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MAGNETIC MEASUREMENTS ON A ROUGH BUMP MAGNET MODEL

(Preliminary Results)

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0. SUMMARY

A rough Bump magnet model has been studied in the azimuthal leakage field between the excitation coils of a CPS magnet unit. The preliminary results of the magnetic measurements are collected in this report. With the given configurations and fields, which were chosen to simulate those in the Serpukhov accelerator, the required field of 1.6 T could normally be reached in the case of equal polarity of accelerator and bump magnets. The field could almost be reached in the case of opposite polarity. There are indications of a shortening of the magnetic length of the accelerator and of a tilt of the magnetic end. This point will be studied in more detail.

CONTENTS

1. INTRODUCTION

The variant proposed by CERN [1)] for the ejection channels in the Serpukhov accelerator makes use of closed orbit deformations created by an array of separated function bump magnets (BM's), situated in the unused , odd numbered short straight sections. These magnets would then be between the excitation coils and in the azimuthal fringing field of the accelerator magnet units. The question whether the latter field would hamper achieving the nominal deflections and whether the distortion of the leakage fields will remain in acceptable limits has been studied on a rough bump magnet model inserted in a corresponding place of a CPS magnet unit.

A preliminary mechnanical design study [2)] shows it to be convenient to choose the distance between the extremities of the BM and accelerator magnet unit to be 20-25 cm. The values of the fringing fields in this region are of the order of 10% of the nominal accelerator field on the central orbit. In the CPS similar field percentages occur when the corresponding distances are 10-12 cm. The value adapted for the present measurements is 12 cm.

The construction of the rough BM model has already been described in an earlier technical note [3)]. The principle of the measurements is also outlined there.

Measurements have been made of the BM alone and then in the fringing field of the accelerator magnet unit. Most of the measurements are in terms of the azimuthal variations on the central orbit and in the magnetic flux return path (yoke) of the BM. In addition, the magnetic lengths of CPS magnet unit and BM have been measured separately (at a great distance from each other) and at the nominal distance of 12 cm. In most measurements pertaining to saturation the CPS magnet was excited to its maximum field of nominally 1.369 T.

2. BUMP MAGNET ALONE

The magnetization curve $B_1 = B_1 (I)$ has been measured far away of the CPS magnet unit. B_1 designates the local field in the centre of the BM, where the field is homogeneous, I designates the current. The result is shown in Fig. 1. For 2000 A of excitation current one obtains ~ 1.8 T in the centre of the magnet. The magnetization curve does not show signs of saturation up to that value.

The azimuthal field variation $B = B(\theta)$ on the centre line of the BM model has been measured with a point by point method for different excitation currents. It is shown in Fig. 2. The slight asymmetry between the two fringing fields may be explained from the different coil and end plate configurations.

3. AZIMUTHAL FIELD VARIATIONS OF BM AND CPS MAGNET AT 12 CM SEPARATION

Figure 3 shows the field variation on the centre line of the BM and the CPS magnet when their separation is 12 cm. The nominal field in the CPS magnet is $B_o = 1.369$ T. The BM magnet is excited to different field levels. From comparing Fig. 3 with Fig. 2 one observes that the presence of the CPS excitation coils and fringing fields does not appreciably affect the performance of the BM, in the case of equal polarity of the field in the apertures. This could be explained by the fact that the two contributions (induced fields CPS magnet unit and pulsed field of BM) have opposite direction in the flux return path such that saturation there is avoided. In the other case, however, where the two magnetic fields have opposite polarity in the apertures, they will add up in the flux return path and earlier saturation may occur.

The latter is effectively shown in Fig. 4 which gives the same azimuthal field variation. In this case one can clearly see the premagnetization by the CPS, since in the first 10-15 cm of the BM neither the field level nor the azimuthal variation are reached as for the corresponding excitation currents in case of equal polarity.

This effect is further illustrated in Figs. 6, 7 and 8. These figures pertain to measurements of the field in the flux return path by means of 10 flux pick-up loops built in on each side of the BM (cf. Fig. 5). Figures 6 and 7 represent the flux induced in the BM iron yoke by the CPS excitation coils and fringing field alone. (The nominal field of the CPS is here 1.014 T.) One observes that in the first 10-15 cm the fluxes are a significant fraction of the required bump field and it must hence be expected that the attainable fields may be affected there if BM and CPS fields add up in the flux return path.

This is further confirmed by the results displayed in Fig. 8 which gives the azimuthal variation of the field in the flux return path of the BM, when CPS induced field and the pulsed fields are superimposed. One observes that in the first 10-15 cm the contribution due to the BM is independent of the excitation current and only a fraction of the one in the rest of the magnet. The contributions of the CPS and the BM add up to a virtually constant value which must correspond to saturation at some cross-sections of the yoke, possibly near the fixation bolts.

4. EQUIVALENT MAGNETIC LENGTH

The equivalent magnetic length, in excess of the physical length (cf. definition in Fig. 9) has been measured on the side where the two magnets (BM and CPS unit) face each other. It was done, both, far away from each other and with the chosen separation of 12 cm.

For the equivalent length L_b of the CPS magnet unit in absence of the BM model we find back the values measured in 1959[4], as shown in the Table 1. The experimental error was 2-3 mm.

TABLE 1 EQUIVALENT LENGTH L_B OF CPS MAGNET UNIT

Nominal Field in CPS B_o [T]	Side	Radial Pos. r [cm]	Equivalent excess length L_B [cm]		
			1959[3]	CPS alone	CPS+ BM
0.013 Dynamical field	closed	+ 3	6.8	6.7	4.3
		0	7.3	7.1	
	open	- 3	7.7	7.3	
0.5000	closed	13	6.8	7.1	0
		0	7.3	7.1	
	open	- 3	7.8	7.3	
0.9200	closed	+ 3	5.7	6.2	0
		0	6.2	6.2	
	open	- 3	6.7	6.6	

5. DISCUSSION

The preliminary results are very encouraging. One can already conclude that construction of BM's for the short straight sections of the Serpukhov accelerator is possible. One recalls, that since the bumps for the proposed variant 1) are towards the centre of the ring the required magnetic fields in the BM's have the same polarity as in the accelerator. Even if opposite polarities would locally be needed for different bump configurations, the required fields will be smaller than for equal polarity. As shown in Section 3, the nominal fields of 1.6 T (and even more) can be reached.

Remains the question of how the presence of the BM steel yoke influences the azimuthal leakage field of the accelerator magnet. From Table 1 we observe that introducing the BM into the accelerator fringing field reduces the equivalent magnetic length of the latter in the central orbit. The reduction is typically $\sim$ 6 cm's. For the injection field levels this can be easily compensated by a d.c. durrent of the order of a few amperes in the BM, excited from a source of high impedance compared to the pulsers of the BM excitation. This d.c. current will also be chosen to compensate the remanent field of the BM. For the higher fields this magnetic length reduction will result in a local closed orbit distortion, if it cannot be corrected by shimming between BM and accelerator magnet. The slope and amplitude of the distortion can be estimated. If one adopts a 13 magnet array and considers it a very first approximation as a uniform reduction of the accelerator guiding field over around 24 units, i.e. about two betatron wave lengths, one would obtain the slope of Fig. 10. The maximum displacement $2\Delta R$ would be given by

$$\frac{\Delta R}{R} \simeq 10^{-2} \frac{\Delta B}{B_o} \quad \text{where} \quad \Delta B/B_o$$

is expressed in terms of the fractional reduction of magnetic lengths in the considered region. One finds an amplitude of about 7 mm with the maximums close to the KM's and SM's. Since it concerns a reduction of the bending length the distortion is outwards.

The radial variation of the equivalent length will probably also change in account of the BM iron yoke. This change in inclination of the magnetic ends will slightly affect the focusing properties of the accelerator and the effect will be studied further. Nothing dramatic is however expected here.

6. ACKNOWLEDGEMENTS

Our thanks are due to Yves Favereau, Albert Bertuol, Yves Sallot and Anton King for the incredible speed and efficiency they manifested in manufacturing the rough BM model. Last but not least we thank René Bonvin for the efficient way he performed the magnetic measurements.

7. REFERENCES

1) B. Kuiper, "Draft report on the design study of a fast ejection system serving channel A of the Serpukhov 70 GeV proton synchrotron", August (1967).

2) S. Milner, B. Kuiper, "A possible construction of the Bump Magnet for the Serpukhov fast ejection", CERN-PS/FES/TN-10, 16 March 1968.

3) B. Kuiper, "Rough bump magnet model for the Serpukhov fast ejection", CERN-PS/FES/TN-1, 20 February 1968.

4) B. Kuiper, "Measurements of the prototype magnet unit", CERN-PS/Int. MM 59-5, 11 June 1959.

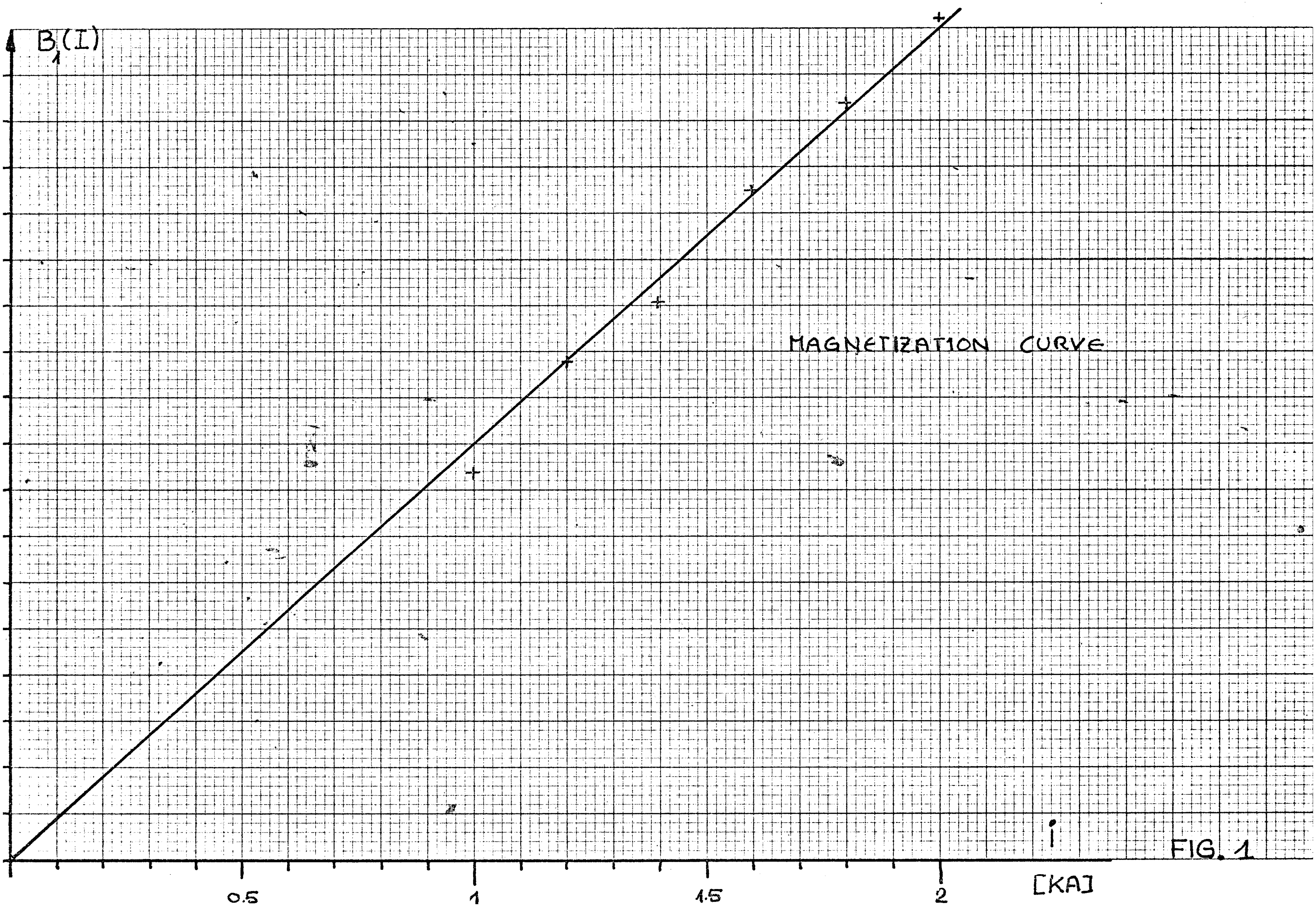


FIG. 1

BUMPMAGNET: AZIMUTHAL FIELD VARIATION B(θ) CENTRE LINE FOR DIFFERENT EXITATION CURRENT I

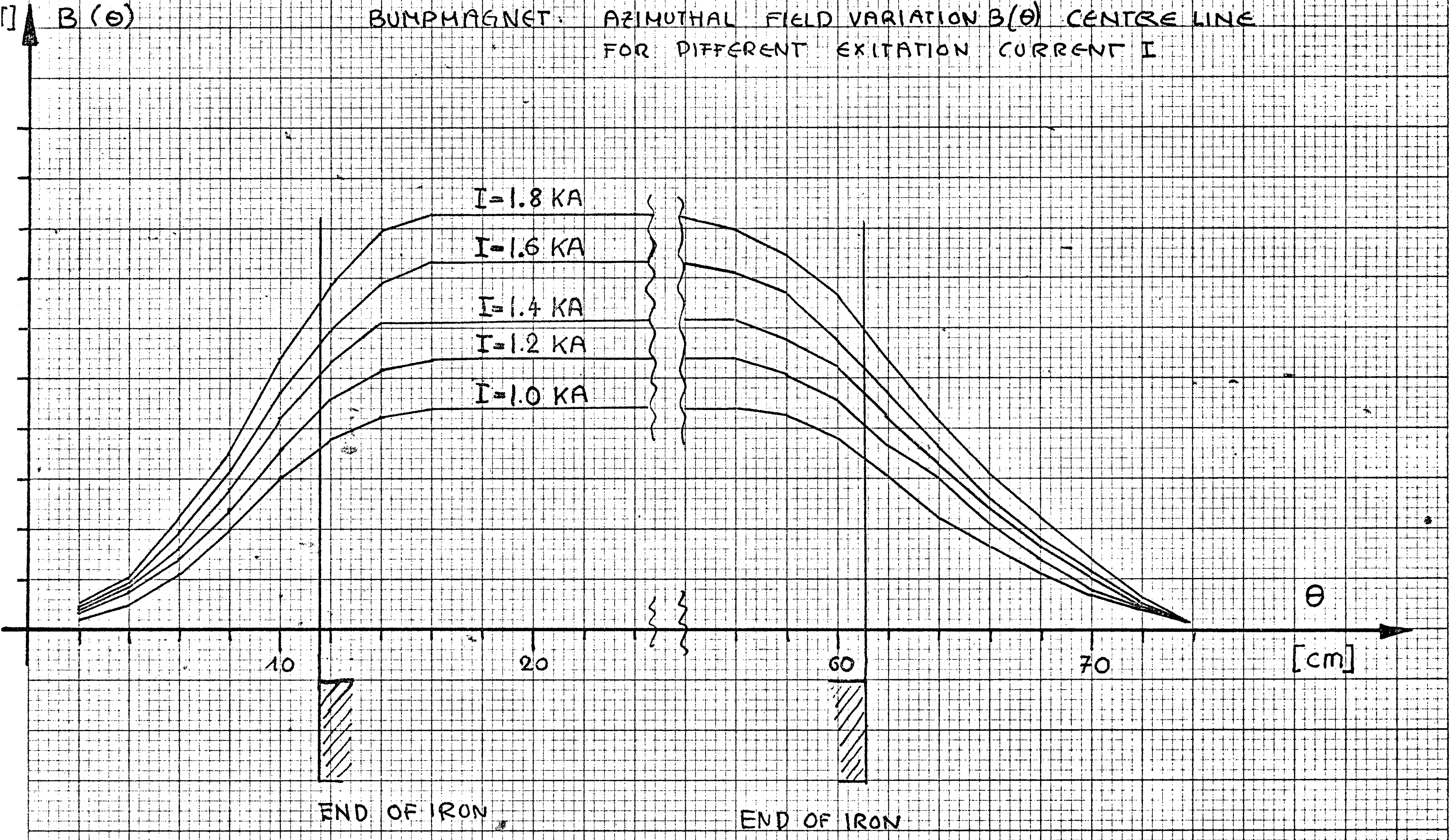


FIG. 2

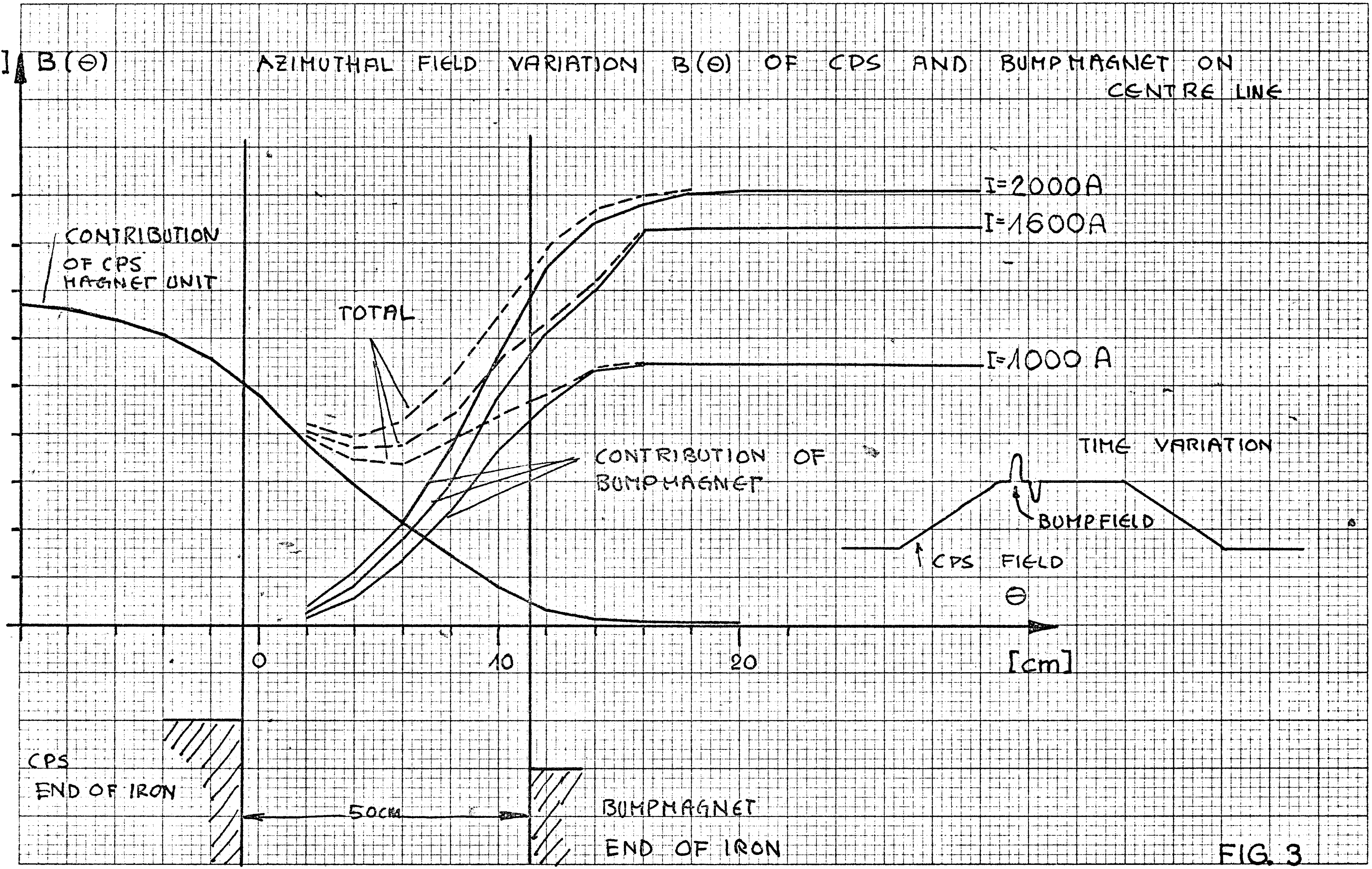

AZIMUTHAL FIELD VARIATION B(Θ) OF CPS AND BUMPMAGNET ON CENTRE LINE

FIG. 3

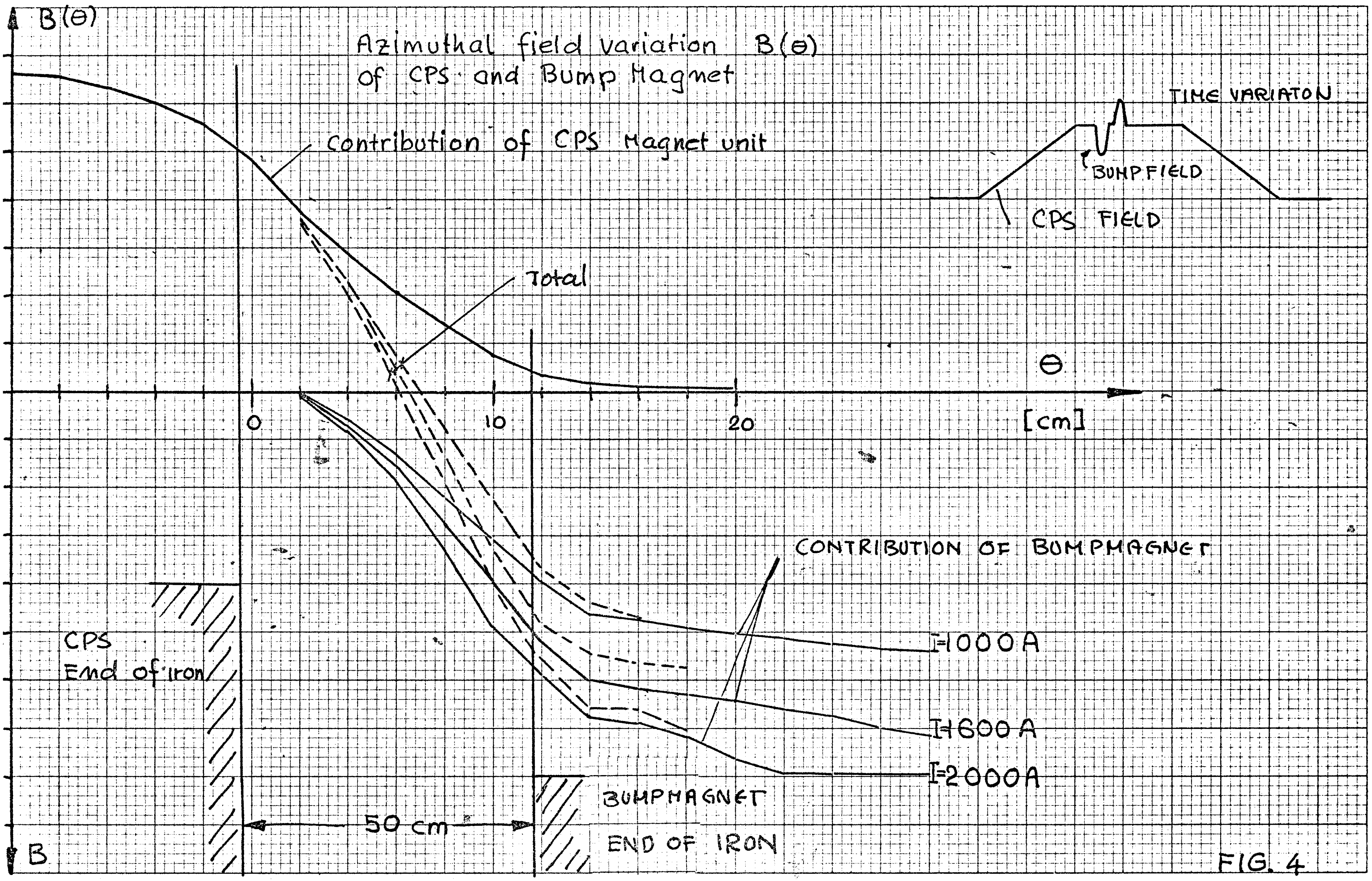
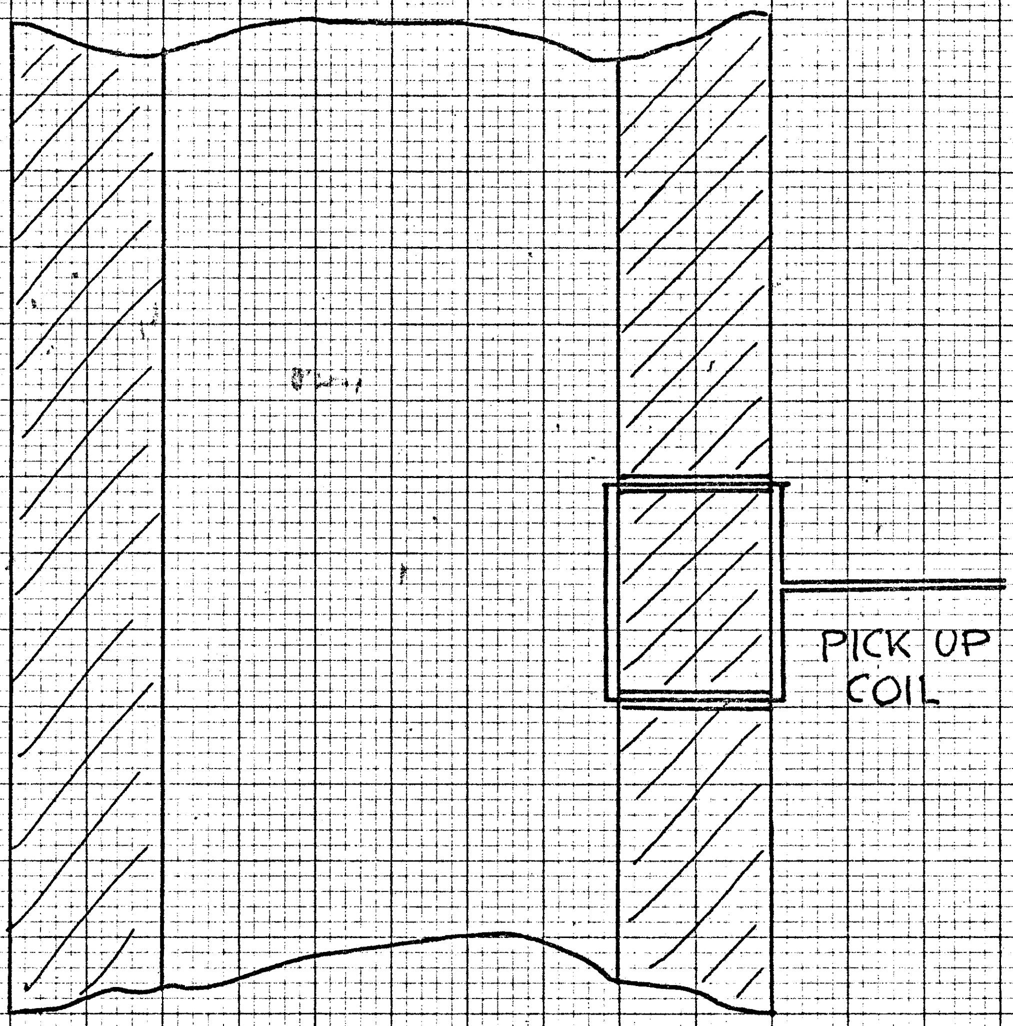

Azimuthal field variation B(θ)
of CPS and Bump Magnet
B(θ)
B
Contribution of CPS Magnet unit
Total
TIME VARIATON
BUMPFIELD
CPS FIELD
θ
[cm]
0
10
20
CONTRIBUTION OF BUMPMAGNET
I=1000 A
I=1600 A
I=2000 A
CPS
End of iron
50 cm
BUMPMAGNET
END OF IRON

FIG. 4



DISPOSITION OF BUMPMAGNET YOKE PICK UP LOOPS

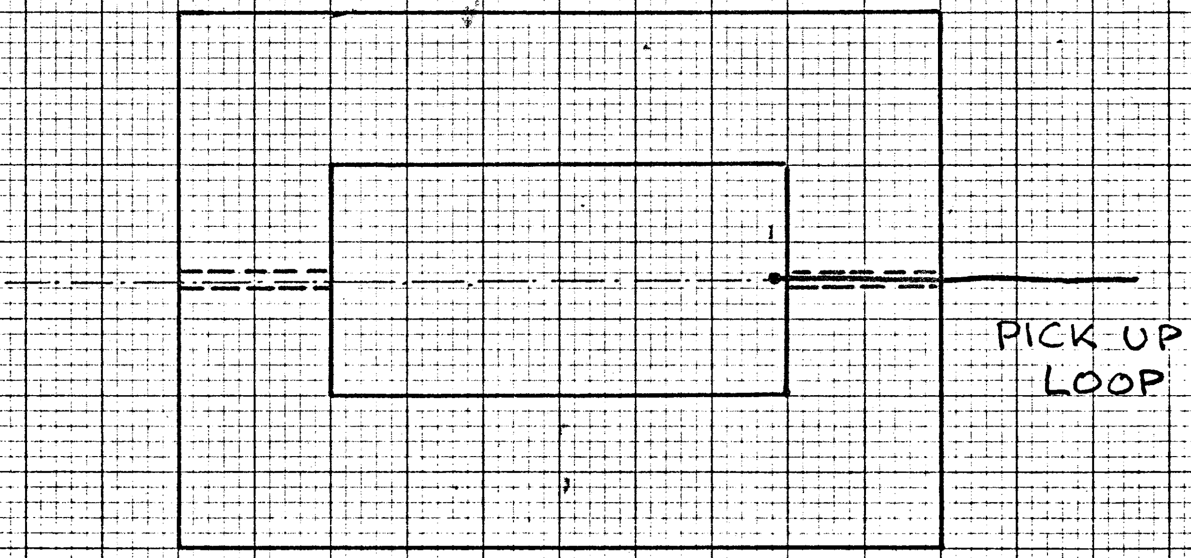
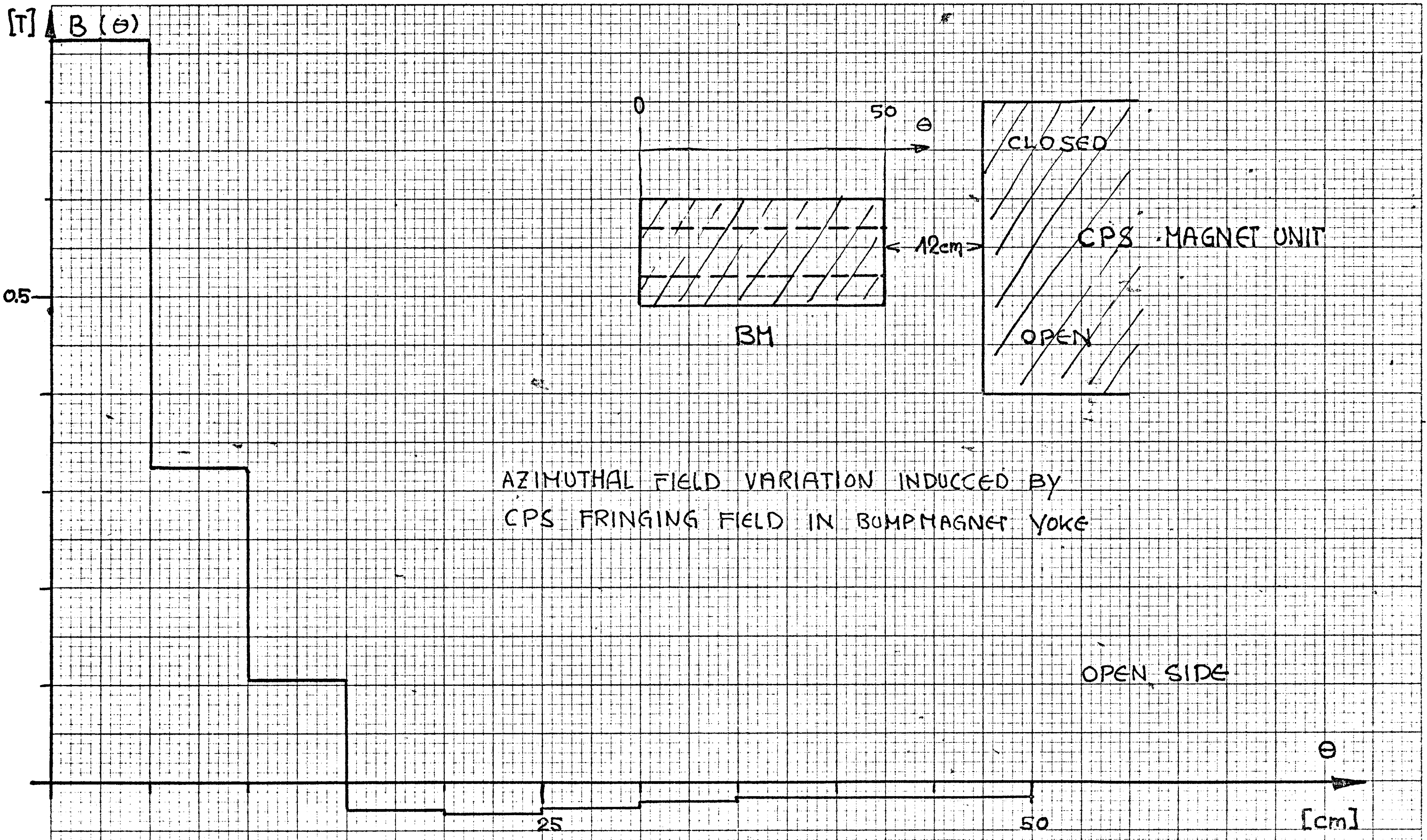
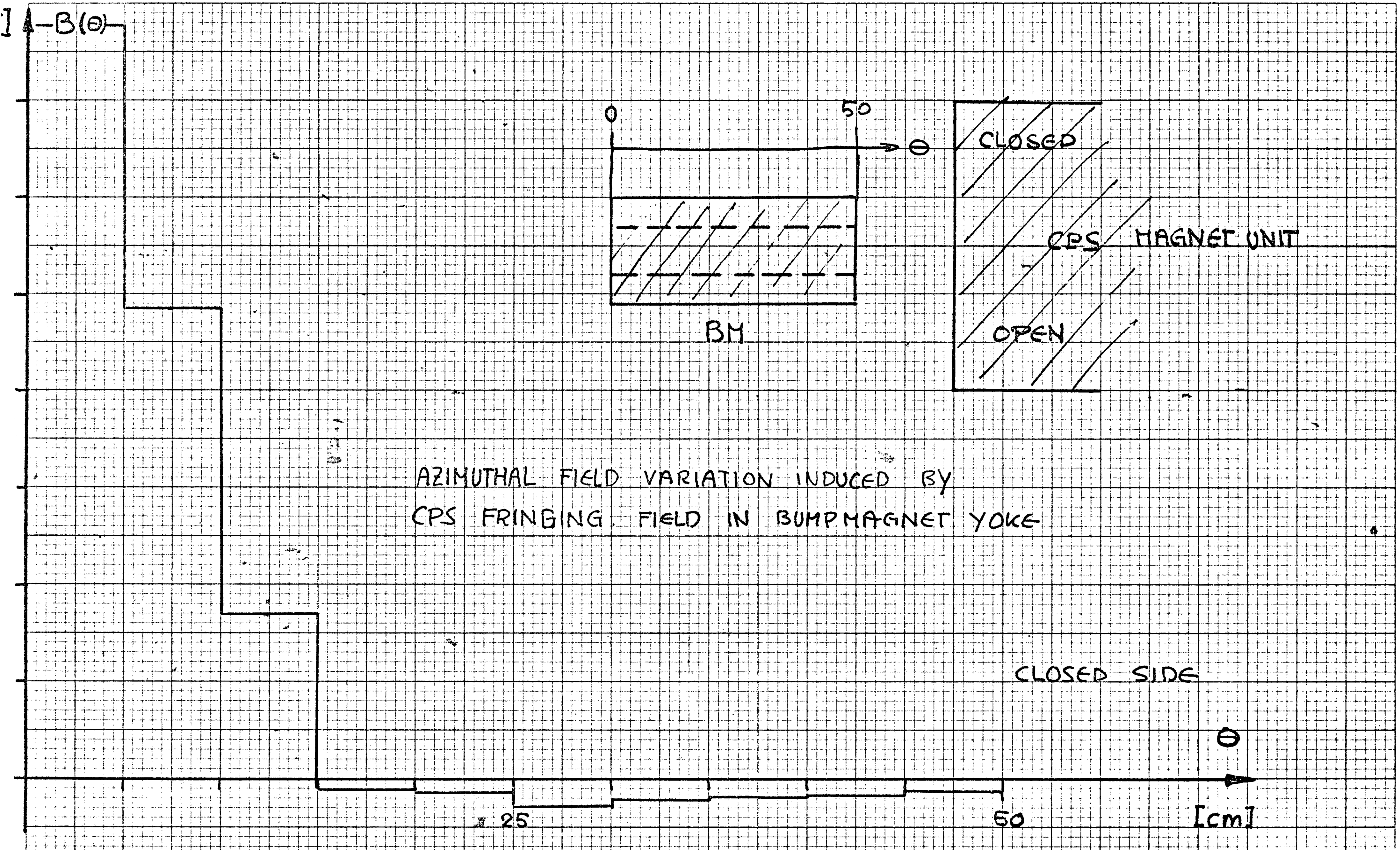


FIG. 5



AZIMUTHAL FIELD VARIATION INDUCCED BY CPS FRINGING FIELD IN BUMPMAGNET YOKE

FIG. 6



AZIMUTHAL FIELD VARIATION INDUCED BY
CPS FRINGING FIELD IN BUMPMAGNET YOKE

FIG. 7

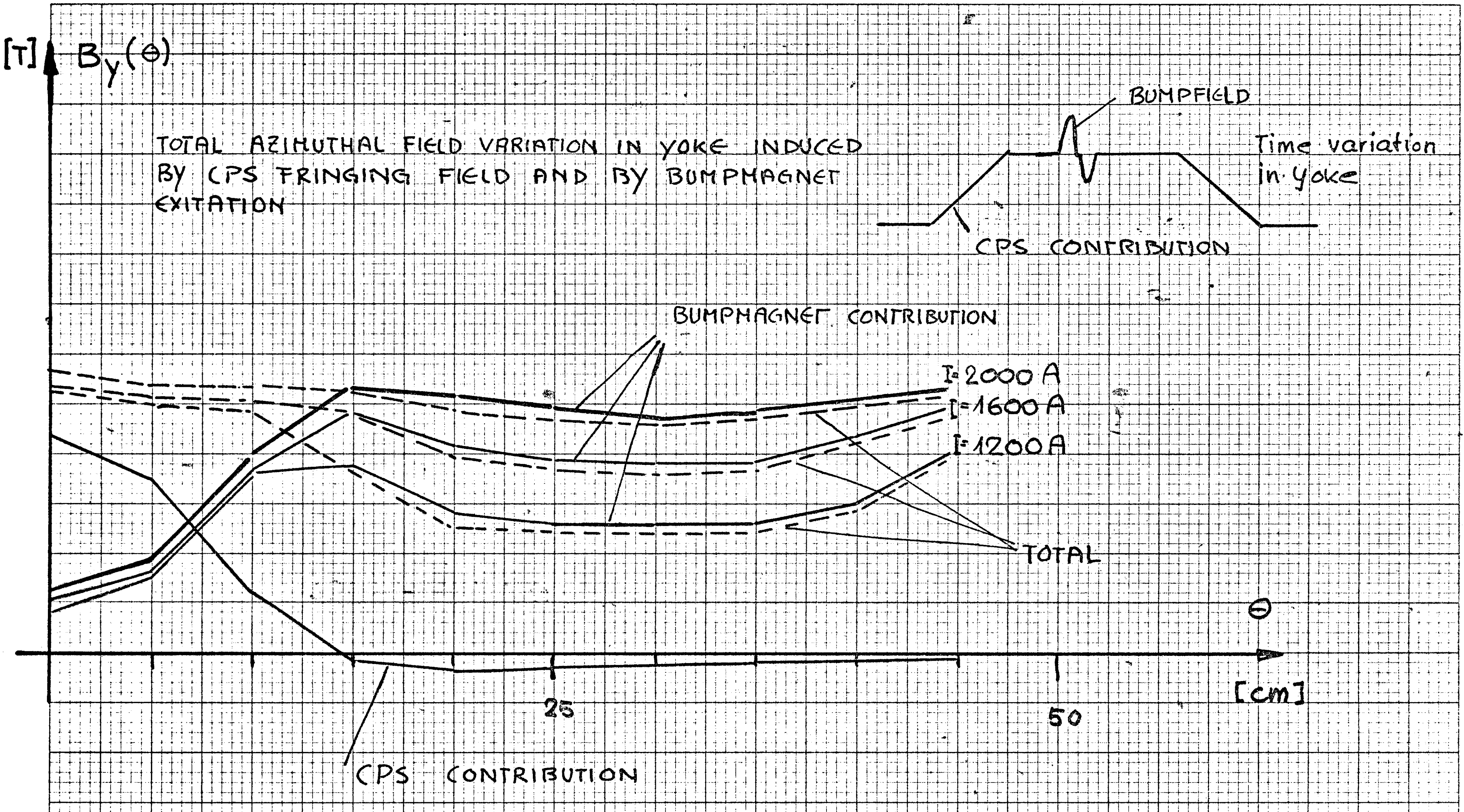

[T]
$B_y(\theta)$
TOTAL AZIMUTHAL FIELD VARIATION IN YOKE INDUCED BY CPS FRINGING FIELD AND BY BUMPMAGNET EXITATION
BUMPFIELD
Time variation in yoke
CPS CONTRIBUTION
BUMPMAGNET CONTRIBUTION
I=2000 A
I=1600 A
I=1200 A
TOTAL
θ
[cm]
25
50
CPS CONTRIBUTION

FIG. 8

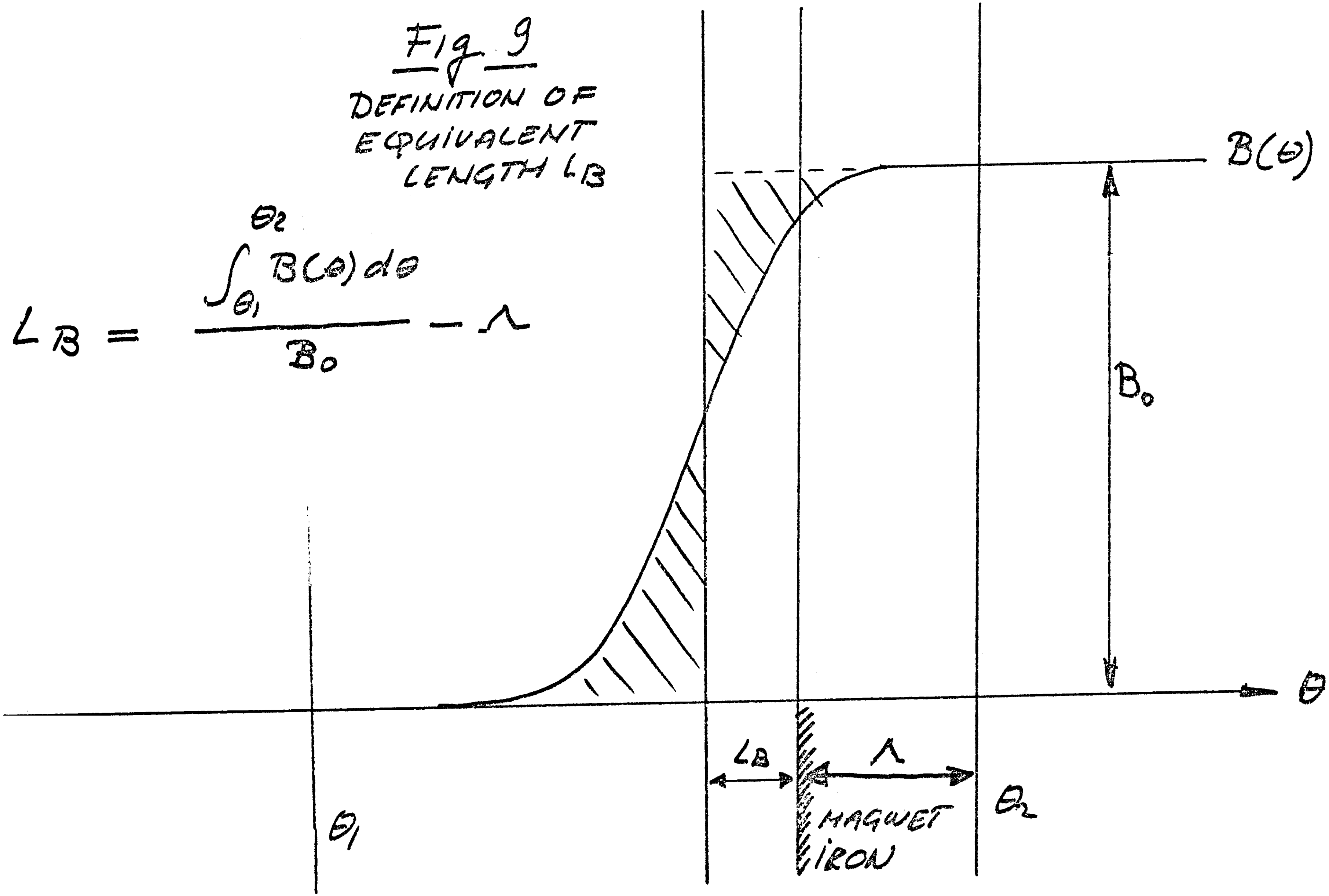


Fig 9

DEFINITION OF
EQUIVALENT
LENGTH L_B

$$L_B = \frac{\int_{\theta_1}^{\theta_2} B(\theta)\,d\theta}{B_0} - \Lambda$$