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# PHYSICS AND ENGINEERING ASPECTS OF THE OAK RIDGE EXPERIMENTAL POWER REACTOR*

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## Summary

The first tokamak experimental power reactor (EPR) is planned for operation in the mid-1980's. The logic leading to the size of the ORNL reference reactor, the technical features of the plasma and energy conversion systems, and the predicted parameters consistent with several operating modes are discussed in this paper. The mechanical aspects of the blanket and shield systems and an evaluation of their nuclear performance including tritium breeding, nuclear heating and radiation damage are also given.

## Plasma System Parameters

All of the objectives for the EPR lead to the requirement that fast-charged particles, both fast ions due to injection and thermonuclear-produced alpha particles, be efficiently contained within the plasma volume. The device must be large enough to contain the drift orbits followed by these particles. This in turn suggests a high value of plasma current. The current is given by,

$$I = \frac{2\pi B_{max}}{\mu_o q} \frac{1}{A^2} \left[(A - 1)\, a - \Delta\right], \qquad (1)$$

where $B_{max}$ is the toroidal field strength at the coil winding, q is the stability factor, A is the aspect ratio, a is the plasma radius and $\Delta$ is the radial distance from the surface of the plasma to the surface of the toroidal field coil winding. For a given plasma radius, I is relatively insensitive to the aspect ratio, A. Qualitatively, the distance $\Delta$ must include the blanket and shield thickness, insulation, and the necessary tolerances to permit remote assembly and disassembly of these components. Quantitatively, $\Delta \approx 1.5$ m. for a power-producing device with $a \approx 2$ m. which is the physical size anticipated for an EPR plasma. The minimum acceptable value of q(a) depends on the radial distribution of plasma current density. Finally, the maximum toroidal field strength chosen must be compatible with the expectations for advances in superconducting technology. These criteria and the requirements of long pulse time, a compatible neutral beam system and an acceptable value for the toroidal field ripple[1] result in the choice of the ORNL-EPR plasma-related parameters as shown in Table 1.

Table I

EPR-1 Reference Parameters
Plasma Subsystem Requirements

| | |
|---|---|
| Plasma radius, a (m) | 2.25 |
| Major radius, $R_o$ (m) | 6.75 |
| Safety factor, q(a) | 2.5 |
| Maximum toroidal field, $B_{max}$(T) | 11. |
| Toroidal field on axis, $B_T$ (T) | 4.8 |
| Plasma Current, I (MA) | 7.2 |
| Plasma edge to winding distance, $\Delta$ (m) | 1.55 |
| Volt-second, (V·s, Wb) | 185 |
| Injection power capability, $P_b$ (MW) | 50 |
| Deuteron energy, $E_b$ (keV) | 200 |
| Number of Injectors, $N_I$ | 6 |
| Number of toroidal coils, $N_c$ | 20 |
| Toroidal field ripple, $\delta$(0=0; r=a) | 2.2% |

## Plasma Performance

The scaling laws which ultimately will apply to EPR-size plasmas are presently uncertain. A simulation model which is time dependent and includes dissipative trapped particle diffusion, pseudoclassical and neoclassical diffusion, conduction and convection losses, impurity effects, radiation, coil fueling, and neutral beam injection effects has been used to model the plasma behavior. The reference plasma described here assumes that the dissipative trapped particle diffusion terms are a factor of 10 more optimistic than those given in reference (2). Figure 1 shows the startup phase and approach to equilibrium for the reference system described above. $P_F^M$ and $P_F^{b-p}$ are the Maxwellian or background and beam-plasma produced fusion power levels, respectively. $P_n/S$ is the neutron wall loading. The plasma ignites in ~ 5 s. In this operating mode the total fusion power is 225 MW immediately before ignition and 175 MW after the beams are terminated at ignition. The neutron wall loading is about 0.2 MW/m$^2$, the ion temperature is 9 keV and $N_e\tau_E = 6 \times 10^{14}$ cm$^{-3}$-s. In this case $\beta_p \approx \sqrt{A}$.

If a $\beta_p \approx A$ could be tolerated, the same system could be operated differently and at a significantly higher power level. Figure 2 shows the ion temperature as a function of time for an operating mode where the system is initially impurity free

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