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Although stellarators offer some considerable advantages over tokamaks, (e.g. in continuous operation, better confinement properties, ab initio equilibrium, freedom from disruptions) difficulties arise in designing large devices due, for instance, to poor plasma access as well as to constructional, electromechanical and maintenance problems associated with continuous helical windings. This paper describes a design for a fairly large device (major radius 2.1 m), based on a set of discrete coil modules arranged in a toroidal configuration to provide the required closed magnetic surfaces, having gaps for unobstructed access to the plasma for diagnostics, etc, and allowing for easy removal for maintenance.

The provisional design parameters, which have been obtained as part of a detailed computational study aimed at optimisation of this type of configuration(1), are as follows: $B \leq 4$ T, $R = 2.1$ m, $\ell = 3$, 8 field periods (each consisting of two modules), $\iota_{max} = 0.59$, mean helical winding radius 0.33 m, separatrix radius $a = 0.25$ m. The equivalent current $I_{eq} = \iota a^2B/2R = 0.35$ MA. It is intended to use ohmic heating currents $I_H \leq 0.2$ MA. The arrangement is shown in Figs. 1 and 2: the helical conductors within each module are to be connected in series with each other and with the toroidal coils, the links between helical conductors contributing to the toroidal field. Mechanical strength is obtained by using large cross-section, single-turn conductors (hard Cu or Cu-Cr alloy), and by fixing the helical windings to the toroidal coils to form a rigid assembly. No azimuthally encircling conductors are used: the transverse field components required to centre the magnetic surfaces, including the separatrix, within the vacuum chamber will be obtained by using a different pitch angle modulation ($\theta = m\phi + \alpha_{1,2} \sin\theta$, $\alpha_1 \neq {}_2$) for each polarity of helical conductor. Fig. 3 shows the separatrix computed for the above arrangement, but with $\alpha_1 = \alpha_2 = +0.05$.

The low impedance electrical characteristics of the assembly form a suitable load to the Canberra Homopolar Generator (stored energy 0.5 GJ, 400 V). With the windings all in series, this will produce $B \approx 3$ T for a 2 sec. 'flat-top' ($I_W \approx 0.3$ MA) and with half the windings in parallel $B \approx 4$ T for 1 sec. ($I_W \approx 0.4$ MA).

From extrapolation of the results from existing ohmically heated

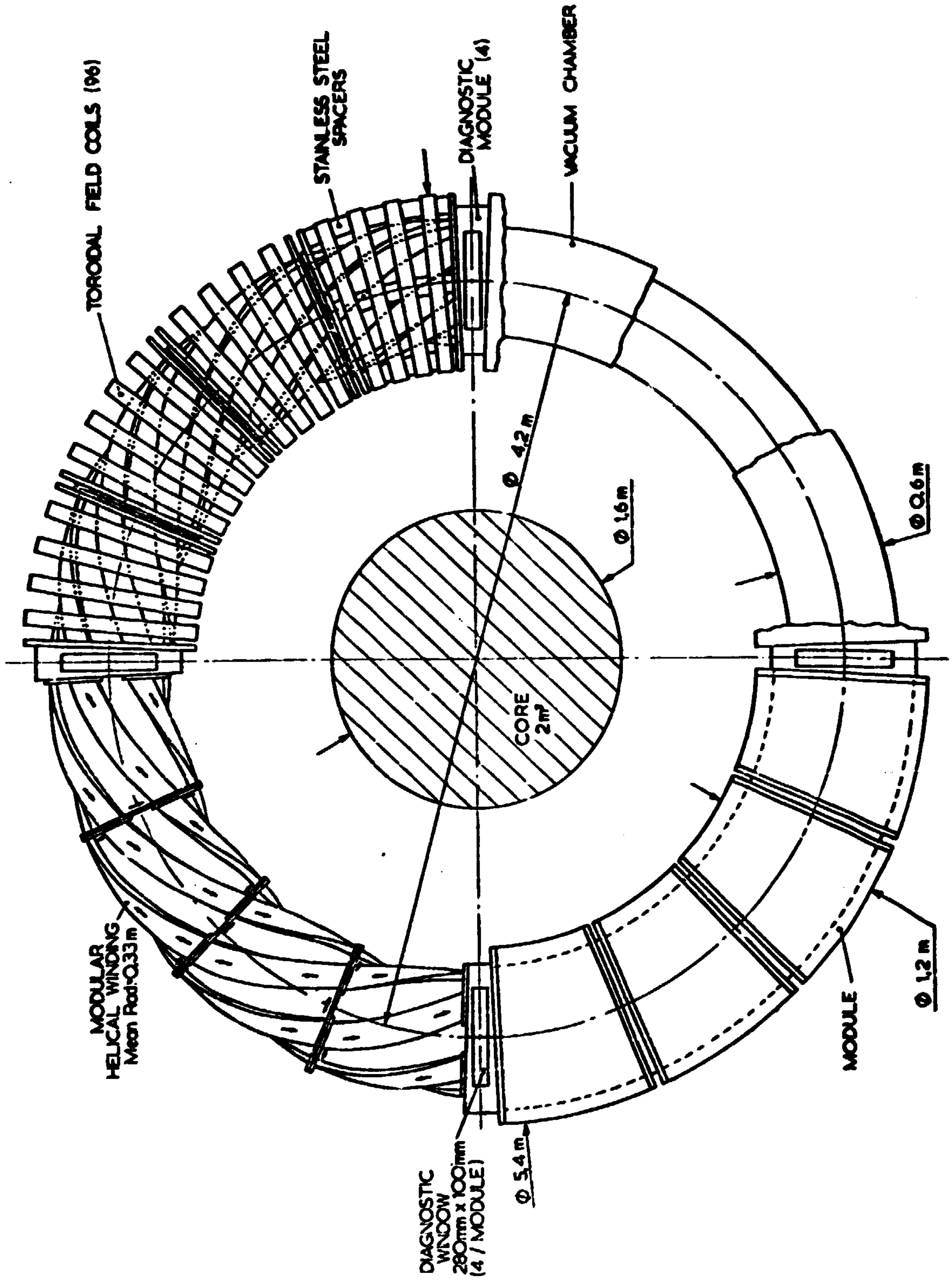

Fig.1. Schematic layout of Canberra Modular Stellarator windings. The 'diagnostic gaps' are 13 cm wide at the mean major radius and offer access to the plasma from all four directions.

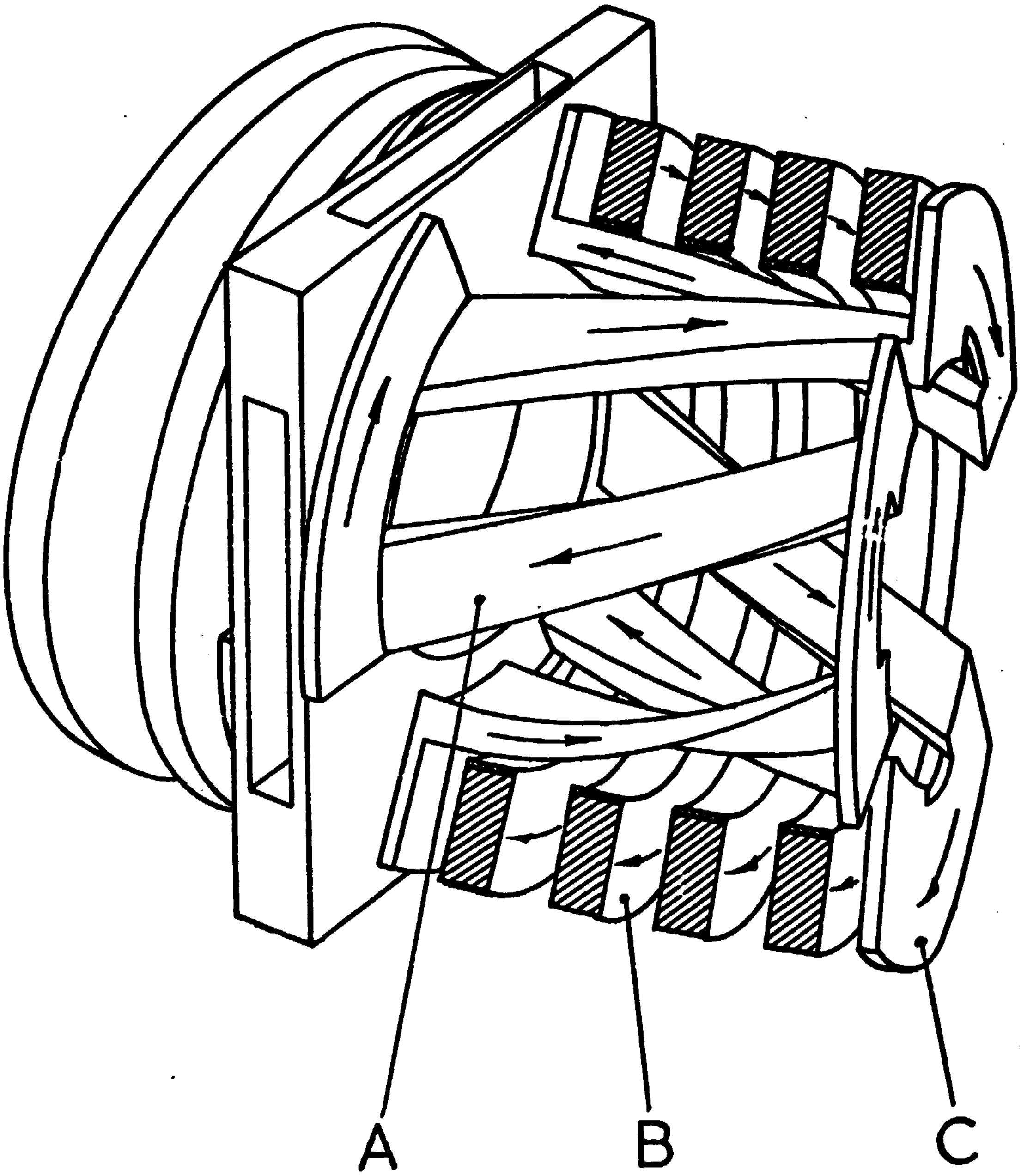

Fig.2. Arrangement of windings in one module (connections now shown). Two modules (of different type) form each field period. The conductor cross-sections and mean minor radii are: A - 17 x 6 cm, 33 cm; B - 20 x 7.5 cm, 48 cm; C - 3 x 20 cm, 48 cm.

stellarators, which suggest $\tau_E \propto I_{eq}^2$, we expect $\tau_E \sim 100$ ms, while experience, e.g. on CLEO[2], suggests that optimum confinement will be obtained at low ohmic current density such that the drift parameter $\xi \equiv v_d/v_e \leq 10^{-2}$. From simple power balance, taking $\bar{n} = 5.10^{19}$ m^{-3}, $Z = 3$, $r_p = 0.21$ m, an ohmic heated current of 200 kA should produce temperatures $T_e \approx T_i \approx 1.3$ keV, ($\xi \approx 10^{-2}$) with a loop voltage ≈ 1 V. Generous space exists (see Fig. 1) for the use of a sufficiently large iron core (say, 5 Vs) with the primary windings close-wound on the central limb to allow long pulse operation (> 1 s) without introducing stray fields due to core saturation.

An engineering design study of this device, supported by the National Energy Development and Demonstration Commission, is under way.

References

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(2) ATKINSON, et. al., 7th Int. Conf. on Plasma Physics and Controlled Fusion, IAEA/CN/37 H.1, 1978.

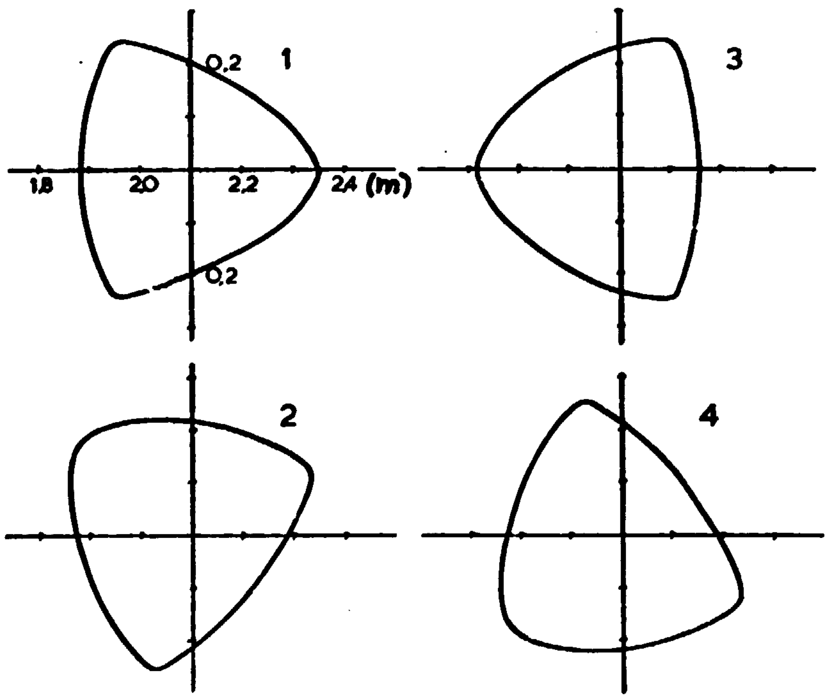

Fig.3. Computed separatrix cross-sections at four positions in one field period. Each conductor is approximated by 3 filaments. There are 4 x 4.5° diagnostic gaps with 1° gaps between each module. 1. - main gap. 2 - 4, quarter, half, three quarter period.