

Quantum Design PPMS DynaCool Base System: Magnetic Field, Temperature, and Diagnostics

Magnetic field

- Field setting **resolution** : 0.16 Oe
- **Sweep rate** limits: 0 – 200 Oe/sec (very low rates will result in stair-steps of 0.2 Oe due to resolution limit)
- Field **stability**: ± 0.05 Oe (noise), ± 0.3 Oe (long term drift), see Figure 1 below; this is a consequence of having a high current power supply always connected to the system.
 - If you need very stable low fields (e.g., 10 Oe for a long M(Temp) run), please see Neil.
 - If a quiet H=0 state is needed, the contactor on the power supply can be closed and the field will not fluctuate. Please see Neil.
- Field **uniformity** (for 9 tesla PPMS): $\pm 0.01\%$ over 3 cm on axis; magnet center located 4 cm above puck surface (center of VSM coil set). At the puck surface (where resistance measurements are made), there is less than 0.1% deviation from the field value at the center (see Tech Note 1084-312 on Pharos).

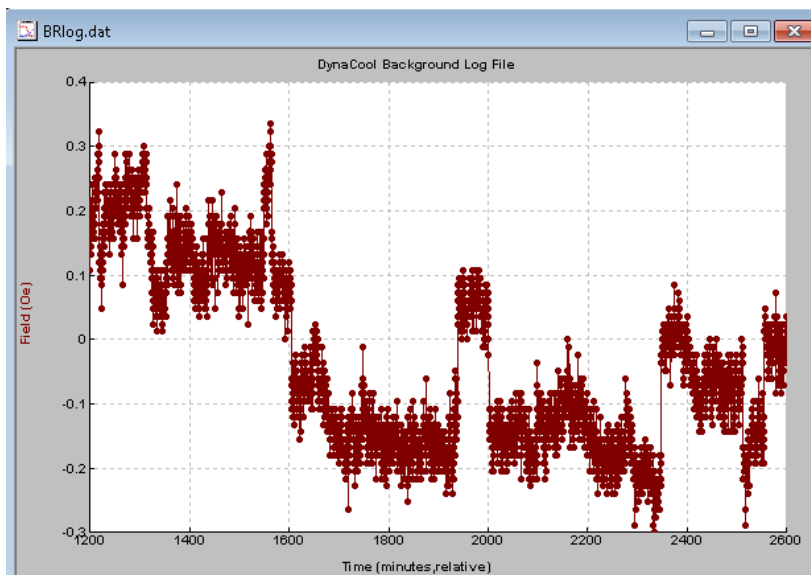


Figure 1: long term field fluctuations at H=0 in DynaCool D-113 at Purdue.

Field **Accuracy above 1 tesla**: better than 0.2% .

Field **Accuracy below 1 tesla**: a systematic offset of up to 20 Oe exists, and is governed by magnet charging history. Note that the magnetic field value reported to the user is based only on the current flowing from the magnet power supply, and does not know about any other magnetic remanence effects near the sample. In our case, the superconducting coil itself remains magnetically polarized at low fields. The origin of this effect and various mitigation strategies are described in detail in the Application Note 1070-207 (posted on www.qdusa.com) and is also included in this training material.

Here are strategies for getting the best field accuracy in your measurements:

1. If you are working at low fields only ($H < 1000$ Oe)

- Oscillate the field down: set +3 tesla, wait for stability, then set zero field in Oscillate mode and wait for it to get there.
- Insert your sample and do all your work at low fields: you will have accuracy of ± 0.5 Oe if you stay below 1000 Oe at all times (orange box in lower plot).

2. If you need to use higher fields ($H > 1000$ Oe) and still care about ± 20 Oe accuracy

- Consult the upper plot in Figure 2 and use as follows: if you came down from +1 tesla (10000 Oe) then there will be a -17 Oe offset in the reported field. That is:

$$\Rightarrow H = H_{\text{reported}} + H_{\text{offset}} = H_{\text{reported}} - (17 \text{ Oe})$$

- One simple approximation is to shift ALL the reported fields DOWN (by the amount given in H_{offset} value) when coming DOWN in field, and opposite when coming UP. Use just the H_{offset} value from the maximum field you last visited.

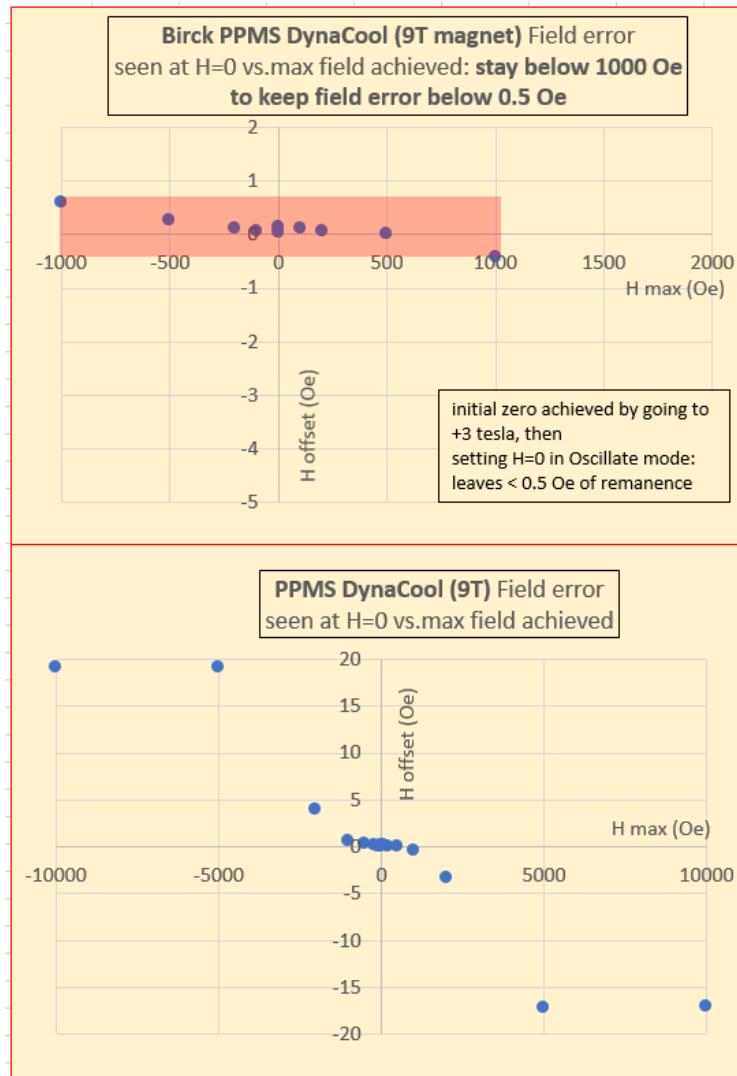


Figure 2: error in the reported field for work at low fields (TOP) and high fields (BOTTOM).

Temperature

DynaCool uses a sophisticated control scheme, balancing helium gas cooling against heat from resistive heaters wrapped on the outside of the sample chamber, in order to produce highly stable temperatures and fast thermal response. The lower 10cm of the chamber is made of a high conductivity copper tube, and this ensures this region is nearly isothermal. At the bottom of this tube is the “block” into which the user puck plugs. A thermometer and heater are both embedded in the outside of this block. As seen in the Log Data dialog in MultiVu, there are actually two other regions where there is a thermometer paired with a heater: the neck (at the top of the isothermal region) and high neck (about halfway up the chamber). Using these, the thermal gradients along the chamber can be measured and controlled.

Temperature accuracy at low temperatures (<20 K): due to magneto-resistance in Cernox thermometers, the reported temperature of an option thermometer (VSM, TTO, rotator, MFP) can be off by a few percent at high fields (9 tesla) and base temperature (1.8 K). The block thermometer is magneto-resistance corrected so the error is much smaller if using that. There is an application note 1307-200 at <https://www.qdusa.com/siteDocs/appNotes/1307-200.pdf> which staff will use to calibrate an option thermometer (takes ~16 hours) if it's decided that is necessary.

transport measurements on a puck: the reported temperature in your data file is the Block thermometer. Getting good temperature accuracy requires that you thermally bond your sample to the puck. This can easily be done using a small amount of Apiezon H grease or similar.

VSM measurements: the thermometer embedded in the VSM coil set is the control thermometer in this case, and the user's sample lags behind this thermometer due to the helium exchange gas in the sample chamber not being a perfect thermal conductor. The lag is as much as 1 minute, so a fast 5 K/min M(T) sweep will reveal the moment lagging by up to 5 K from its value if one went slowly (0.5 K/min) or stepped the temperature.

Rotator Probe: the green sample mount has an embedded thermometer which is activated when Rotator option is activated, and all users need to use this thermometer and the associated User Experiment dongle at the grey Lemo port to route the thermometer wires and remap the user wiring (see discussion in ETO section).

MultiFunction Probe (MFP) for custom experiments: this has a green “rotator-style” sample mount with an embedded thermometer which can be used as control thermometer. The user is not required to use that (in which case the system keeps on using the block thermometer), and in fact this is what the group is doing currently. Users can choose to build their own mounts in the MFP user space with no thermometry, but – just as in the case of rotator probe – if you care about better temperature reporting at your sample location then this MFP thermometer is still recommended.

Diagnostic data

All the critical system variables are being logged continuously and stored in a file called `BRLog.dat` which is stored in the `c:\qddynacool\multivu` folder and is also viewable in MultiVu under *Utilities > Tools > open background logfile BRLog* .