Superconducting helical coils

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Specification
The helical coil is cooled with liquid helium at 0.12 MPa. Its inlet temperature can be lowered to 3.2 K with a subcooling pre-cooler that was added in 2006.

Table 1 Major design values of the helical coil.

He bath temperature	3.9 K - 4.4 K (saturated)
Coil current density	40 A/mm^2
Operating current	< 11.0 kA (at 4.4 K) < 11.6 kA (at 3.9 K)
Magnetic stored energy	0.77 GJ
Major radius / Minor radius	3.9 / 0.975 m
Number of turns	450 (150×3 blocks)
Wetted surface fraction	0.417 ~ 0.692
Accuracy for manufacturing (mm)	±2
Critical current of the conductor	> 20 kA at 7 T
Total inductance	10.9 H
Voltage to earth	±874 V
Inventory of LHe in coils / tanks	~ 2 / 2 m^3
Thickness / gap length of ground insulator	> 2.5 / 23 mm
Thickness of spacer between blocks	> 6.0 mm
Thickness of spacer between layers / turns	> 2.8 / 1.8 mm
Resistance of joint in coils	< 0.7 nΩ
Number of joints in coils	32

Drawing of device/facility

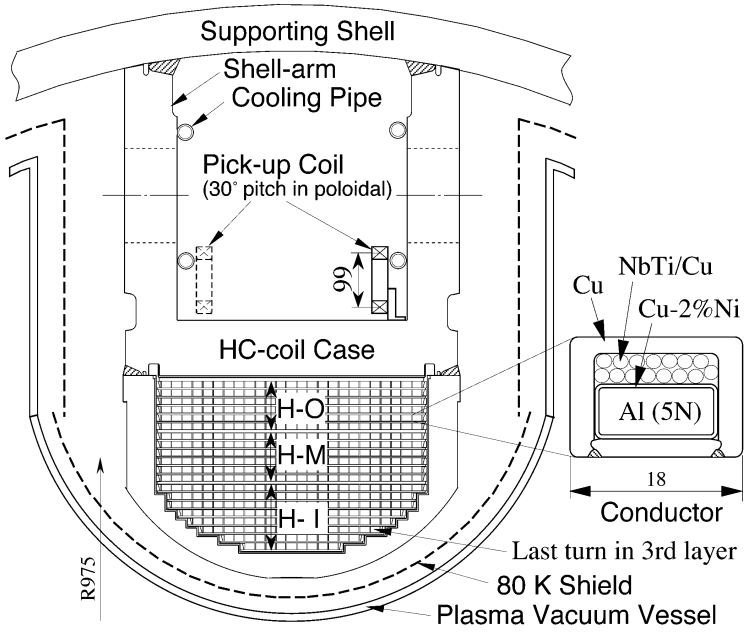

Fig.1 Cross-section of the helical coil

Arrangement plots (relation to port, structure, etc.)
Two helical coils are surrounding the plasma vacuum vessel, and they are fixed to a cylindrical supporting structure.

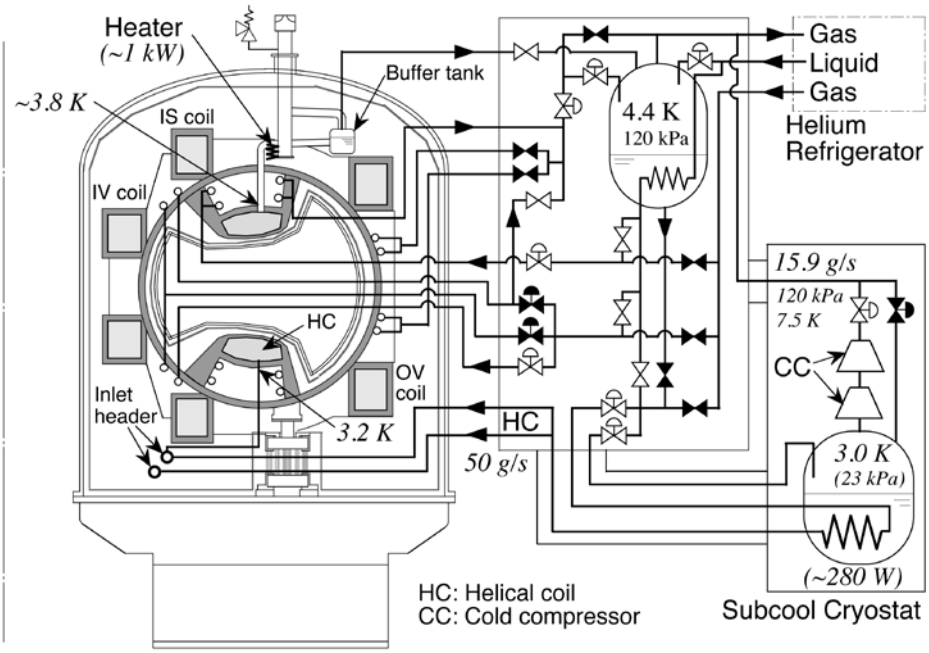

Fig. 2 Cooling flow of the helical coil and the supporting structures.

Note for operation

・The operating currents of the helical coils are limited to 11.0 kA at 4.4 K and 11.6 kA at 3.9 K of the outlet temperature.

・In order to avoid the conductor movement by the interaction from the plasma currents, the helical coils should be exited up to the higher currents by 0.1 kA than the operating currents before plasma experiments.

・The ramp rate of the helical coils are limited to 7 A/s and 1.4 A/s at up to 10 kA and the higher, respectively, to maintain good cooling condition against AC losses in the conductors.

References

(1) Shinsaku Imagawa, Nagato Yanagi, and Toshiyuki Mito, "Reconsideration of evaluation of balance voltages during a normal zone propagation in the LHD helical coils", IEEE Transaction on Applied Superconductivity, Vol. 23 (June 2013) Art. ID. 4700904.

(2) S. Imagawa, T. Mito, K. Takahata, S. Yamada, N. Yanagi, H. Chikaraishi, R. Maekawa, H. Tamura, A. Iwamoto, S. Hamaguchi, T. Obana, T. Okamura, Y. Shirai, T. Ise, T. Hamajima, LHD Experiment Group, "Overview of LHD Superconducting Magnet System and Its 10-Year Operation", Fusion Science and Technology, Vol. 58, No. 1 (July 2010) 560-570.