§40. Cooling System for LHD Vacuum Vessel

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Heat removal is one of the main functions required for the LHD vacuum vessel. The LHD vacuum vessel is located inside the cryostat that is in a vacuum state to keep the superconducting helical and poloidal coils in isolation thermally. Thus the quantity of heat, which is transferred to the cryostat by the heat conduction, convection, and radiation, has been designed to be small, so that the total power for plasma production and heating is forced to be removed by a cooling system.

In LHD, 'steady-state' plasmas whose duration is longer than 1 hour are planned to be produced and heated with the total input power of 3 MW. Half of the total input power is assumed to be finally carried to the vacuum vessel by the radiation from the plasma, while the rest is assumed to be carried to the divertor plates by the particle flux. The cooling system for the vacuum vessel has been designed for this 3-MW steady-state operation with the maximum heat flux of 15 kW/m^2. The plasmas yielding the heat flux larger than this value can be also produced in the pulse operation, that is, changing the duration of the discharge.

The spatially-averaged temperature of the vacuum vessel is required below 70℃, because the quantity of heat, transferred from the vacuum vessel to thermal-isolation plates, called 80K shields, is limited to that removed with the cryogenic system. The 80K shields are supported with props standing in the vacuum vessel, and located between the vacuum vessel and helical coils or the cryostat.

The cooling system for the vacuum vessel has been designed to use water as coolant, and to form water passes by welding pipes with the U-shape cross section to the vacuum vessel, as shown in Fig. 1. The water passes are located on the plasma side, and their intervals are in the range of 80-400 mm, depending on their locations. Protection plates, which consist of stainless-steel and copper plates, are mechanically jointed to the water passes, putting saddles between them. The copper plates increase the heat conductivity, and reduce the temperature of the water passes and the radiation from the protection plates to the vacuum vessel. Figure 2 shows the water passes and protection plates around the upper port of the vacuum vessel.

Optimization of the mechanical joint between the protection plate and water pass is under way.

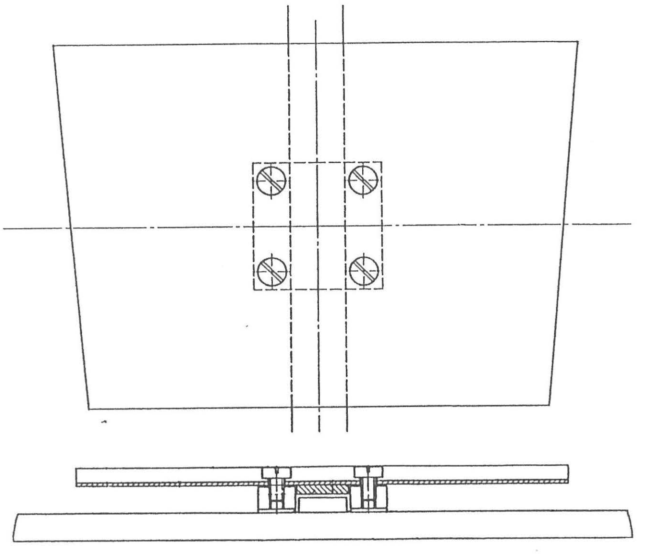

Fig. 1. Water pass on the vacuum vessel and protection plate. Shaded parts are made of copper.

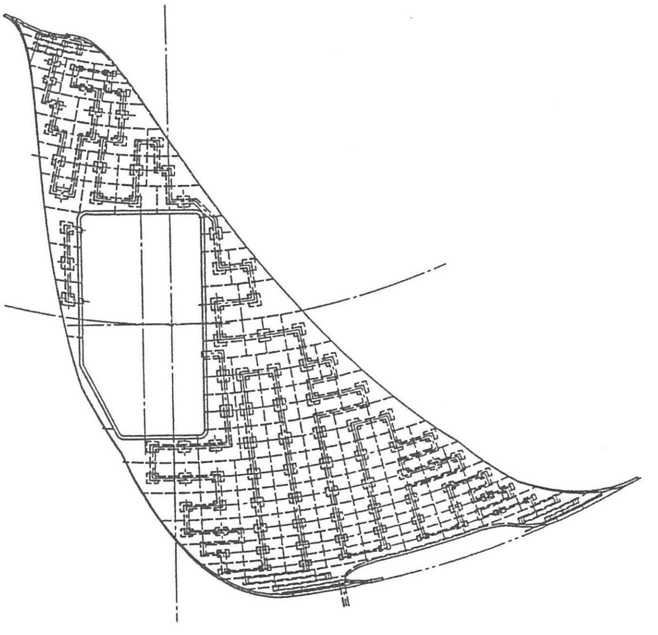

Fig. 2. Water passes and protection plates around the upper port of the vacuum vessel.