



DynaCool Application Note 1307-200

Magneto-Resistance Calibration of DynaCool Option Thermometers

Section I: Introduction

The resistive thermometers used to measure temperature in the DynaCool base system and Dynacool options exhibit magnetic field induced temperature errors due to magneto-resistance (MR). Typically the error at 1.8 K and 9 T is a few percent, and can be above 5 % at 14 T. In order to correct for magneto-resistance errors, a MR table is used. The MR table contains percent temperature corrections as a function of magnetic field and apparent temperature, the temperature obtained from a simple R vs. T table lookup ignoring MR. Because there are two independent variables in MR tables, they are often called 2D tables.

DynaCool is supplied with the sample chamber block thermometer MR calibrated, so temperature values reported by the base DynaCool are always corrected for magneto-resistance. However, some option thermometers are supplied without an MR calibration. In order to calibrate these thermometers, you measure MR correction values for an option thermometer using the already MR calibrated block thermometer as a reference.

The utility ThermCal.exe automates this procedure. ThermCal.exe acquires temperature readings at a series of temperatures and magnetic fields, generates an MR table, then verifies that the residual MR errors are below 0.5 % at another series of temperatures and magnetic fields. The entire process takes about 16 hours on a 9 T system and about 30 hours on a 14 T system.

ThermCal.exe does not set up option software to apply the MR table during normal option measurements. See the section **Using the MR Correction in Option Measurements** for instructions on how to set up option software to apply the MR table.

Currently, ThermCal.exe supports MR calibration of the following option thermometers:

- Vibrating Sample Magnetometer (VSM) coil set
- AC Magnetic Susceptibility (ACMS) II
- Horizontal Rotator
- Multi-function Probe (MFP)
- Thermal Transport Option (TTO)

ThermCal.exe is included in the standard DynaCool software installation. Shortcuts to run the program are located in the directory `C:\QDDynaCool\Tools\ThermCal\`. If this directory is not present on your system, or files for one or more options are missing, you may have an older software release. Contact Quantum Design to upgrade.

Section II: Running the Calibration

To start the calibration, double-click one of the shortcuts in `C:\QDDynaCool\Tools\ThermCal\`. For VSM, use the shortcut `VSM_MRCal`. For rotator or MFP, use the shortcut `MFPRotator_MRCal`. For TTO, use the shortcut `TTO_MRCal`. These shortcuts start `ThermCal.exe` with the appropriate configuration for MR calibration and verification on DynaCool. Follow the on-screen prompts to start the calibration. You will be directed to:

- **Enter serial number (not applicable to TTO)**
 - Enter the serial number of the item you are calibrating. Locate the serial number as follows, depending on which option you are calibrating
 - VSM standard coil set: serial number is `VSM-###` where `###` are the numbers on the outside diameter of the bottom insulating ring of the puck. (Do not use the letters on this ring.)
 - VSM large bore coil set: serial number is `VSM-LB###` where `LB###` is printed on the outside diameter of the bottom insulating ring of the puck. (Do not use the letters on this ring.)
 - ACMS II coil set: serial number `WF###`, where `###` are numbers. The serial number is printed on the outside diameter of the bottom insulating ring of the puck.
 - Horizontal Rotator: serial number is `HRE###` and is printed on a label near the top of the rotator. The serial number might contain a letter prefix different from `HRE`.
 - Multi-function Probe: serial number is `MFF###` and is printed on a label affixed above the KF vacuum flange on the probe. The serial number might contain a letter prefix different from `HRE`.
- **Select calibration files (TTO only)**
 - Select the calibration file for each TTO thermometer. These files contain R vs. T calibration data for the thermometers. They are located at `C:\QDDynaCool\ThermalTransport\Calibration\` and have file names like `Therm####.cfg`. Thermometer A and Thermometer B locations are defined in Figure 2-9 of the TTO user manual.
- **Set up the system for the calibration**
 - Insert option hardware into the sample chamber according to the instructions in the option manual. For TTO, mount the thermometer shoes using the copper sample as described in section 2.4 of the TTO user manual.
 - Purge and seal the sample chamber.
 - Hook up cables for the option according to instructions in the option manual.
 - For VSM, verify that the option is set up so that no MR correction will be applied to the option thermometer (this is handled automatically for rotator and MFP). In order to do this, open the coil configuration file for the coil you are MR calibrating, located at `C:\QDDynaCool\VSM\Calibration\`. There should be no line starting with `MR Therm =`. If this line exists, the coil is already MR calibrated and you should not take calibration data in this condition.
 - Activate the option software, and if necessary, start option temperature control.
 - Verify that the system is controlling on the option thermometer. To do this, look in MultiVu Log Data and verify that both "Sample Therm (ID)" and "Control Therm (ID)" match the values in Section 4.3.4 of the DynaCool Reference Manual for the option you are using.

Once the program indicates the temperature and fields at which the calibration will be performed and you press Next to continue, the calibration and verification will run unattended.

Section III: Output Files

The program creates a subdirectory inside `C:\QDLogs\ThermCal\` for storage of calibration files. The subdirectory name is `ABC-###_YYYYMMDD_HHMM` where `ABC-###` is the serial number of the assembly you entered into ThermCal. (For TTO, `ABC-###` will be replaced with `Therm###_Therm###` where each `###` is replaced with a thermometer shoe serial number.) The calibration start time is encoded as `YYYYMMDD_HHMM` where `YYYY` is the year, `MM` is the month, `DD` is the day number, `HH` is the hour in 24-hour format, and `MM` is the minute. The following files are created inside this directory:

- **ABC-###_YYYYMMDD_HHMM.dat**: A MultiVu data file that contains calibration and verification data. ThermCal automatically opens this file in MultiVu for viewing. The comment column contains comments "Starting MR calibration" and "Starting MR verification" to make it easy to find the start of each procedure.
- **log-ABC-###_YYYYMMDD_HHMM.dat**: A MultiVu log data file that contains a full log of the calibration. ThermCal automatically opens this file in MultiVu for viewing.
- **ABC-###_YYYYMMDD_HHMMSS.xml**: These XML files contain configuration and state information as well as calibration and verification data. ThermCal generates one of these files each time it takes a data point and at certain critical steps in the calibration process. The timestamp `YYYYMMDD_HHMMSS` indicates when the file was written. To view an XML file, open it in a web browser. As long as you keep the `Style` directory and its contents inside the calibration directory, the XML file will be displayed in a structured format. You can restart a calibration using one of these files. See **Restarting a Calibration** for details.
- **ABC-###_YYYYMMDD_HHMM.txt**: This plain text file contains debug information. Normally you do not need to look at this file. This file prints out all messages that are shown in the GUI as well as internal status messages.
- **ABC-###-2D.tab**: This file contains the magneto-resistance table generated by the program. This file is generated at the end of the calibration procedure, before the verification procedure. For TTO, there will be two of these files (**Therm###-2D.tab**), one for each thermometer.
- **ABC-###-2D.cfg**: Magneto-resistance table in `cfg` format. For TTO, there will be two of these files (**Therm###-2D.cfg**), one for each thermometer.

Section IV: Description of the Calibration and Verification Process

The program performs the following steps

1. Go to 9 K and wait for 30 minutes. This step reduces temperature gradients that would otherwise result in small drifts at the beginning of the calibration.
2. Calibration
 - a. Go to a calibration temperature, starting with 16 K. At each calibration temperature:
 - i. Go to a calibration field, starting with zero field.
 - ii. Wait for the reference and option thermometers to stabilize.
 - iii. Average many readings of reference and option temperatures. Record data.

- iv. Repeat steps i through iii for each calibration field, up to the maximum field of the instrument.
 - b. Repeat step a and a.i - a.iv for each calibration temperature (16 K to base temperature).
 3. When finished acquiring calibration data, generate the MR table.
 4. Verification
 - a. Go to a verification temperature, starting with 20 K. At each calibration temperature:
 - i. Go to a verification field, starting with zero field.
 - ii. Wait for the reference and option thermometers to stabilize.
 - iii. Average many readings of reference and option temperatures. Record data.
 - iv. Repeat steps i through iii for each verification field, up to the maximum for the instrument.
 - b. Repeat step a and a.i through a.iv for each verification temperature (1.8 K to 20 K).
 5. Display the worst measured error in the program window. The error is less than 0.5 % for a successful calibration.

Section V: Examine the Data

Figure 1 shows typical calibration data. The data items are as follows:

- **Reference T (K)**: The sample chamber block temperature, which is MR corrected.
- **Therm1 T (K)**: The option temperature, which is not MR corrected during the calibration phase, and is MR corrected during the verification phase. For TTO, the program records both **Therm1 T (K)** (Thermometer A) and **Therm2 T (K)** (Thermometer B).
- **Therm1 Err (%)**: The percent error between the block temperature and option temperature. This is the MR error during the calibration phase, and residual error during the verification phase. For TTO, the program records both **Therm1 Err (%)** (Thermometer A) and **Therm2 Err (%)** (Thermometer B).
- **Field (Oe)**: The magnetic field.

In this case, the MR error is as large as about -4.5 %. During the verification phase, the errors have been reduced to < 0.2 % by application of the MR table that was generated from the calibration data.

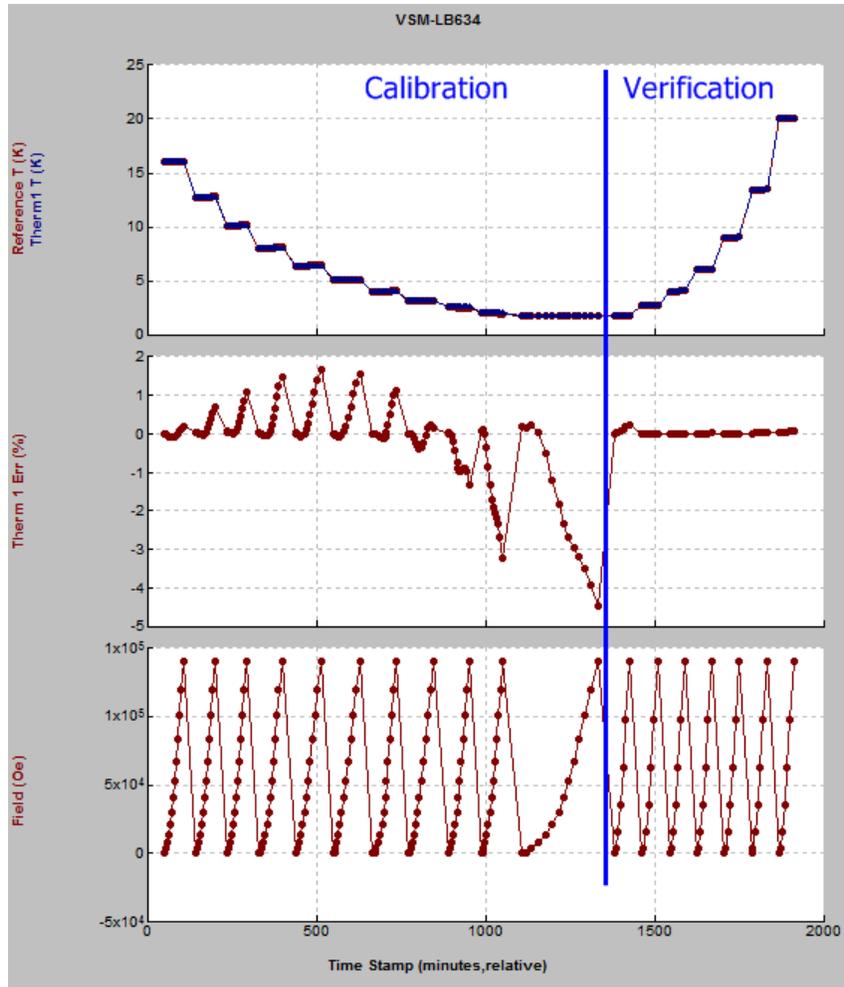


Figure 1. Typical MR calibration and verification data.

Section VI: Using the MR Correction in Option Measurements

After ThermCal finishes, you must perform further steps to apply the MR correction during option measurements. Follow the procedure below, depending on which option you are using.

Vibrating Sample Magnetometer MR table usage

1. Using Notepad, open the MR calibration table generated by the program. Navigate to the calibration folder, and select a file with a name like ABC-###-2D.tab.
2. Select the MR table. Start with the text Tbl2dHex and select all the way to the first semicolon. Do not select the text starting with Table2D_ID. Copy the table to the clipboard using the Edit/Copy menu command.
3. Using Notepad, open the coil configuration file for the coil you calibrated. The file is located at C:\QDDynaCool\VSM\Calibration\ and has a name like VSMcoil-###.cfg for a standard coil set or VSMcoil-LB###.cfg for a large bore coil set.
4. After the line starting with Therm = , create a new line starting with MR Therm =
5. In Notepad, paste the table after MR Therm =
6. The file should contain an MR table as shown inside the blue lines in Figure 2. Depending on the details of the file before you added the MR table, it may look slightly different than the figure.

7. Save and close the file.
8. Follow the instructions in the section **Verifying the MR Table is Applied** to make sure the correction is being applied correctly.

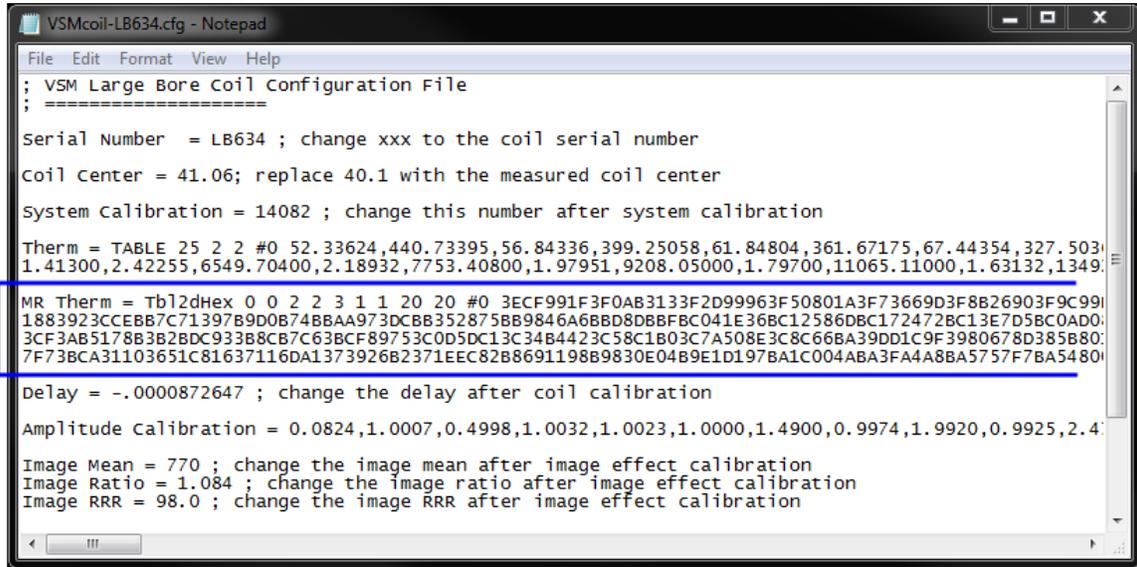


Figure 2. VSM coil calibration file with MR table.

AC Magnetic Susceptometer MR table usage

1. Using Notepad, open the MR calibration table generated by the program. Navigate to the calibration folder, and select a file with a name like ABC-###-2D.tab.
2. Select the MR table. Start with the text Tbl2dHex and select all the way to the first semicolon. Do not select the text starting with Table2D_ID. Copy the table to the clipboard using the Edit/Copy menu command.
3. Using Notepad, open the coil configuration file for the coil you calibrated. The file is located at C:\QDDynaCool\ACMSII\Calibration\ and has a name like ACMSCOIL-WF###.cfg.
4. After the line starting with Therm = , create a new line starting with MR Therm =
5. In Notepad, paste the table after MR Therm =
6. The file should contain an MR table as shown inside the blue lines in Figure 2. Depending on the details of the file before you added the MR table, it may look slightly different than the figure.
7. Save and close the file.
8. Follow the instructions in the section **Verifying the MR Table is Applied** to make sure the correction is being applied correctly.

Rotator and Multi-function probe MR table usage

1. Using Notepad, open the MR calibration table generated by the program. Navigate to the calibration folder, and select a file with a name like ABC-###-2D.tab.
2. Select the MR table. Start with the text Tbl2dHex and select all the way to the first semicolon. Do not select the text starting with Table2D_ID. Copy the table to the clipboard using the Edit/Copy menu command.
3. Deactivate the Rotator or Multi-function Probe option if it is running.

Figure 3. Example file BRT_Srom.srom read from BRT module.

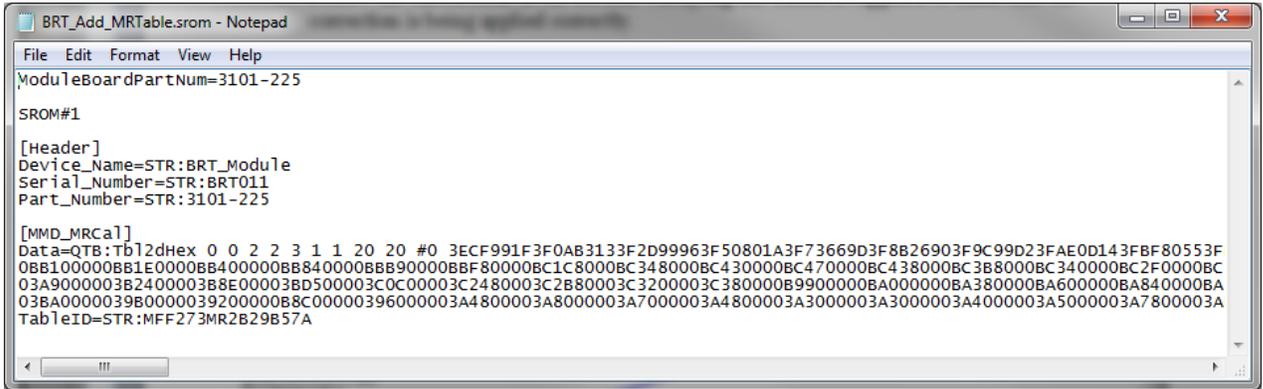


Figure 4. Example file BRT_Add_MRTable.srom after adding MR table.

Thermal Transport Option MR table usage

1. Using Notepad, open the MR calibration table generated by the program for one of the thermometers. Navigate to the calibration folder, and select a file with a name like Therm###-2D.tab.
2. Select the MR table. Start with the text Tb12dHex and select all the way to the first semicolon. Do not select the text starting with Table2D_ID. Copy the table to the clipboard using the Edit/Copy menu command.
3. Using Notepad, open the thermometer calibration file for the same thermometer. The file is located at C:\QDDynaCool\ThermalTransport\Calibration\ and has a name like Therm###.cfg. Be sure the serial numbers match.
4. Paste the table at the end of the thermometer calibration file.
5. The file should contain an MR table as shown inside the blue lines in Figure 5. Depending on the details of the file before you added the MR table, it may look slightly different than the figure.
6. Save and close the file.
7. Repeat steps 1-6 for the other TTO thermometer.
8. Follow the instructions in the section **Verifying the MR Table is Applied** to make sure the correction is being applied correctly.

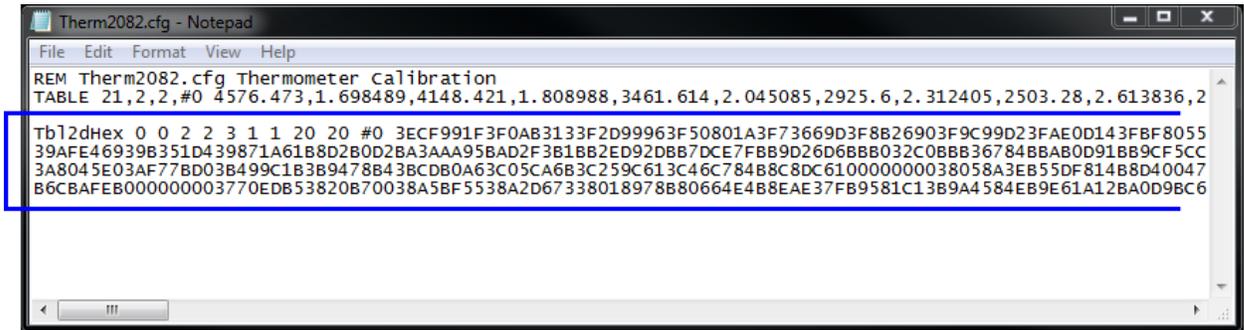


Figure 5. TTO thermometer calibration file with MR table.

Section VII: Verifying the MR Table is Applied

For options other than TTO, follow these steps to make sure the table is correctly applied during option measurements.

1. Set up the option as described in the option user manual.
2. Activate the option software, and if necessary, start option temperature control.
3. Set a temperature and field at which verification data were taken by ThermCal. Look in the *.dat file to find a temperature. For example, set 2.67 K and full field.
4. Start a log in MultiVu using Utilities/Log Data... and select all items on the Standard Items and Diagnostic Items tabs.
5. After the system stabilizes at the set temperature and field, look at the values of "Temperature (K)" and "Block Temp (K)". The percent difference between these temperatures should be the same (within noise) as the value for "Therm 1 Err (%)" in the *.dat file created by ThermCal. Be sure to compare at the same temperature and magnetic field.
6. If the values match, the calibration is correctly applied. If the values do not match, the correction is not being applied or there is a problem with the MR table. Contact Quantum Design for assistance.

For TTO, you can tell that the MR tables are being applied by looking in the Thermal Transport Log window when you activate the option. If the MR tables are applied, you will see the lines "Hot Thermometer magneto-resistance correction loaded" and "Cold Thermometer magneto-resistance correction loaded". If you do not see these lines, the MR tables are not applied. Contact Quantum Design for assistance.

Section VIII: Restarting a Calibration

If a calibration must be aborted or fails for any reason, you can restart the calibration using the XML files created by ThermCal (see the section **Output Files**). Normally you choose the file with the latest date and time stamp. However, you might choose an earlier file if you suspect faulty data are present in later files. (Open the files in a web browser to examine them.)

To restart a calibration, start the program

C:\QdDynaCool\Tools\ThermCal\System\ThermCal.exe, press the Browse... button, and select the desired XML file. Follow the on-screen prompts to restart the calibration.

Section IX: Configuring the Calibration

Normally the ThermCal XML configuration files supplied by Quantum Design do not need to be modified. If you wish to modify the configuration files, read the documentation included with ThermCal. Start the program

(C:\QdDynaCool\Tools\ThermCal\System\ThermCal.exe), then select Help/ThermCal Help... The help window that opens includes descriptions of all the parameters in the XML configuration files.

The configuration files are located at C:\QdDynaCool\Tools\ThermCal\Config\. In order to use a modified configuration file, run ThermCal.exe, press the Browse... button, and select the desired XML file.