CONF-790602--35

UC-20A
WFPS:TME-79-006
PREPRINT
JANUARY 25, 1979

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SUBMITTED FOR PRESENTATION AT THE
ANS 1979 ANNUAL MEETING, ATLANTA GA
JUNE 3-8, 1979

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ACKNOWLEDGEMENT

This work was performed for the Office of Fusion Energy of the U.S. Department of Energy under Contract EG-77-C-02-4544, Fusion-Fission Hybrid Studies. Reproduction, translation, publication, use and disposal, in whole or in part, by or for the United States Government is permitted.

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Price: Printed Copy $3.50; Microfiche $3.00

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SUMMARY

The conclusion of this work is that a bundle divertor[1], using an improved method of designing the magnetic field configuration[2], is feasible for the Demonstration Tokamak Hybrid Reactor (DTHR)[3] investigated by Westinghouse. The most significant achievement of this design is the reduction in current density (1 kA/cm^2) in the divertor coils in comparison to the overall averaged current densities per tesla of field to be nulled for DITE (25 kA/cm^2) and for ISX-B[2] (11 kA/cm^2). Therefore, superconducting magnets can be built into the tight space available with a sound mechanical structure.

This divertor design is scalable; the scaling relationships, the variation of the divertor flux configuration with field intensity, and divertor coil angle effects have been studied. When the null point is fixed, the flux is diverted to larger major radius and has a larger expansion for larger divertor coil angle, α, at a fixed B_t (see Figure 1). The flux, current, and current density in the divertor coils vary with the size of the reactor and depend on the number and the size of TF coils, but are dominated by the toroidal field intensity which has to be nulled. The upper limit of B_{null} is about 4.0 T. Consistent with $B_{null} = 4.0$ T, it is possible to design a bundle divertor for a reactor having a field on axis of 6 T with A = 3, and a = 2 m.

The plan view of DTHR with a bundle divertor is shown in Figure 1. Additional expansion of the magnetic flux is achieved by a pair of mirror coils with a nominal current of 100 kA each. The important design parameters are shown in Figure 1. The divertor coil winding is a composite cable of 2 cm x 2 cm cross section Nb_3Sn/Cu cooled by force flow supercritical helium at four atm inlet pressure. The current carried by the cable is 32 kA. The thermal power for helium pumping is 4.2 MW including nuclear heating, and the electrical power supply for a 30 minute charging time is less than 1 MW; therefore, the power requirement is insignificant.

The divertor coil structure is of the grooved pancake type with two cables per groove. The maximum Lorentz force on a cable pair are $F_\rho = 0.3$ kN/cm in the radial direction and $F_z = 5.5$ kN/cm in the normal direction. Considering a safety factor of two the required tooth and bottom thicknesses of each groove are 1.78 cm and 1.08 cm respectively. The outward horizontal translational force of 20 MN can be adequately restrained. The placement of the divertor inside or outside the vacuum vessel duct extensions has been carefully designed and evaluated. Maintenance is feasible when the coils are inside the vacuum vessel duct extensions.

The particle collector consists of Zr/Al pressed on Amzirc (Zr/Cu alloy) tubing cooled by high pressure water. The collector panels are arranged in a sawtooth pattern such that the overall arrangement of the assembly is accordion shaped. The peak thermal flux at normal incidence is 3.2 kW/cm^2 at the end near the separatrix. The sawtooth shape will reduce this by a factor of ten, i.e., 0.32 kW/cm^2 on the panel surface; therefore, the heat removal can be easily handled. The short section of the front edge will be protected by a thermal shield consisting of an Amzirc tube attached to a rectangular backing bar.

The particles which escape from the plasma are trapped by the collector panels which are operated at 300°C for high trapping efficiency. The panel will be reactivated before it reaches saturation (about seven cycles or ten minutes). One-half of the collector assembly will then be moved into the chambers on the top or bottom alternately to be heated up to above 500°C for regeneration.

The nuclear shielding for the coils is assessed based on an allowable dosage to the insulator (3×10^9 to 10^{10} rads). The insulation life-time is about one to three years for 60 cm of shielding space, which is adequate for initial experimental operation. Studies are underway to extend this life-time for high duty cycle reactor applications.

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$R_o = 5.2$ m

$B_o = 5.45$ T

$I_D = 14$ MA-T/COIL

$I_{axil} = 6.4$ MA-T/COIL

α 40°

$I_{mirror} = 200$ KA-T/COIL

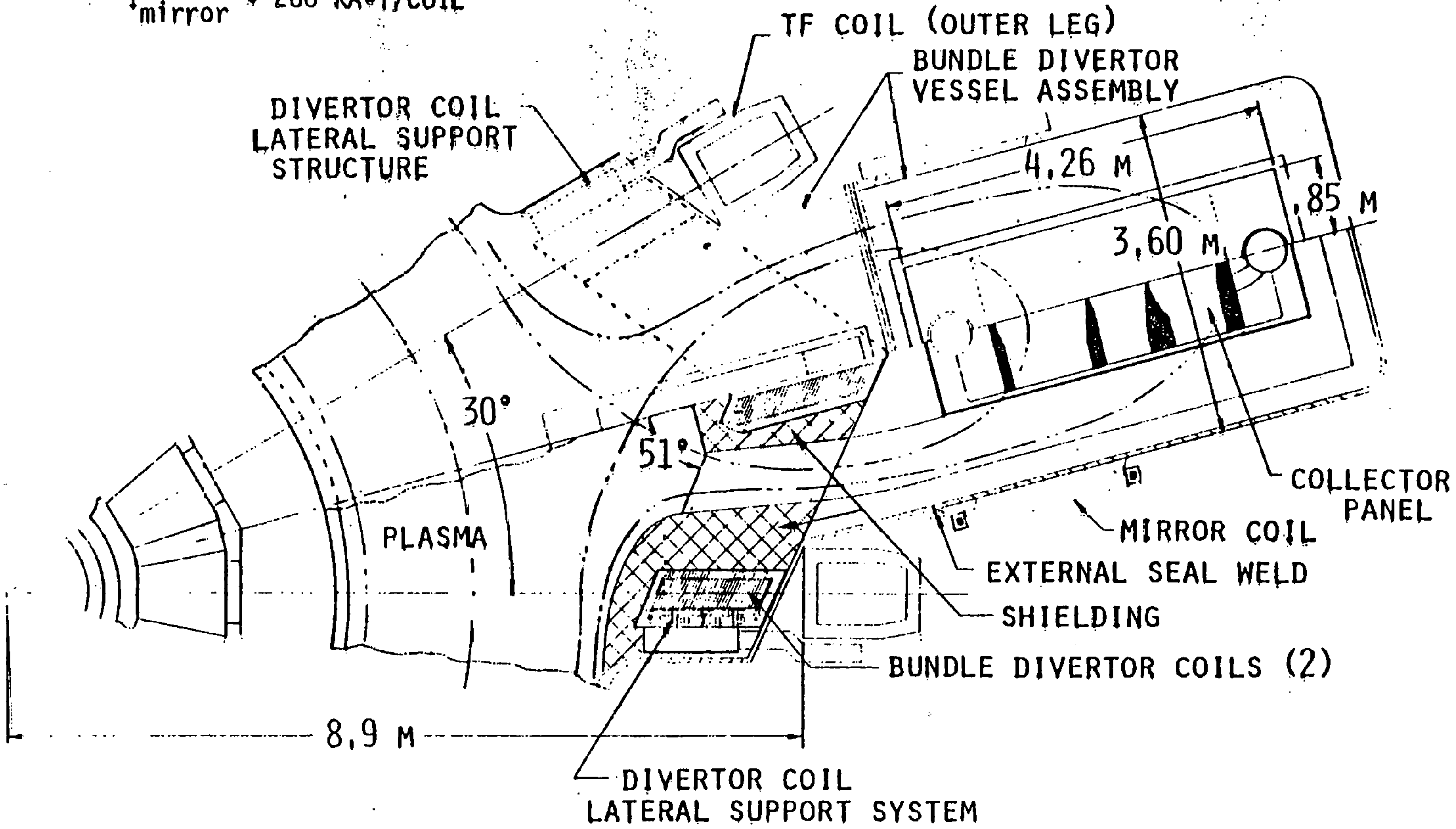
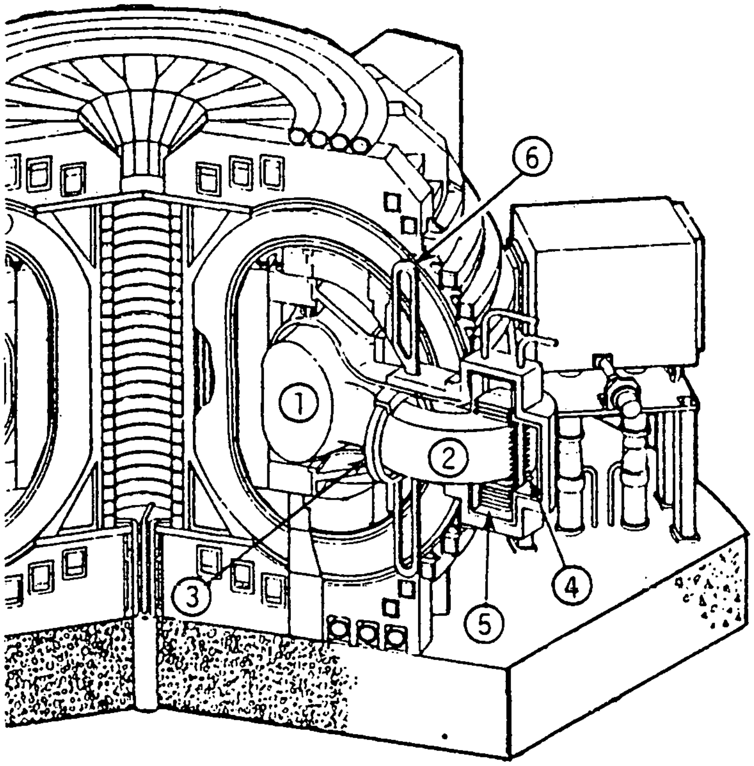


Figure 1. DTHR Bundle Divertor Plan View.



(1) PLASMA
(2) DIVERTED FLUX BUNDLE
(3) DIVERTOR COILS
(4) ACCORDION SHAPE COLLECTOR
(5) DISCHARGE CHAMBER
(6) AUXILIARY COIL

Figure 2. Demonstration Tokamak Hybrid Reactor Showing the Installation of the Bundle Divertor.