ISTITUTO NAZIONALE DI FISICA NUCLEARE

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CALCULATION OF THE EFFECTIVE CRITICAL FIELD OF THE CABLE FOR LHC DIPOLE MAGNETS

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ABSTRACT

In order to handle the critical current values of the cables for LHC dipole magnets, the effective critical field at the cable was calculated in several conditions. The paper shows the results of the calculations.

1. - INTRODUCTION

In the present work are shown the results of the calculations of the critical field of the cables for LHC dipole magnets when critical current measurements are performed. This kind of cables, carring very high currents, experience strong field inhomogeneity due to the self field: the critical field that we consider is an

average field called "effective critical field", described in a previous work(1). The calculation was performed for a couple of cables with opposite current in straight configuration (the distances we considered between the samples are 1, 0.2 and 0.02 cm). This configuration is the one designed by CERN in order to measure short samples of the cable at external field up to 10 Tesla (obtained by a superconducting dipole magnet) in a superfluid helium bath.
The effective self field is shown as function of the peak self field at the cable at several external fields (from 6 to 10 Tesla), temperatures and n-values.

2. - CABLE PARAMETERS AND FIELD CALCULATION

The cable under consideration is a Rutherford type one having trapezoidal shape with dimension 0.205-0.250 cm X 1.7 cm and copper/superconducting ratio 1.6(2). The measurement will be performed on two parallel samples of the cable (the thin edge of one is corresponding to the thick edge of the other) inside a superconducting high field dipole magnet; the samples will be series connected, so that the currents are opposite, and will be supplied by a superconducting transformer(3). Three different distances between the samples were taken into account performing the field calculation: 1 cm, 0.2 cm, 0.02 cm.
In order to obtain the effective critical field we calculated the distribution of field at the samples due to an external field of 8 Tesla plus a self field corresponding to a current of 10 KA. The results are shown in fig.1.
Due to the twisting each strand experiences a variable field along the cable(1)as shown in fig.2: B=B_{ext} + $\Delta B_{Max} \cdot f(x)$. The load line ΔB_{Max}= K I of the cable can be easily deduced by the field map at 10 KA. For the three cases considered we obtain K=3500 Gauss/KA (distance 1 cm), K=2500 Gauss/KA (distance 0.2 cm) K=1900 Gauss/KA (distance 0.02 cm). Starting from the field distribution it is possible to calculate the effective self field by using(1):

$$\Delta B_{eff} = \frac{1}{a}(1-(\frac{2\pi}{G})^{1/n})(b-a\cdot B_{ext})$$

where a and b are constants that define the dependance of the critical current on both the temperature and the magnetic field according to Lubell[4] and G is a function related to $\Delta B_{Max} \cdot f(x)$, B_{ext} and the n-value. The calculations of $f(x)$ were performed at B_{ext}=8 Tesla but the results can be applied with good approximation between 6 and 10 Tesla. Figures from 3 to 15 show the effective self field vs. the maximum self field in the three configuration at two temperatures and two values of n.

3. - DETERMINATION OF THE EFFECTIVE CRITICAL FIELD

After the measurement of critical current of a sample the problem is to determine the effective critical field at the cable.

First of all it is necessary to obtain the maximum self field at the critical current by the load line. As second step, being known temperature and n-value, figures from 3 to 14 allow to determine the effective self field at an external field between 6 and 10 Tesla for n=15, n=18 and for T=1.8 K, T=2.0 K.

For different temperatures and n-values (not too far from the given ones) a linear interpolation can be done.

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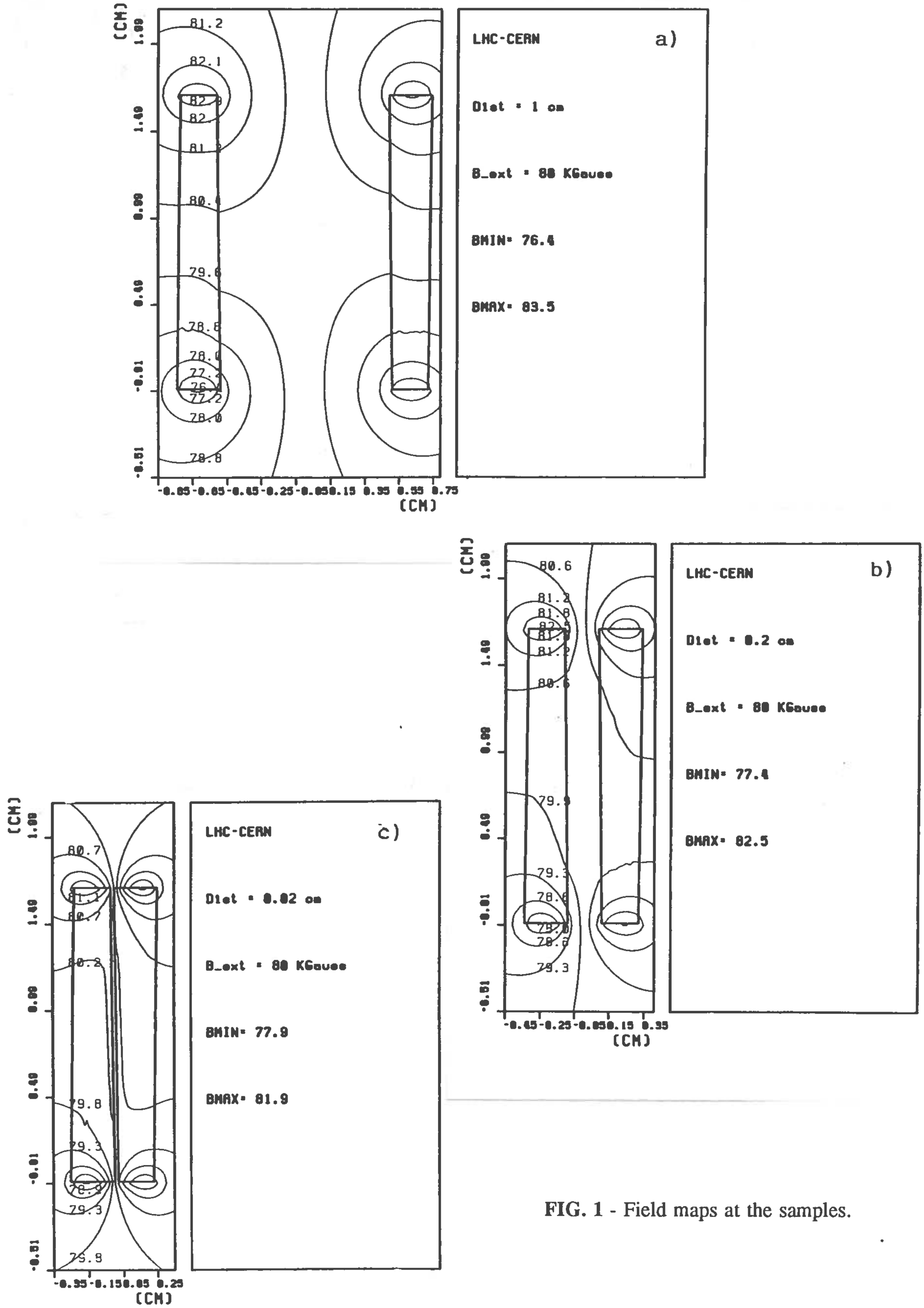

FIG. 1 - Field maps at the samples.

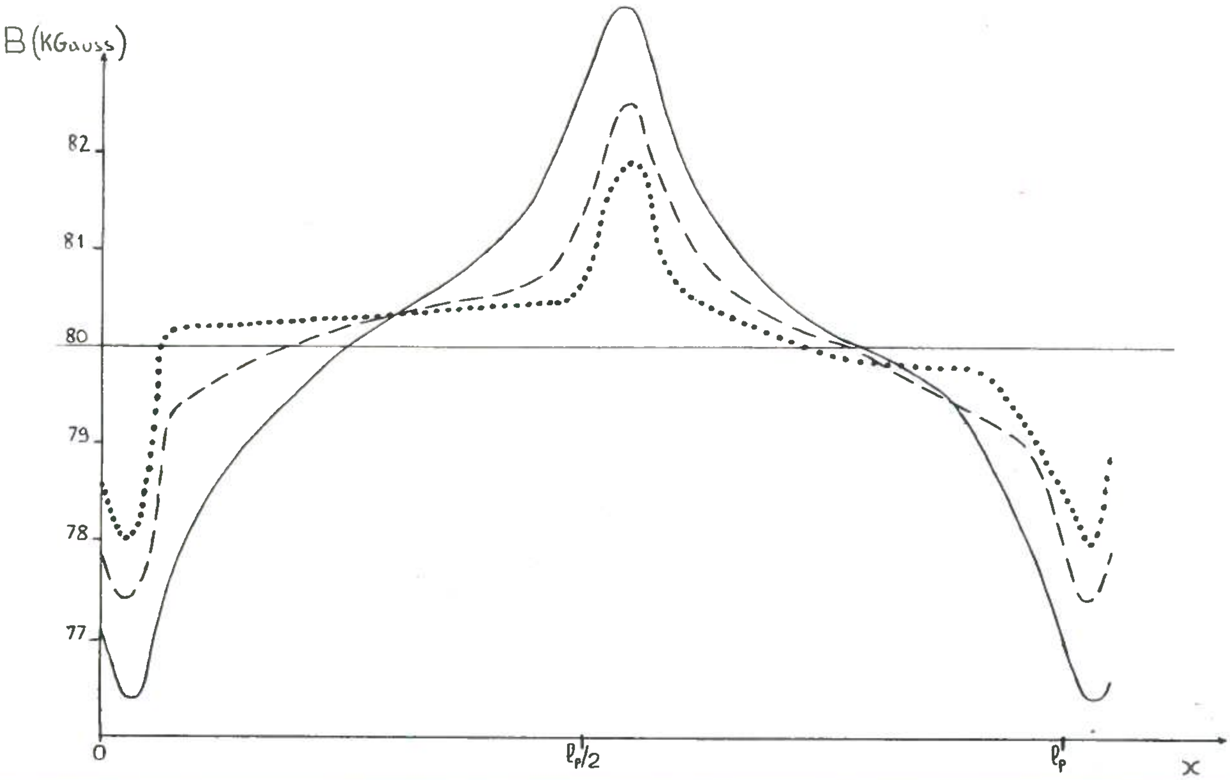

FIG. 2 - Field profile at the samples edge, corresponding to the field experienced by a strand along the twist pitch (The length is given in units of the twist pitch l_p). Three curves are shown for the three configurations: distance between the cables 1 cm (continuous line), 0.2 cm (dashed line) and 0.02 cm (dots).

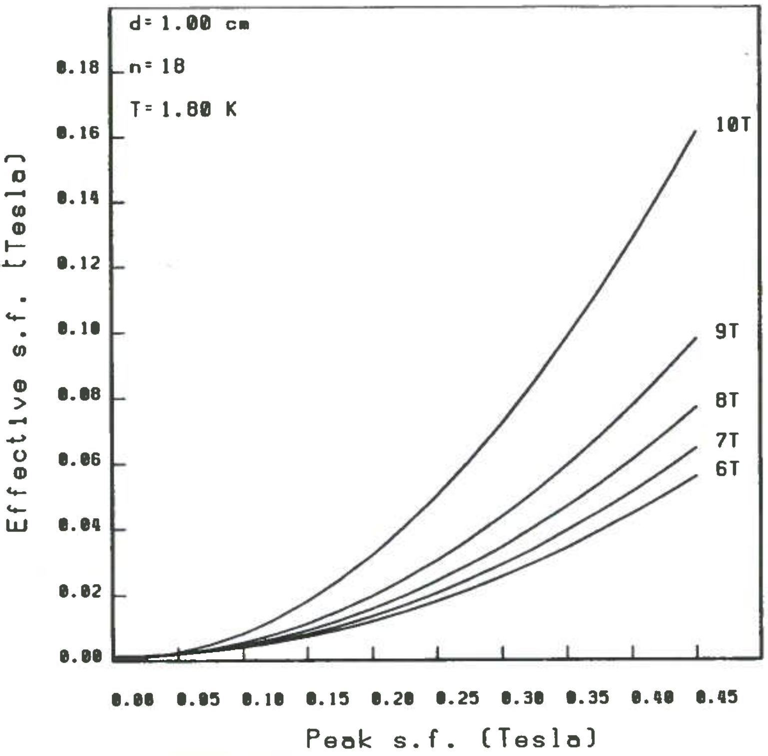

FIG. 3 - Effective self field vs maximum self field for d=1.00 cm, n=18, T=1.80 K.

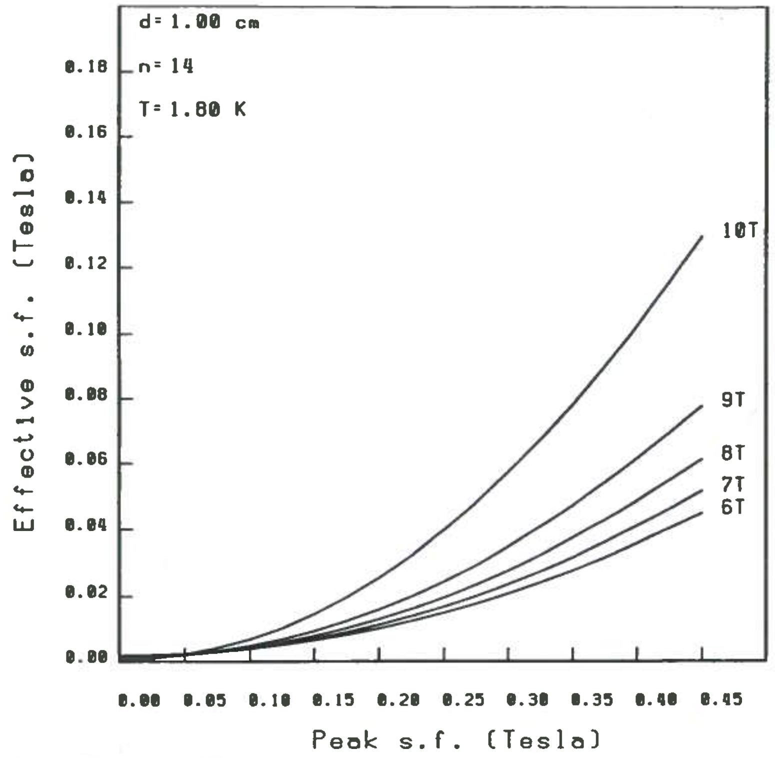

FIG. 4 - Effective self field vs maximum self field for d=1.00 cm, n=14, T=1.80 K.

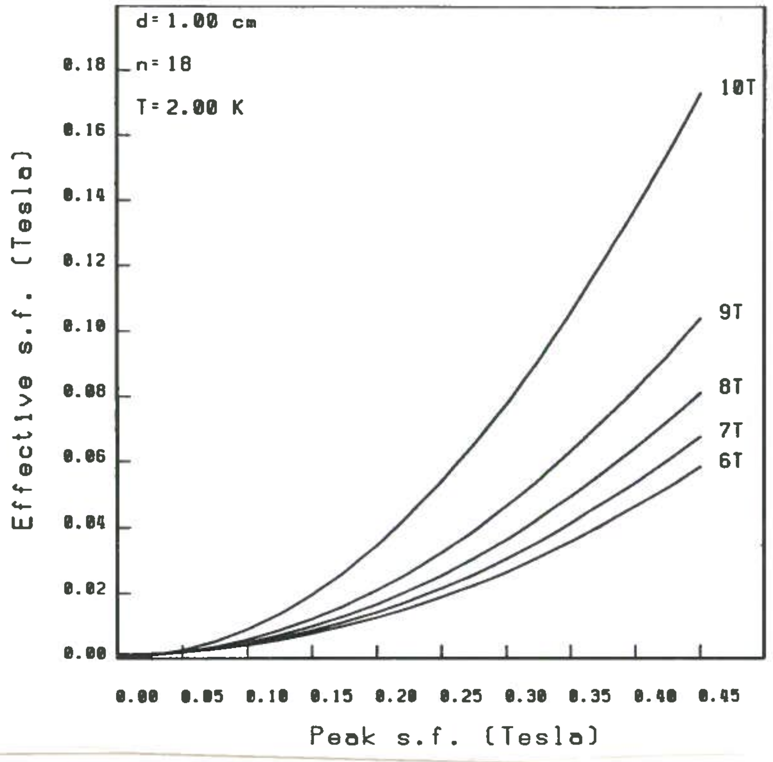

FIG. 5 - Effective self field vs maximum self field for d=1.00 cm, n=18, T=2.00 K.

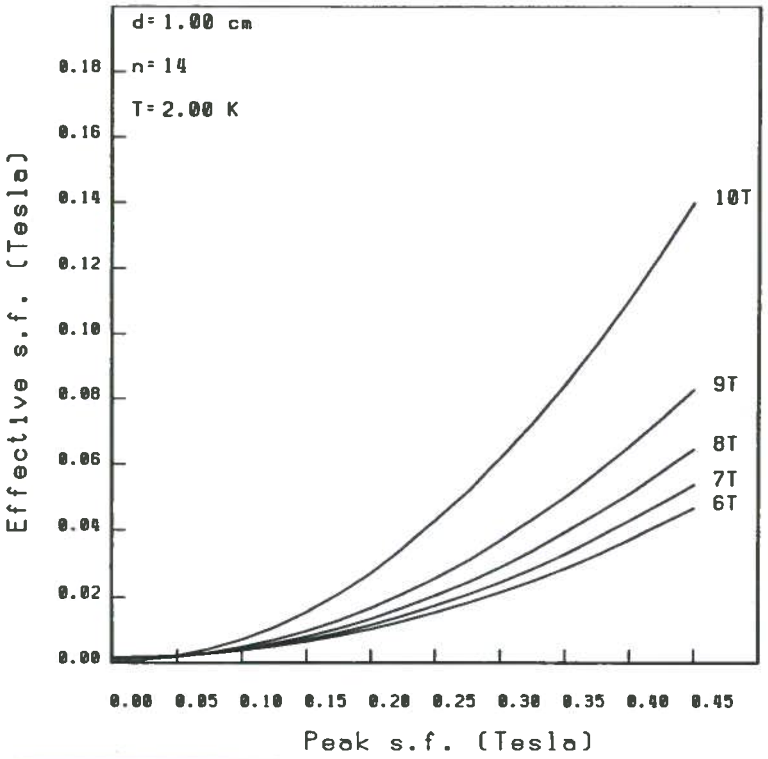

FIG. 6 - Effective self field vs maximum self field for d=1.00 cm, n=14, T=2.00 K.

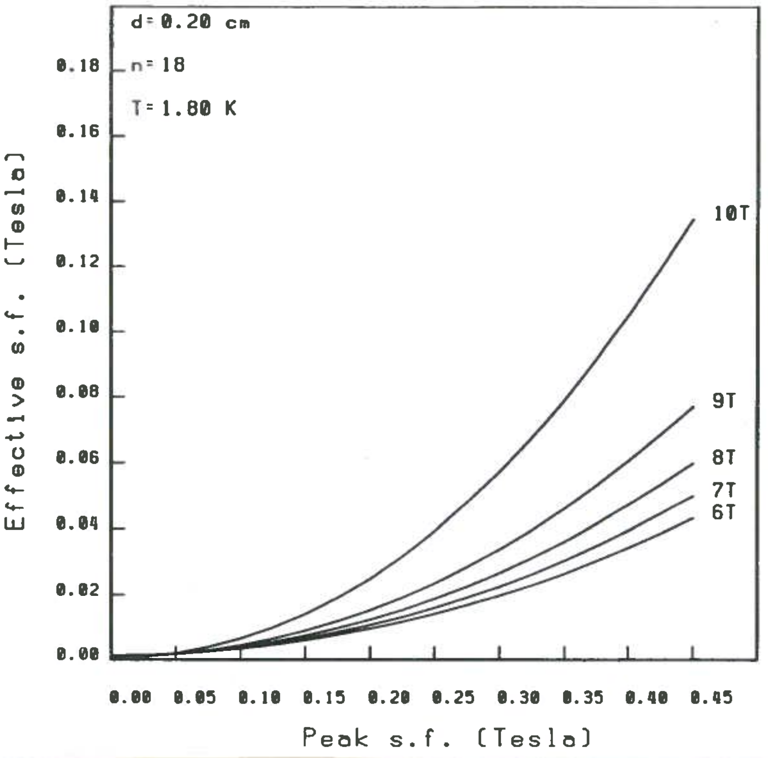

FIG. 7 - Effective self field vs maximum self field for d=0.20 cm, n=18, T=1.80 K.

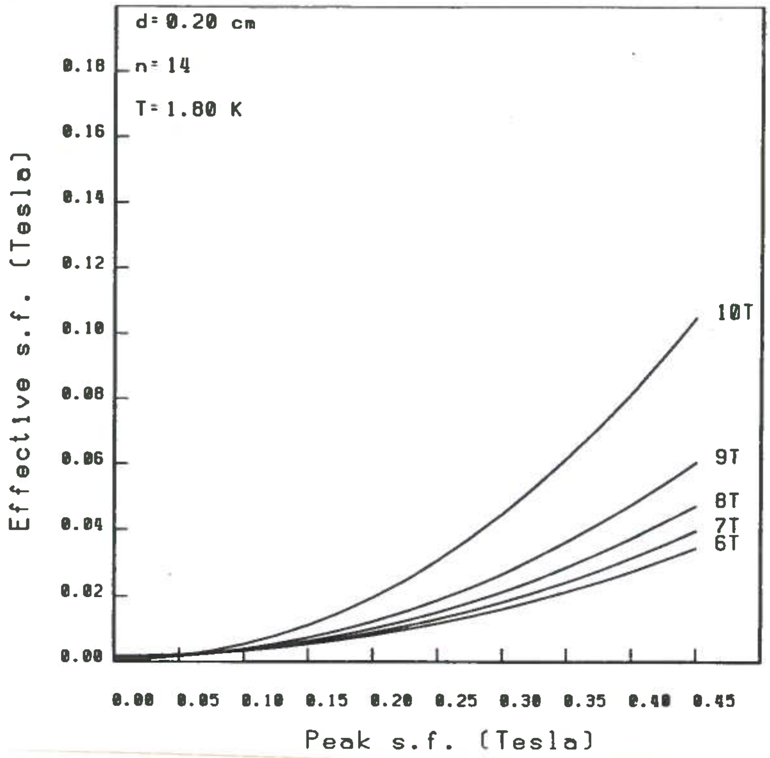

FIG. 8 - Effective self field vs maximum self field for d=0.20 cm, n=14, T=1.80 K.

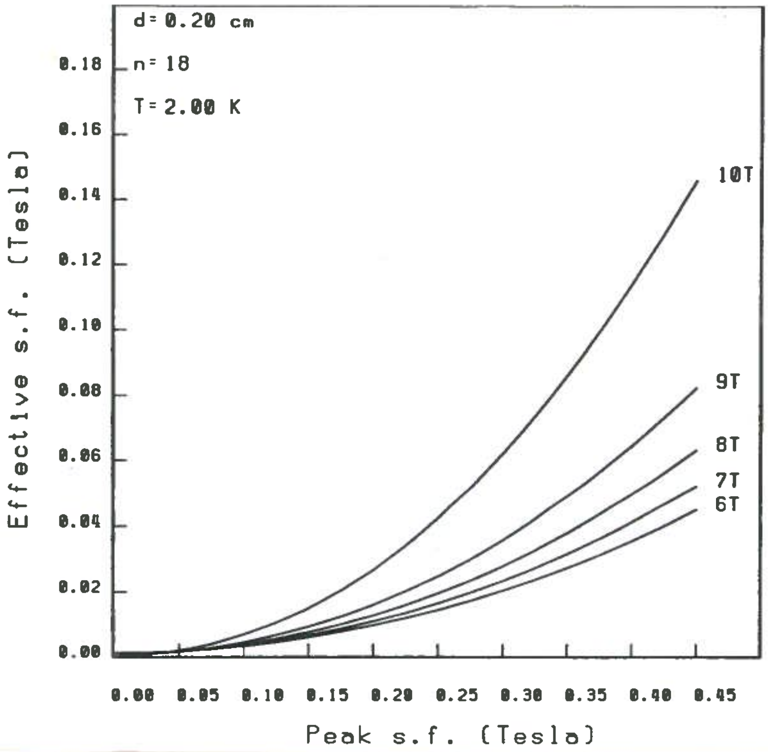

FIG. 9 - Effective self field vs maximum self field for d=0.20 cm, n=18, T=2.00 K.

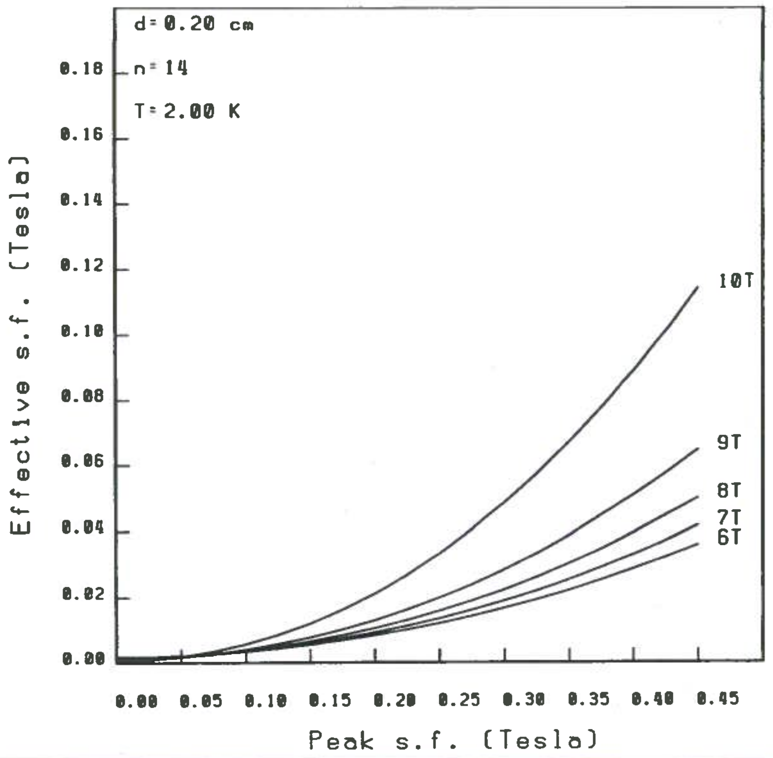

FIG. 10 - Effective self field vs maximum self field for d=0.20 cm, n=14 T=2.00 K.

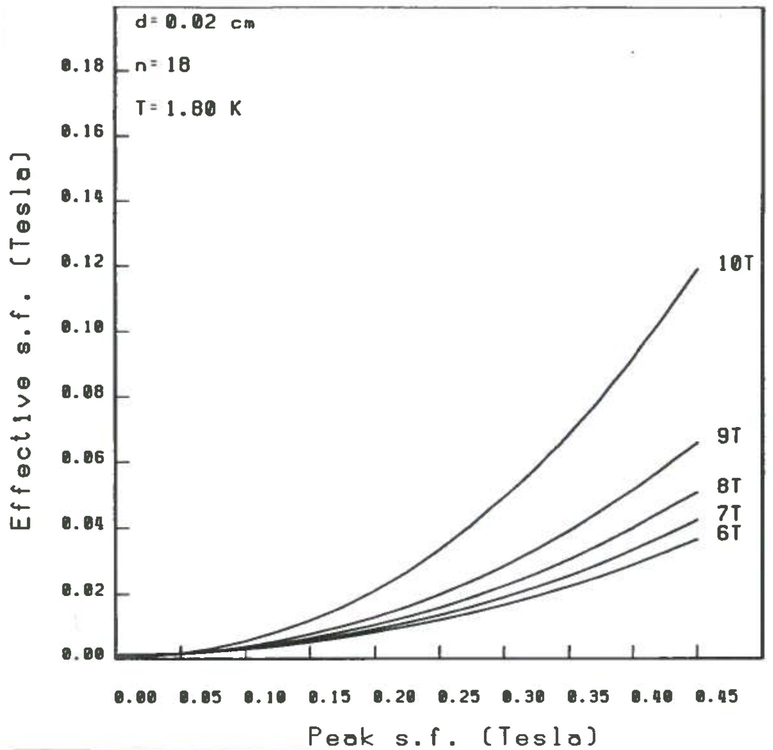

FIG. 11 - Effective self field vs maximum self field for d=0.02 cm, n=18, T=1.80 K.

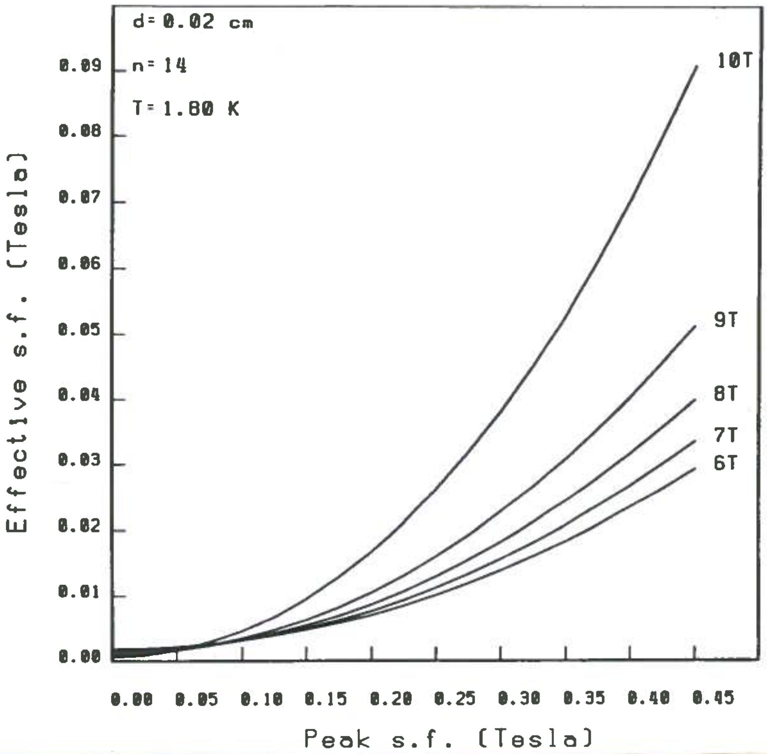

FIG. 12 - Effective self field vs maximum self field for d=0.02 cm, n=14, T=1.80 K.

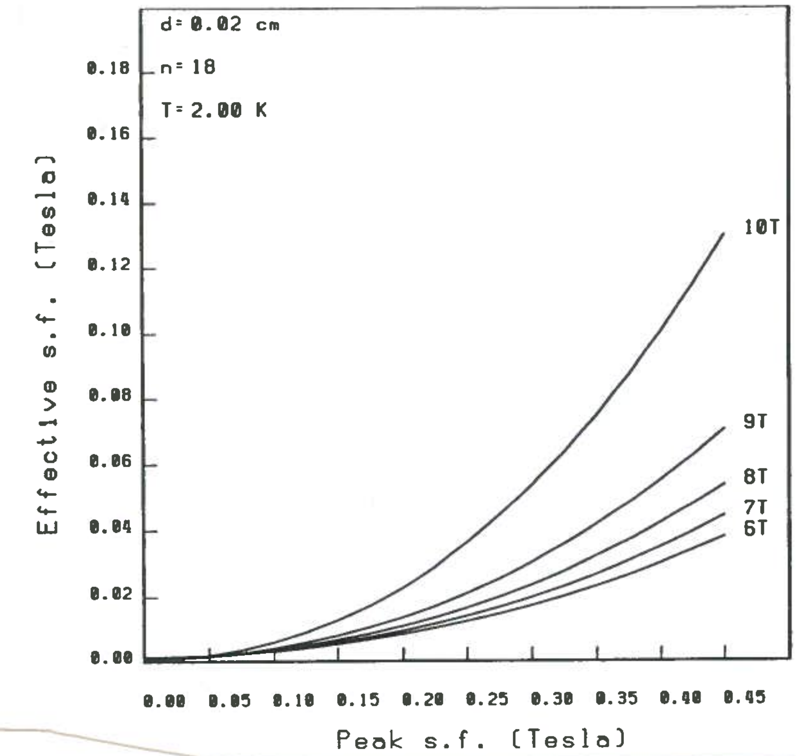

FIG. 13 - Effective self field vs maximum self field for d=0.02 cm, n=18, T=2.00 K.

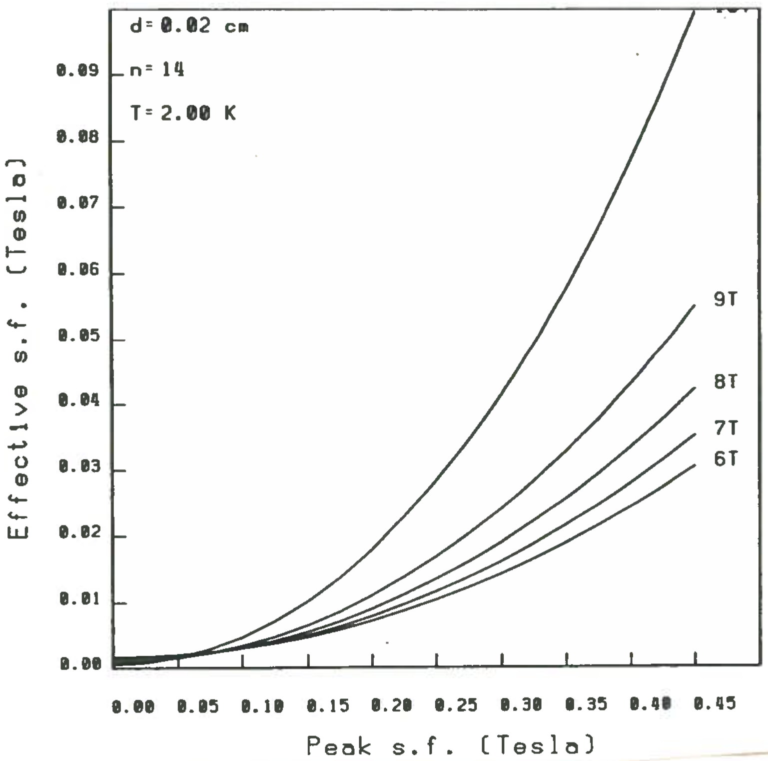

FIG. 14 - Effective self field vs maximum self field for d=0.02 cm, n=14, T=2.00 K.