PLASMA/NEUTRAL GAS TRANSPORT IN DIVERTORS AND LIMITERS

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ABSTRACT

The engineering design of the divertor and first wall region of fusion reactors requires
accurate knowledge of the energies and particle fluxes striking these surfaces. Simple
calculations indicate that ~10 MW/m² heat fluxes and ~1 cm/yr erosion rates are
possible, but there remain fundamental physics questions that bear directly on the en-
engineering design. The purpose of this study was to treat hydrogen plasma and neutral
gas transport in divertors and pumped limiters in sufficient detail to answer some of the
questions as to the actual conditions that will be expected in fusion reactors.

This was accomplished in four parts: (1) a review of relevant atomic processes to
establish the dominant interactions and their data base; (2) a steady-state coupled 0-D
model of the plasma core, scrape-off layer and divertor exhaust to determine gross modes
of operation and edge conditions; (3) a 1-D kinetic transport model to investigate the
case of collisionless divertor exhaust, including non-Maxwellian ions and neutral atoms,
highly collisional electrons, and a self-consistent electric field; and (4) a 3-D Monte Carlo
treatment of neutral transport to correctly account for geometric effects.

The edge model was applied to comparing particle and energy flows in INTOR and
ALCTOR-DCT with a single-null poloidal divertor, toroidal pumped limiter or advanced
bundle divertor. All options yielded reasonable edge conditions. The poloidal divertor and
pumped limiter were sensitive to uncertainties in cross-field diffusion coefficient and core
particle confinement – small variations could trigger transition from a "hot" to a "cold"
edge. The bundle divertor naturally operated in a cold, high recycling condition because
of the difficult return path for neutrals, and so is insensitive to the same variables. The
high neutral density may also eliminate the need for high-vacuum pumps.

The expected range of applicability of the kinetic model is to divertor plasmas with
temperatures above roughly 50 eV – a condition that is plausible, yet is not adequately
addressed with currently available collisional fluid models. The results include the charac-
terization of a family of solutions with an electrostatic potential peak in the divertor
region, as opposed to a monotonically decreasing potential profile.

The neutral transport model utilizes a simple geometry that allows fast evaluation
of complex 3-D systems, as long as interactions with plasma, other neutrals, or walls
produce an approximately isotropic flux. It has been applied to determining geometric
effects for the 0-D edge model, and to neutral transport calculations in advanced bundle
divertors.

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