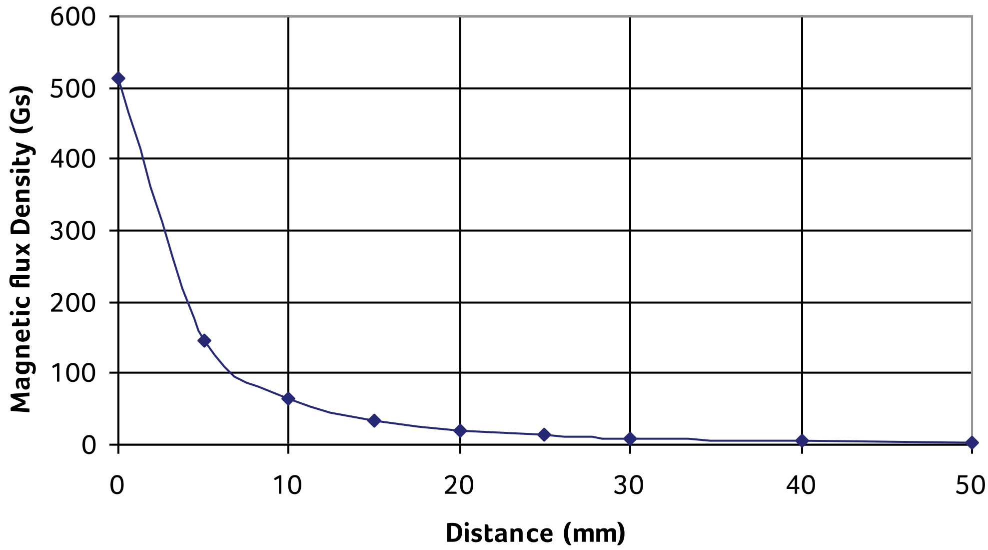


Figure 9 Horizontal Measurement of Magnetic Flux Density Against Distance For Holding Magnet A with Spacers

Table 5 Test 3 Horizontal Flux Density Measurements Along the Horizontal Plane From the Side of Holding Magnet B with Spacers.

Distance (mm)	Flux Density (Gs)
0	509.1
5	143.9
10	64.9
15	34.8
20	21.3
25	14.1
30	9.9
40	5.6
50	3.6
60	2.5

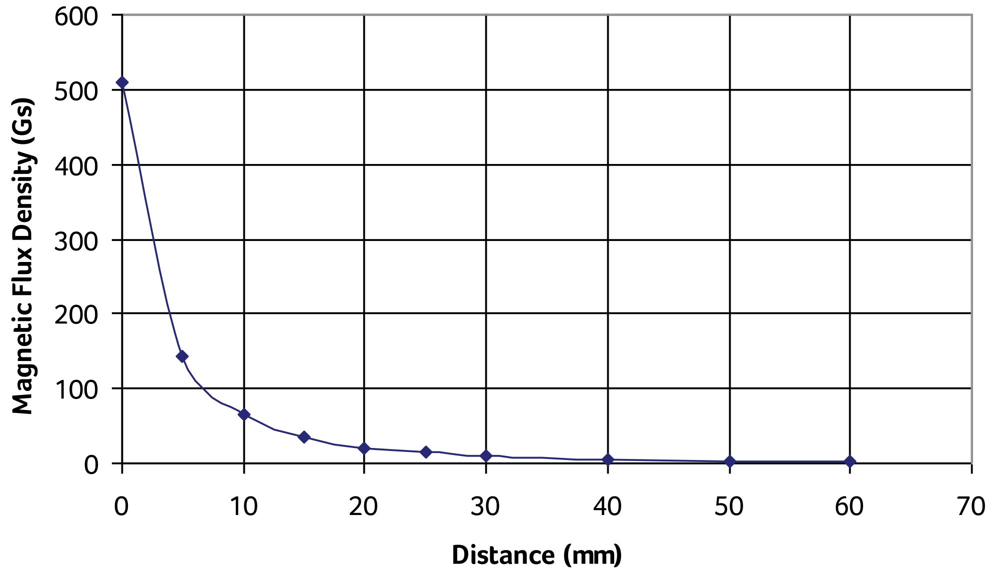


Figure 10 Horizontal Measurement of Magnetic Flux Density Against Distance For Holding Magnet B with Spacers

Table 6 Test 3 Horizontal Flux Density Measurements Along the Horizontal Plane From the Side of Holding Magnet C, D, E, F, G, H, I, J and K with Spacers.

Test	Magnet Set	Distance (mm) (mm)	Magnetic Flux Density (Gs)
3	C	0	378.9
		51	2.9
C Magnet set with no spacers inserted and the test repeated			
3		0	260.2
		41	2.9
3	D	0	284.0
		44	2.9
3	E	0	224.0
		44	2.9
3	F	0	287.2
		45	2.9
3	G	0	271.8
		46	2.9
3	H	0	141.3
		32	2.9
3	I	0	200.0
		34	2.9
I Magnet set displaced Approx 1.5 mm Horizontally and test repeated			
3		0	162.8
		33	2.9
3	J	0	421.8
		50	2.9
		69	-2.9
3	K	0	456.4
		47	2.9

Discussions.

Tests on Holding Magnet A and B

Measurements were carried out until the distance moved resulted in the magnetic flux density falling below the recommended level, for pacemakers to be subjected to, of 3 Gs.

As the system is symmetrical measurements in one direction will be very close to the mirror image. Assuming the magnet is homogeneous. Measurement taken and shown in Table 2 positions 12 and 82 show that the system is symmetrical as these are along the axis of the holding magnet away from the surface of each end.

The half magnet set Test 1 show that there are large magnetic fields close to the pole surfaces when the two halves are put together the outer surface magnetic fields reduce significantly.

In terms of magnetic leakage both A and B 'leak', I believe because the mild steel return paths are being saturated by the flux levels in the Neodymium magnets. This is proven by the field seen on the rear of the holding magnets away from the pole face. The flux is escaping from the steel not being conducted by it. To reduce the leakage further the steel needs to be thicker.

The quality of the machining of the magnet holder also has a significant effect on flux leakage. Magnets A and G had the same dimensional specification but differed in the quality of the machining. The distance from the magnet centre at which the flux level fell below 3 Gs was 80 mm and 67 mm respectively.

References

International Commission on Non-Ionizing Radiation Protection (ICNIRP)
https://www.icnirp.org/

British Standards BSEN60601 2008

The Society of Radiographers
207 Providence Square
Mill Street
London SE1 2EW
Telephone 020 7740 7200
Facsimile: 020 7740 7233
E-mail: info@sor.org
Website: www.sor.org