A DISCRETE COIL TORUS WITH
LOWER FIELD RIPPLE

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ABSTRACT

A new toroidal field coil configuration is described which allows one to reduce the volume of a toroidal field coil system or the number of coils constituting such a system without increasing the toroidal field ripple.

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I. INTRODUCTION

One of the constraints on the design of toroidal field systems for controlled thermonuclear research devices is the size of the field ripple which results from the gaps between discrete coils. This ripple constraint can be met by increasing the size of the torus but this approach has the disadvantage of increasing the volume of the system which is economically costly. This paper presents an alternate winding configuration for the toroidal field coil which reduces the field ripple without changing the volume of the torus.

II. THE NEW COIL CONFIGURATION

Previous work on reducing the field ripple in linear discrete coil solenoids (1) showed that laminated iron rings under each coil would smooth the field ripple. This was accomplished because the iron tended to weaken the field under the coil and to strengthen it in the gaps between coils. This ferromagnetic technique is not very practical at the high toroidal fields of present devices and, therefore, an electromagnetic technique was sought which would achieve the same end. The result of this work is shown in Figure 1. This figure shows the standard circular coil and the new coil configuration which consists of the circular coil plus a segment section defined by an angle, α , and carrying a fraction, f , of the coil current. The effect of the segment section is to weaken the field

under the coil and to strengthen it in the gap between coils. The result is that the segment section, like the iron rings, tends to smooth out the toroidal field ripple.

The quantitative effect of the segment section is shown in Figure 2. This figure shows a plot of the toroidal field ripple as a function of the major radius of the torus for various fractions of the coil current flowing in the chord section of the new configuration. At a radius of 3.6 meters, 15.5 percent of the coil current flowing in the chord of the coil reduces the field ripple from 4.1 percent to 0.6 percent. These results are for a chord angle of 90 degrees.

III. A MEASURE OF THE EFFECTIVENESS OF THE NEW COIL

A study was made to establish how effective this new configuration is in reducing the field ripple as compared to increasing the size of the torus. The results of this study are shown in Figure 3 in the form of a plot of ripple as a function of radius for different size conventional toroidal coil systems with the same poloidal bore. It can be seen that a torus with a major radius of 3.03 meters and a minor radius of 1.9 meters gives a field ripple of 0.6 percent at a radius of 3.6 meters. A comparison of the magnetic energy of this large torus with the magnetic energy of the smaller torus with a chord current of 15 percent should give a measure of the efficiency of the two approaches. The energy calculations indicate that the smaller torus with the segment section has 85 percent of

the magnetic energy of the large conventional torus. These same computations showed that the segment section accounts for 4 percent of the magnetic energy of new configuration torus.

IV. REDUCING THE NUMBER OF COILS IN A TORUS

Another possible use of this new coil configuration would be to allow a reduction in the number of coils forming a torus without an increase in the field ripple. Figure 4 shows the ripple as a function of radius for various numbers of coils forming the torus for the case with 15 percent chord current. The dashed line in this plot is for the conventional coil case with 20 coils. It is apparent that, with the new configuration, the number of coils could be reduced from 20 to 17 without increasing the field ripple above that of the 20 coil conventional case.

V. PLANS FOR FURTHER STUDY

The new coil configuration shown in schematic in Figure 1b will look somewhat different in a more realistic embodiment. Figures 5a and 5b show sketches of two possible configurations. The characteristics of these more realistic coils may differ somewhat from the characteristics of the coil analyzed in this paper. For this reason, a study is currently underway to analyze the more realistic

configuration and the results of this work will be reported at a later date.

VI. CONCLUSION

The new coil configuration described in this report appears to offer the possibility of reducing the volume of toroidal field coil systems or of reducing the number of coils forming such systems without increasing the toroidal field ripple.

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Fig. 1. a) Standard toroidal field coil configuration b) New toroidal field coil configuration.

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Fig. 2. Toroidal field ripple vs. radius for different fractions of the coil current flowing in the chord.

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Fig. 3. Toroidal field ripple vs. radius for different size tori with the same poloidal bore.

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Fig. 4. Toroidal field ripple vs. radius for different numbers of coils forming the torus.

Fig. 5a

Fig. 5b

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Figs. 5a and 5b. More realistic
embodiments of the new toroidal field
coil configuration.