§5. Performance of the LHD Cryogenic System during Cooling and Excitation Tests

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1. Introduction

The LHD cryogenic system succeeded in 6400-hour operation in the first year, and proved its high reliability. The emergency programs, corresponding to a power failure, apparatus faults, an emergency shut-off of the coil power-supplies and so on, are installed into the system. And, the protections of apparatus and recovery in a short time period are possible by the function of them.

2. Performances during the excitation tests

During the excitation tests of the LHD SC coils up to 2.75 T, the normal zone propagation was observed in the helical coil and the emergency shut-off of the coil power supplies (1Q) was carried out. Figure 1 shows the pressure rise of the helical coil outlet header when 1Q occurred. Four kinds of pressure relief valves; two recovery valves (the operating pressure of 1.4 kg/cm^2), two release valves (1.6 kg/cm^2), ten spring-loaded safety valves (1.85 kg/cm^2) and ten rupture disks (2.2 kg/cm^2), were set up in the header. Pressure rise of the helical coils was restrained less than 1.8 kg/cm^2 by the function of the recovery and release valves, which were programmed in the LHD cryogenic control system (LHD-TESS). The total operating time of the release valves, which opened 2 times, was 17 seconds, and the evaporating helium gas of 900 Nm^3 exhausted within 1 minute. The coils and the helium refrigerator were separated automatically with 1Q-signal and the helium refrigerator could keep its steady state operation. Figure 2 shows the characteristics during the recovery process from 1Q; outlet temperatures of the poloidal coils, liquid helium levels of helical coil header, temperatures of the helical coil cans and the supporting structure. The events from the 1Q occurrence to the restoration on October 21, 1998 are listed in Table 1.

Table 1. Events from 1Q occurrence to the restoration

11:44	1Q-signal occurrence He refrigerator and cooling objets were separated
11:55	Helical coils returned to the normal pressure Evaporated liquid helium was 2700 ℓ Recovery gas 1,000 Nm^3, exhaust gas 900Nm3
11:56	Poloidal coil SHe cooling restarted
12:25	Supporting structure cooling restarted
12:33	Helical coils LHe supply restarted
13:25	Poloidal coil outlet temperatures recovered
15:05	Helical coil header LHe level recovered
15:12	Supporting structure temperatures recovered LHD cryogenic system restored to the coil-excitation-enable-condition

3. Summary

After the normal transition of the SC coils and the emergency shut-off of the coil power supplies, it could be restored to the coil-excitation-enable-state only in three-hour half by the function of the LHD cryogenic system corresponding to the emergency process. And, the supplement of the exhausted helium gas and purification were completed at 10:50 of the next day.

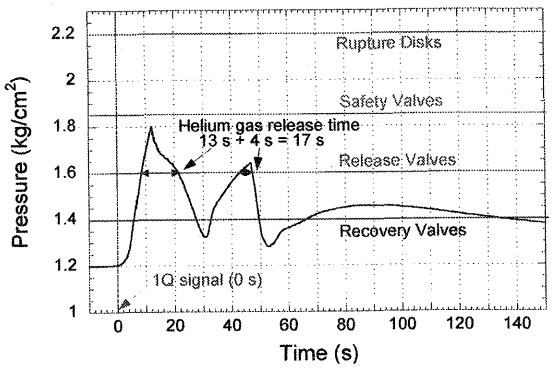

Fig. 1. Pressure rise of the Helical coil header after 1Q.

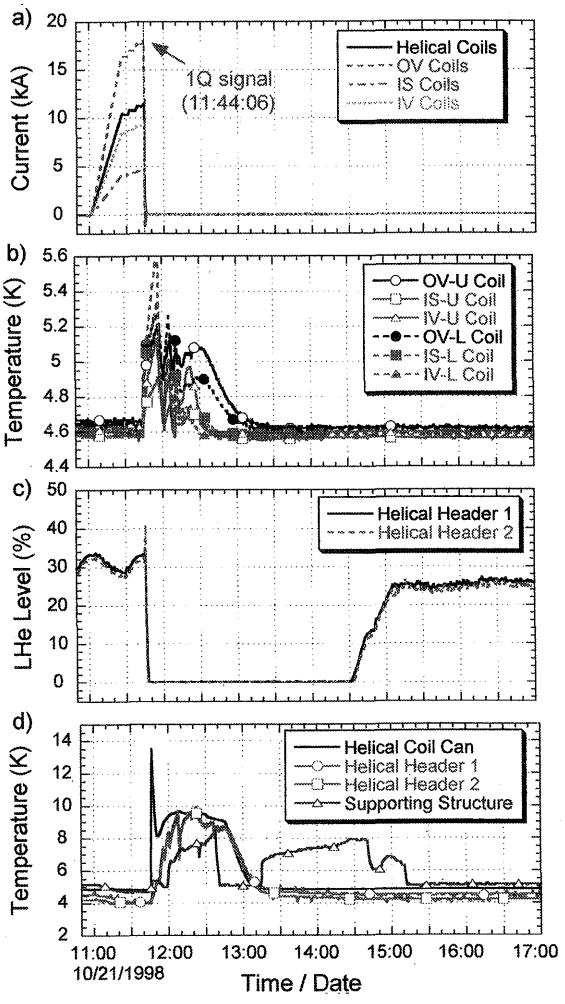

Fig. 2. Recovery characteristics after 1Q, a) Coil currents, b) Poloidal coils outlet temperatures, c) Helical coil header liquid helium levels, d) Helical coils & Supporting structure temperatures.