Quantum Design

Application Note 1070-208

Magnet Charging Guidelines in the PPMS

In Section 3.5 of the *PPMS Hardware Manual*, the user is advised to keep the helium level above 60% if charging the superconducting magnet to full field. The level of 60% marks the approximate top of the magnet in most PPMS configurations. If there is not sufficient helium in the dewar, the top of the magnet can warm and thus make a quench more likely. Furthermore, a quench from high fields in the absence of sufficient cooling by the helium can heat the magnet and cause severe damage to it. A magnet quench is an event in which the magnetic energy in the magnet $E_{magnet} = \frac{1}{2}LI^2$ (where L is the inductance of the magnet and I is the current in the magnet windings) is converted very quickly into thermal energy that is dissipated in the magnet, the protection diodes on the magnet, the protection diodes in the tray of the magnet power supply, or some combination of these three places. For a standard 9 tesla PPMS magnet, the inductance is L = 40 henries (typical) and when charged to full field I = 47 amps (typical), thus in this example $E_{magnet} \sim 44$ kJ.

Due to the quadratic dependence on current in the energy equation, operating the magnet at a low field like 1 tesla will greatly reduce the magnetic energy and thus the severity of a quench. As long as a reasonable fraction of the magnet is immersed in liquid, we find that there is a very low risk of quenching if staying at low fields. Recall that one of the heat loads into the dewar is due to the Joule heating $P = I^2R$ of the magnet leads (where R is the resistance of the leads), so this heating will be 81 times lower when the field is in driven mode at 1 tesla versus being driven at 9 tesla.

The recommendation for maximum charging field as a function of helium levels are summarized in the table below. Note that the dewar belly diameter decreases below 40% (50% for 7T transverse and 16T magnets) thus the level will start falling very quickly at this point. It is strongly recommended to keep the helium level above this value at all times.

Helium Level (%)	Maximum Field (T) 7T, 9T, 14T	Maximum Field (T) 7T Transverse, 16T
> 60	Full Field	Full Field
40 – 60	1	0*
< 40	0*	0*

* - transfer liquid helium as soon as possible.