Superconducting magnet system of LHD

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The Large Helical Device (LHD) is a superconducting experimental fusion apparatus [1-3]. The magnet system in the LHD consists of two types of superconducting coils, i.e., pool-cooled helical coils and force-flow cooled poloidal coils. Together with the superconducting coils, superconducting bus-lines, a helium liquefier/refrigerator and power supplies play key roles in the magnet system. The construction of the world's first superconducting helical device was a challenging project. The magnet system was completed and successfully excited up to 2.85 T at the plasma center (R = 3.6 m) in 1998 (2.9 T in 2007). The system has been providing high accuracy magnetic surfaces and it has been contributing in confining currentless plasmas with long pulses. In a subsequent decade, the magnet system has experienced eleven plasma experimental campaigns. The twelfth campaign is now running. This means that the superconducting coils were cooled down a dozen times and warmed up eleven times. It takes about a month to cool down or to warm up the magnet system which weighs 850 tons. After each cool-down, the steady-state operation of the cryogenic system runs for five months. This has resulted in a total accumulated operating time of 35,000 h (about four years). We emphasize that the cryogenic system has exceeded an average availability factor of 99%. Only twenty failures resulted in halts of the cryogenic system, including five power outages. The coils are usually excited from 9 am to 7 pm on weekdays except Mondays during an experimental campaign. Over a thousand excitations have been carried out. The power supply system has also shown high availability factors of 98 % in a total operating time of about 7,000 h. No degradation is observed in the performance of the superconducting magnets. These experiences of the long-term operation of the LHD magnet system should be useful for the development of next large superconducting magnet systems.

[1] O. Motojima, et al., Fusion Engineering and Design **81** (2006) 2277.
[2] T. Mito, et al., Proc.19th IEEE/NPSS Symposium on Fusion Engineering (2002) 144.
[3] S. Imagawa, et al., Nucl. Fusion **47** (2007) 353.