§46. LHD Divertor Experimental Scenario

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The divertor is the key ingredient in the LHD device, in enhancing the helical plasma quality. We have developed several innovative divertor concepts and technologies, described below.

The experimental scenarios we conceive now are as follows: In the very early stage of the LHD experiment, the expected heating power will be low and the wall conditioning for the LHD will not be established. The first divertor configuration is the helical divertor (HD divertor) with open geometry. The HD divertor configuration is inherent to heliotron type devices, characterized with large volume of the open edge region. It is suitable for radiative cooling operation, in which the high density cold divertor plasma convert the entire heat flux from the core into radiative power. Because of large cooling volume, the radiative cooling is substantially easier than conventional divertor discharges. It may, however, cause thermal corruption, i.e., excessive cooling. The density at the last closed flux surface (LCFS , even though difficult to be defined in this configuration), tends to be high and thus H-mode type confinement improvement is unlikely to occur.

We will superimpose an $m/n=1/1$ magnetic island at the edge to add new important features. (i) the LCFS can be defined sharply i.e., within a few mm instead of 50 mm for the HD. This could be important for generating so called H-mode thermal barrier located just inside of the LCFS with typical radial width of 10-20 mm. (ii) the cooling volume can be reduced through short-circuiting of the ergodic region or be adjustable to the plasma conditions in some extent by choosing the island size. If the plasma pressure is constant in the open region, a decrease in the temperature along the field line accompanies an increase in the density along the field line. Through this mechanism, the density in the scrape-off layer surrounding the closed region can be kept low even with high density, cold plasma in the divertor channel. The separation of the low density and high density open regions is the key for the simultaneous attainment of the H-mode and radiative cooling (SHC boundary).

In the early experimental phase, various wall conditioning techniques will be attempted. But the wall conditioning may not be adequate because the vacuum vessel temperature is limited to 100 ^{o}C and helium glow discharges between shots, a very effective conditioning is not possible because of steady state magnetic field. We expect that the Local Island Divertor (LID), a closed divertor with high pumping efficiency can be very effective even in such conditions. In the LID, the outward heat and particle flux cross the separatrix of the $m/n=1/1$ island by perpendicular diffusion and flow along the field lines toward the rear of the island, where target plates are placed to remove heat load. The particles recycled there are pumped away very effectively.The LID plasma discharges will be low recycling discharges, which may lead to better confinement regime. The input power will, however, be limited below 4 MW even for relatively short discharge duration because of localization of outward flowing plasma flux. In addition to the LID physics experiment, the LID discharge operation with an hour at low power (100~500 kW) will be the most effective discharge cleaning scheme ever attempted.

With carbon sheet pumping installed, the recycling can be minimized, allowing high temperature divertor plasma operation. The edge temperature will be raised up to ~ 5 keV by efficient pumping, thereby leading to enhancement in the energy confinement. In this case, central fuelling such as NBI beam and pellet must be used. The stored energy of high energy ion component in neutral beam heated discharges may be significantly large because of longer slowing down time due to high electron temperature and hence the β-value can exceed 5 % energetically even at $B = 3$ T, thus providing a good test for the MHD stability limit of the helical plasma.

After these experiments and their analyses, the LHD divertor system will be upgraded. Our present thought is to install a closed helical divertor with baffle plates. The membrane pump, presently under development may also be used to pump bulk particles efficiently in a steady state.