§7. Heat Load of 80K Thermal Shield of the Main Cryostat for the Large Helical Device

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The thermal shields of the main cryostat for the Large Helical Device are grouped into Inner 80 K shields and Outer 80 K shields that are attached to the plasma vacuum vessel and the vacuum chamber of the cryostat. 1) Multi-layer insulation (MLI) made of aluminum coated polyster films are inserted between them to reduce heat inputs. The thickness of the thermal shield is 3 mm, and cooling pipes are attached on them with a distance of 200 mm around by metal cleats. The gaps between the pipes and the shields are buried by an epoxy resin of STYCAST 2580FT for thermal contact. The Inner 80 K shield is divided into three groups which are a "bottom", a "side" and a "torus" confronting the half pitch of helical coil cases, the half pitch of shell-arms, and the upper or lower half of 1/10 of the supporting shell, respectively. Two "bottoms" and four "sides" are in a series, and two "tori" are in a series. The shields surrounding the ports are included in the "torus". One path for the Outer 80 K shield covers 1/10 in toroidal. The cryogen goes through 1/20 part of the base plate, inner cylinder, the rest of the base plate, 1/20 part of the outer cylinder, top roof, and the rest of the outer cylinder. The shields of the two cylinders are suspended by long rods made of stainless steel. The other shields are fixed by grass-fiber-reinforced plastics (GFRP) bolts with sliding mechanism to avoid thermal stress.

Steady heat loads of the thermal shields were measured from the temperature increase of the cryogen. The design and measured heat loads are listed in Table 1, and the temperature changes during the 95 °C baking of the plasma vacuum vessel are shown in Fig. 1. The measured heat loads of the Inner 80 K shields are about 45 to 70% of the design values. On the contrary, the heat loads of the Outer 80 K shields are slightly larger than the design. The former reasons are considered to be overestimation of conduction through the support and heat flux of the MLI. The latter reason is considered to be underestimation of radiation. Since it seemed to be difficult to assemble the Inner 80 K shield, 5.7 W/m^2 was used as the design value for the average heat flux of the MLI between 300 and 80 K with considering contingencies. On the other hand, 3.3 W/m^2 was used for the Outer 80 K shield. The actual value is estimated to be 4.5 W/m^2 in both the shields from the temperature dependance of the heat loads. Furthermore, the contact thermal resistance is not negligible especially for the sliding mechanism. The conduction in the Inner 80 K shield may become almost half of the design values.

Since the surface areas are wide, large number of parallel paths is indispensable to obtain enough flow rates. In spite of large numbers of parallel paths without control valves, the temperature difference among the ten sectors of the Inner and Outer 80 K shield became less than 2 and 10 K, respectively, at steady-state. Besides, the pressure drops of cooling pipes were in good agreements with the design values based on circular pipes in turbulent flow. These results prove the validity of the design and construction.

Table 1 Heat Loads of 80K thermal shields

item	area (m^2)	number of support	heat load (kW) (*1) design	heat load (kW) (*1) measured
Inner 80 K shield				
bottom	97.6	1440	1.89 [3.03]	0.86 [1.34]
side	99.6	1680	1.28 [2.26]	0.88 [1.39]
torus	222	2244	2.38 [4.46]	1.49 [2.50]
Outer 80 K shield				
base and inner	208	580	1.55 [1.92]	1.88 [2.26]
top and outer	367	545	1.45 [1.71]	1.71 [1.94]

(*1) The values out of and in the brackets are at 300 and 368 K of the plasma vacuum vessel, respectively.

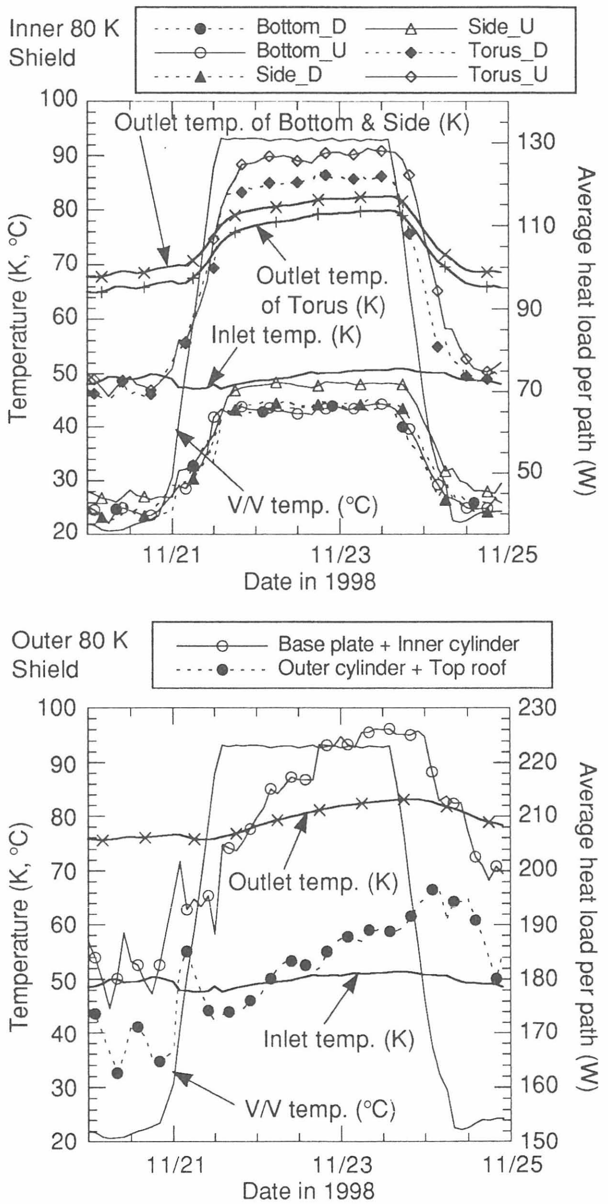

Fig. 1. Temperatures and heat loads of the Inner and Outer 80 K shield when baking the plasma vacuum vessel up to 368 K. Each heat load was calculated by averaging the temperature rise of ten parallel paths. U and D mean upper and lower half, respectively.

Reference

1) S. Imagawa, et al., presented at CEC 1999, COB-4.