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Product Description

MPMS® SQUID VSM

(Features/Specifications)

Quantum Design proudly presents its new **MPMS SQUID VSM** dc Magnetometer. This new member to the MPMS magnetometer family offers you $\leq 10^{-8}$ emu sensitivity. By combining the speed of a Vibrating Sample Magnetometer with the sensitivity of a SQUID (Superconducting QUantum Interference Device) magnetometer, this new system ushers in new levels of performance in magnetic research. Joining the popular MPMS XL line, the MPMS SQUID VSM gives researchers the choice between the world's most versatile SQUID magnetometer and the fastest.

The new MPMS SQUID VSM incorporates major advances in data acquisition, temperature control and magnetic field control.

Data Acquisition

The FastLab™ data acquisition combines Quantum Design's dc SQUID sensor and novel Vibrating Sample Magnetometer technology thus providing the ability to achieve <1 x 10^{-8} emu sensitivity at zero magnetic field. Further noise reduction in the design allows this system to achieve an unprecedented <8 x 10^{-8} emu sensitivity at the full field of 7 tesla.

Temperature Control

The MPMS SQUID VSM uses the newly designed RapidTemp™, an innovative temperature control design that allows you to cool samples from room temperature to a stable 1.8 K in <30 minutes.

The temperature control insert of the MPMS SQUID VSM is a vacuum-insulated chamber into which cold helium is drawn, through a variable flow valve, for purposes of cooling the sample chamber with pumped helium to temperatures as low as 1.8 K. A finely tuned flow impedance and sophisticated temperature control software allows continuous operation at 1.8 K as well as smooth temperature control through the 4.2 K liquid helium boiling point. Heaters on the sample chamber can raise the temperature as high as 400 K. A thermal shield, anchored to a liquid nitrogen tank, intercepts heat from a warm sample chamber and minimizes liquid helium consumption when operating at higher temperatures. By flattening the thermal gradient along the cold end of the temperature control insert, this shield also allows the entire insert to be constructed with a relatively short geometry, minimizing heat capacitance and enabling rapid temperature control.

The diameter of the temperature control insert was selected to allow a 9 mm sample bore and to provide the smallest diameter pickup coils possible to optimize the magnetometer's sensitivity.

Magnet Control

The MPMS SQUID VSM utilizes a 7 Tesla, superconducting, helium-cooled magnet and a hybrid digital/analog magnet controller designed specifically for the SQUID VSM to achieve precise, quiet control of the magnetic field. SQUID precision in a magnetic measurement requires a stable magnetic field. The SQUID VSM accomplishes rapid switching between charging and discharging states and stable fields with a unique superconducting switching element called the QuickSwitch™ (patent pending), which changes between superconducting and normal states in less than one second. This allows rapid collection of high precision data.

The high open state resistance and low thermal mass of the QuickSwitch design also helps to minimize liquid helium consumption when ramping magnetic field, as compared to more traditional superconducting persistent switch technology. Further aiding the instrument's low helium consumption is the use of high temperature superconductor (HTS) magnet leads anchored to a liquid nitrogen tank. The nitrogen shield in this design absorbs a large amount of room temperature heat that would otherwise be conducted to the helium bath. Quantum Design is proud of the contributions made to HTS research and development, and is excited to add this new member to the MPMS family—to the benefit of future researchers.

The MPMS SQUID VSM comes with an integrated Environmental Magnet Shield. This shield allows sensitive measurements to be made in locations with excessive magnetic noise by creating a locally quiet environment. It also serves as a return path for the system's superconducting magnet, permitting use of the system in close proximity to other sensitive devices,

System Specifications
(Standard system specification apply to non-EverCool base configuration):

Temperature control
Feature: New TCM design, Rapid Temp™
- Operating Range: 1.8 K to 400 K (1,000 K with optional Oven)
- Cooling Rate: 30 K/min (300 K to 10 K stable in 15 min.); 10 K/min (10 K to 1.8 K stable in 5 min.)
- Temperature Stability: +/- 0.5%
- Temperature Accuracy: lesser of +/- 1% or 0.5 K
- Sample Chamber I.D.: 9 mm

Magnetic field control
Feature: QuickSwitch™
- Magnetic Field Range: -70 kOe to +70 kOe
- Field Uniformity: 0.01% over 4 cm
- Field Charging Rate: 4 Oe/sec to 700 Oe/sec
- Field Charging Resolution: 0.33 Oe
- Remanent Field: ~5 Oe (typical) when oscillating from full field back to zero

Magnetization measurements
Feature: SQUID based VSM FastLab™
- Maximum DC moment: 10 emu
- Sensitivity: ≤ 2,500 Oe: $< 1 \times 10^{-8}$ emu (with less than 10 second averaging)
  > 2,500 Oe: $< 8 \times 10^{-8}$ emu (with less than 10 second averaging)
- Variable drive amplitude: 0.1 to 8 mm (peak)

General System Details
- Power Requirements: 200 VAC - 230 VAC, 50/60 Hz, 10A Max.
- Liquid Helium Usage: 4 liters/day (typical) + 0.05 liters per sample cooldown
- Liquid Helium Capacity: 65 liters
- Liquid Nitrogen Usage: 5 liters/day (typical)
- Liquid Nitrogen Capacity: 60 liters
- Maximum Hold Time: 12 days (typical)

Integrated system performance examples demonstrating instrument resolution:

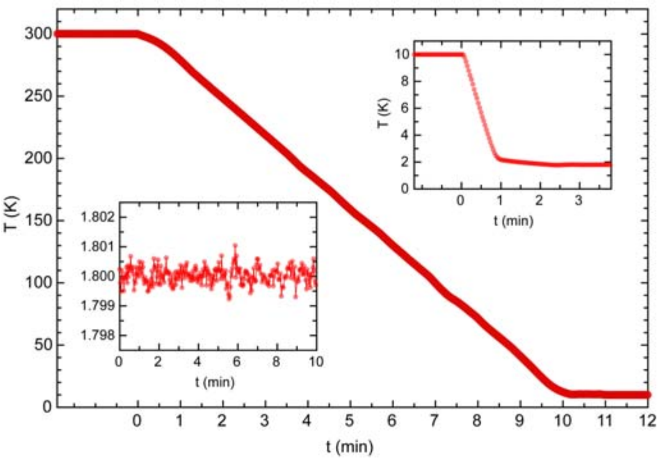


Figure 1. The cooling performance and low temperature stability of the SQUID VSM is shown. In 10 minutes, the chamber goes from 300 K to a stable 10 K. From 10K to a stable base temperature of 1.8 K takes about 2 minutes.

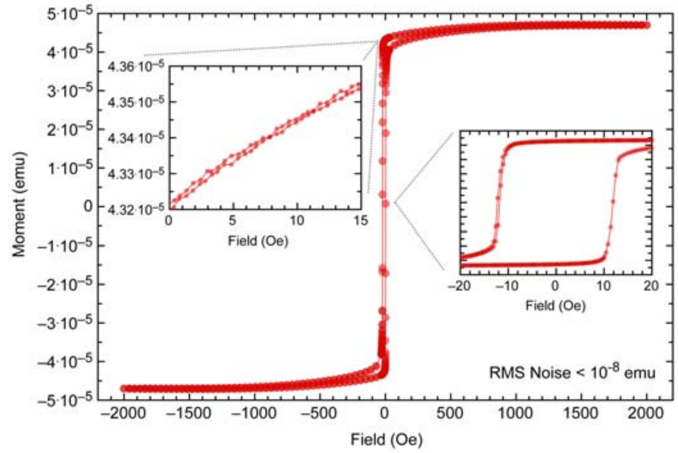


Figure 3. The quality of moment versus field data, at 5 K, is shown for a thin film ferromagnetic sample provided by Professor Eckert of Harvey Mudd College. The left inset illustrates the reproducibility in coming from 2 kOe to zero field. The right inset demonstrates in particular the small field setting resolution of the new SQUID VSM magnet power supply.

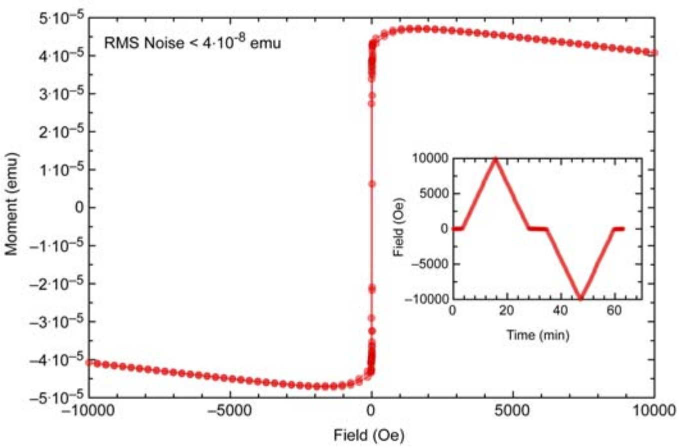


Figure 2. A fast scan of the moment versus field at 5 K is shown for a thin film ferromagnetic sample provided by Professor Eckert of Harvey Mudd College. The inset illustrates the speed of the measurement process and the higher resolution data at the lower fields.

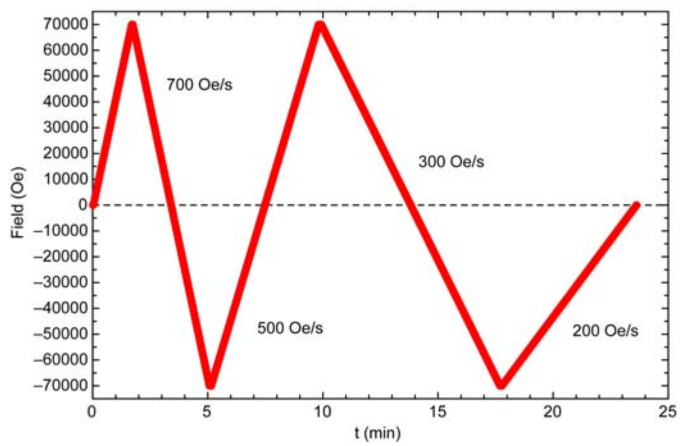
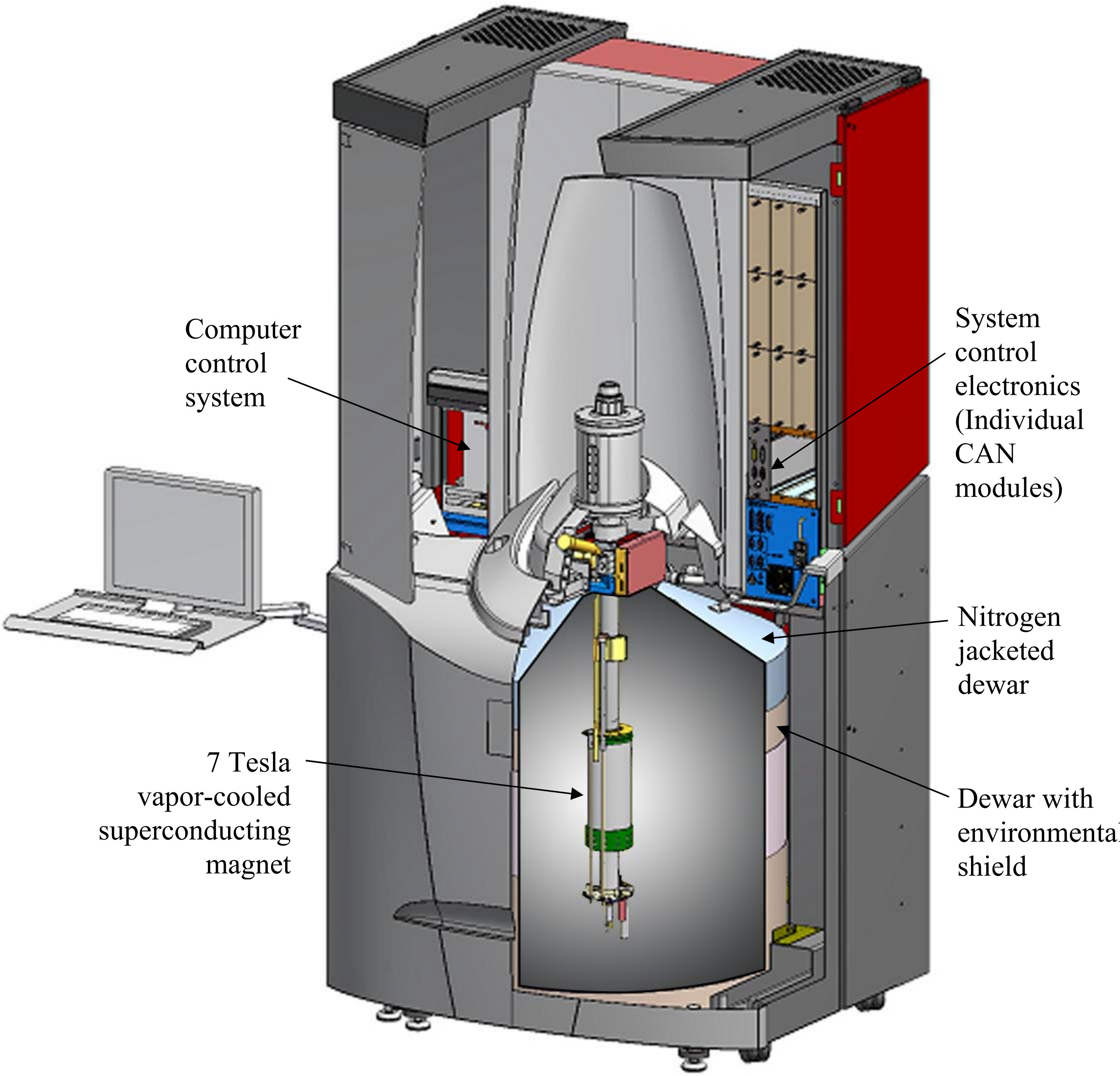


Figure 4. The versatility of the new SQUID VSM magnet power supply is shown. Charging rate of 4 Oe per second can be achieved.

Photograph of an actual MPMS SQUID VSM at Quantum Design. Helium dewar is in the lower part of the cabinet and the computer and system electronics are in the upper half behind swinging smoked plastic doors.



Cutaway view of the MPMS SQUID VSM (Pump Console is not shown)

Options for the MPMS SQUID VSM

M103 MPMS SQUID VSM Oven

Temperature Range: 300K – 1000K
Maximum rate: 1000 K/min
Maximum controlled cooling rate: ~75K/min (1000K-500K)
Maximum controlled heating rate: ~250K/min (full temperature range)
Typical heating time from 400K to 1000K: 4 minutes (to stability)
Typical cooling time from 1000K to 400K: 12 minutes (to stability)

Noise Floor (ultimate sensitivity limit) at T=300K with 10s averaging time:
One order of magnitude worse than the SVSM
Low Field (<2500 Oe): $\leq 1.0 \times 10^{-7}$ emu
Full Field (~7T): $\leq 8.0 \times 10^{-7}$ emu

Sample Temperature Accuracy:
Reported sample temperature better than 2% after stabilizing

Transport evacuation time:
Non-Evercool:
Less than 12 minutes to high vacuum after a long storage sample rod period.
Less than 4 minutes to high vacuum after a sample change.
Evercool:
Less than 15 minutes to high vacuum after a long storage sample rod period.
Less than 7 minutes to high vacuum after a sample change.

Temperature stability: +/- 0.5K

Sample Stick Dimensions:
160mm Long x 5mm Wide x 0.5mm Thick
25mm long heater region in the center of the stick
66mm from the bottom of the stick to the recommended sample mounting position.

Maximum Recommended sample size dimensions:
10mm Long x 5mm Wide x 2mm Thick

M150 MPMS SQUID VSM AC Susceptibility Measurement

Many materials display dissipative mechanisms when exposed to an oscillating magnetic field, and their susceptibility is described as having real and imaginary components – the latter being proportional to the energy dissipation in the sample. The key is resolving the component of the sample moment that is out of phase with the applied AC field. The SQUID technology is the measurement system of choice because it offers a signal response that's virtually flat over a broad frequency range from 0.1 Hz to 1 kHz. In a SQUID system, the output voltage is proportional to the magnetic flux in the pick-up coil instead of its time derivative as in conventional AC systems. The SQUID VSM therefore is able not only to achieve unprecedented sensitivity as in its base configuration, but also a minimal variation in sensitivity over the entire frequency range. The SQUID VSM AC option typically provides better than 5×10^{-8} emu sensitivity on the AC moment and better than ±0.5° phase angle sensitivity over the entire AC measurement frequency spectrum.

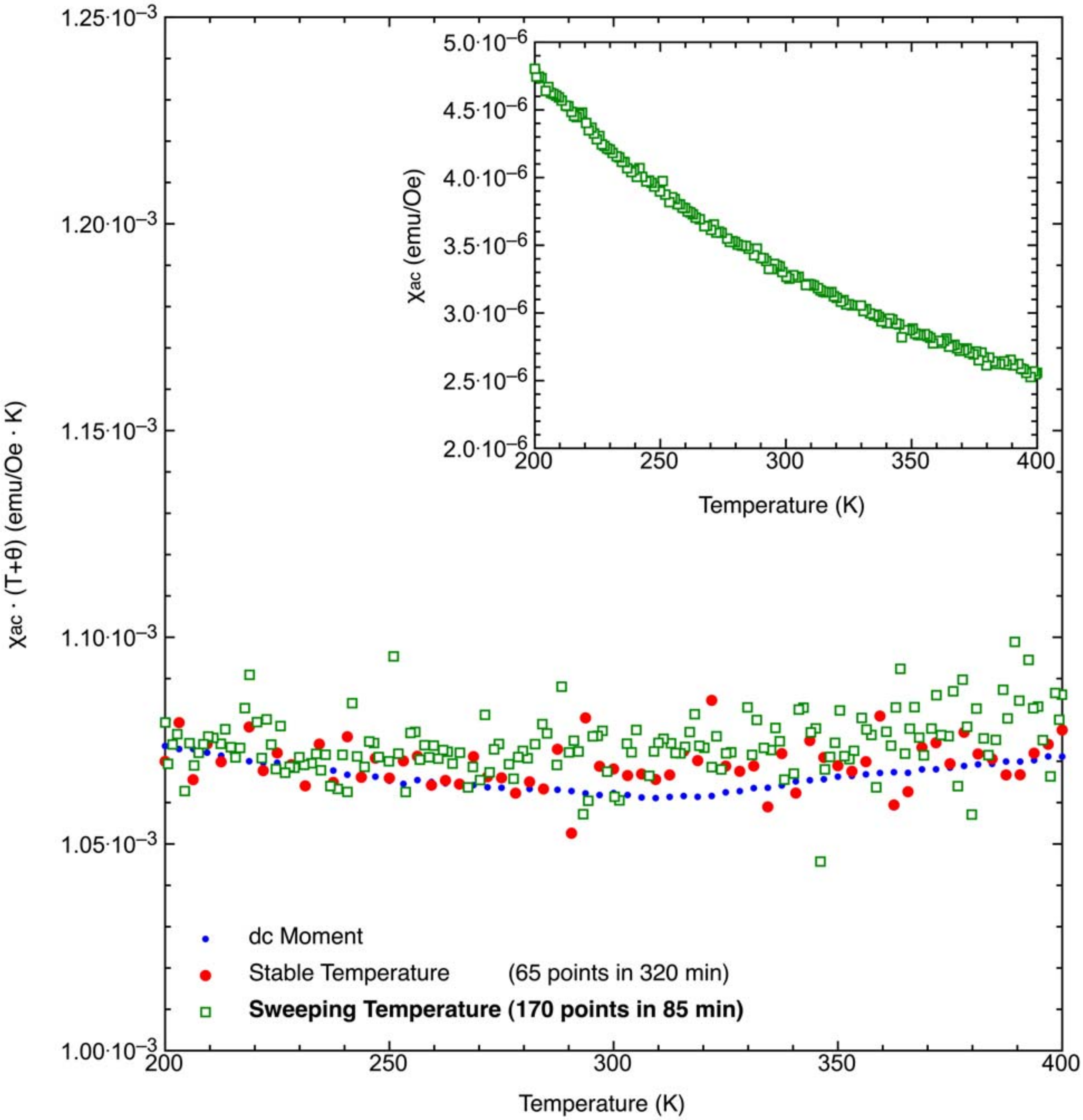
The SQUID VSM AC option is composed of a dedicated controller module which integrates seamlessly into the existing system and user interface.

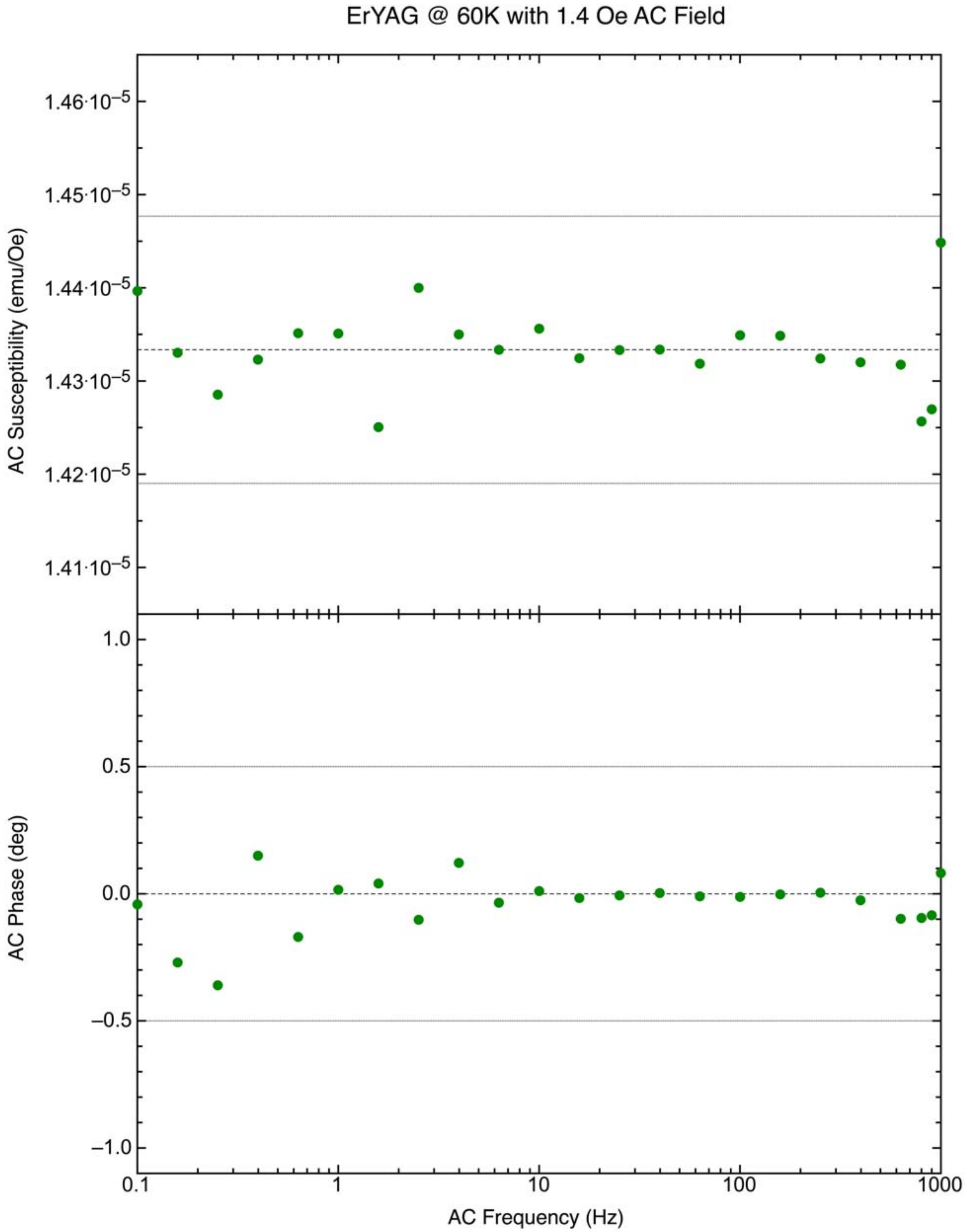
(Preliminary Specifications)

AC frequency range	0.1 Hz to 1 kHz
AC Amplitude[1]	0.1 Oe up to 10 Oe[2]
AC Moment Sensitivity[3]	≤ 5×10^{-8} emu (typical)
AC Moment Accuracy[4]	≤ ±1% (typical)
Phase Angle Accuracy[5]	≤ ±0.5 (typical)
Frequency[6] and Temperature[7] dependencies	
on AC Moment	≤ ±1% (typical)
on Phase Angle	≤ ±0.5 (typical)

1. *Peak amplitude of applied ac field*
2. *Maximum drive amplitude is frequency dependent. Software will dynamically reduce the maximum amplitude at higher frequencies.*
3. *Smallest moment change that can be detected. Specification defined for a moment of about 5×10^{-6}emu using reference sample at 300 K with 10 Hz ac frequency and a maximum of 10s averaging.*
4. *Reported ac susceptibility for reference sample agrees with measured dc susceptibility. Specification defined using reference sample at 300 K, dc susceptibility extracted from dc MvsH measurement between ±100 Oe with 5 Oe field steps, ac susceptibility measured at 10 Hz with a maximum of 10s averaging and an ac amplitude to give moment of at least 2×10^{-5}emu.*
5. *Reported phase angle for reference sample agrees with expected value. Specification defined using reference sample at 300 K with 10 Hz with a maximum of 10s averaging and an ac amplitude to give a moment of at least 5×10^{-6}emu – specification denotes maximum deviation from zero phase angle for reference sample.*
6. *Variation for frequencies between 0.1 Hz and 1 kHz for moments larger than 2×10^{-5}emu.*
7. *Variation for Temperatures between 2 K and 400 K for moments larger than 2×10^{-5}emu.*

ErYAG measured with 6.3Hz AC Field





ErYAG @ 60K with 1.4 Oe AC Field
AC Susceptibility (emu/Oe)
1.46·10^−5
1.45·10^−5
1.44·10^−5
1.43·10^−5
1.42·10^−5
1.41·10^−5
AC Phase (deg)
1.0
0.5
0.0
−0.5
−1.0
0.1
1
10
100
1000
AC Frequency (Hz)

M155 MPMS SQUID VSM Ultra-Low Field Capability (ULF)

This option actively cancels residual magnetic flux in the superconducting solenoid so samples can be cooled in a very low field – typically less than ±0.05 Gauss. The capability is extremely important for measurements of high temperature superconductors and spin glass materials. Besides allowing zero-field measurements, the option also allows to set fields up to ±20 Gauss with a resolution improved by two orders of magnitude over the standard system.

The Ultra-Low Field option incorporates additional electronics and a custom fluxgate specifically designed for this application. In basic operation, the SQUID VSM measures the residual field profile along the solenoid's longitudinal axis using the fluxgate and then nulls it by setting a DC field, using compensation coils installed in the superconducting solenoid.

Nulling Specifications:	
Field nulling window[1]	up to ±10 mm
Field uniformity[2]	±0.05 Gauss
Target field range[3]	±5 Gauss
Field stability[4]	24 hours
Fluxgate Specifications:	
Fluxgate range[5]	±10 Gauss
Sensitivity[5]	±0.002 Gauss
Accuracy	±(0.02 Gauss + 0.5% measured field)
Additional Specifications:	
Magnet profiling length[7]	up to 50 mm
High resolution field range[8]	±20 Gauss
Field resolution	better than 0.002 Gauss
Field accuracy	±(0.002 Gauss + 0.5% set field)

1. Window in which field is nulled (distance from magnet center).
2. Maximum field at any point along the magnet axis inside the nulling window.
3. Any target field within this range can be set with quoted uniformity and verified with fluxgate.
4. Stability (within uniformity specification) over time of the applied field
5. Field range which can be read by the fluxgate.
6. Intrinsic noise on fluxgate reading.
7. Maximum length along magnet axis which can be profiled using the fluxgate.
8. High resolution field range which can be applied by the option.

C060 MPMS SQUID VSM EverCool Dewar

Features:

A. Novel pulse tube and dewar design allows reduced vibrations, lower noise specifications, while having the cryocooler continuously running. There is no need to switch compressor off to reach highest sensitivity.
B. Cool-down does not require liquid helium and is done within a day.
C. System has virtually zero helium loss (with the exception of negligible volumes of gas lost when venting the sample chamber). Huge savings on helium consumption.
D. Pulse tube design does not require specific maintenance.

Specifications:

Helium Liquefaction Capacity: ~12 liquid liters/day
This is the net liquefaction rate while the system is running and represents the amount of liquid helium that can be generated in excess of the normal daily system usage.

Nominal LHe Capacity: ~ 16 liters
Full capacity is defined when level reaches bottom of magnet.

Estimated Cool-Down Time: ~ 30 hours to reach thermally steady state, ready for normal system operation. No liquid helium is required for cool-down. An additional 20 hours are necessary to reach the normal helium level.

Potential Effect on System Sensitivity: The EverCool configuration has a permanently running cryocooler, which has no influence on the system specifications. The noise performance is identical to the standard SQUID VSM.

Physical Configuration: (a) EverCool Dewar with integrated Pulse Tube cold head housed in existing standard SQUID VSM cabinet; (b) Pumping module, gas handling control and integrated EverCool controller housed in existing standard SQUID VSM pump console; (c) Compressor with stainless steel hoses connecting to main cabinet.

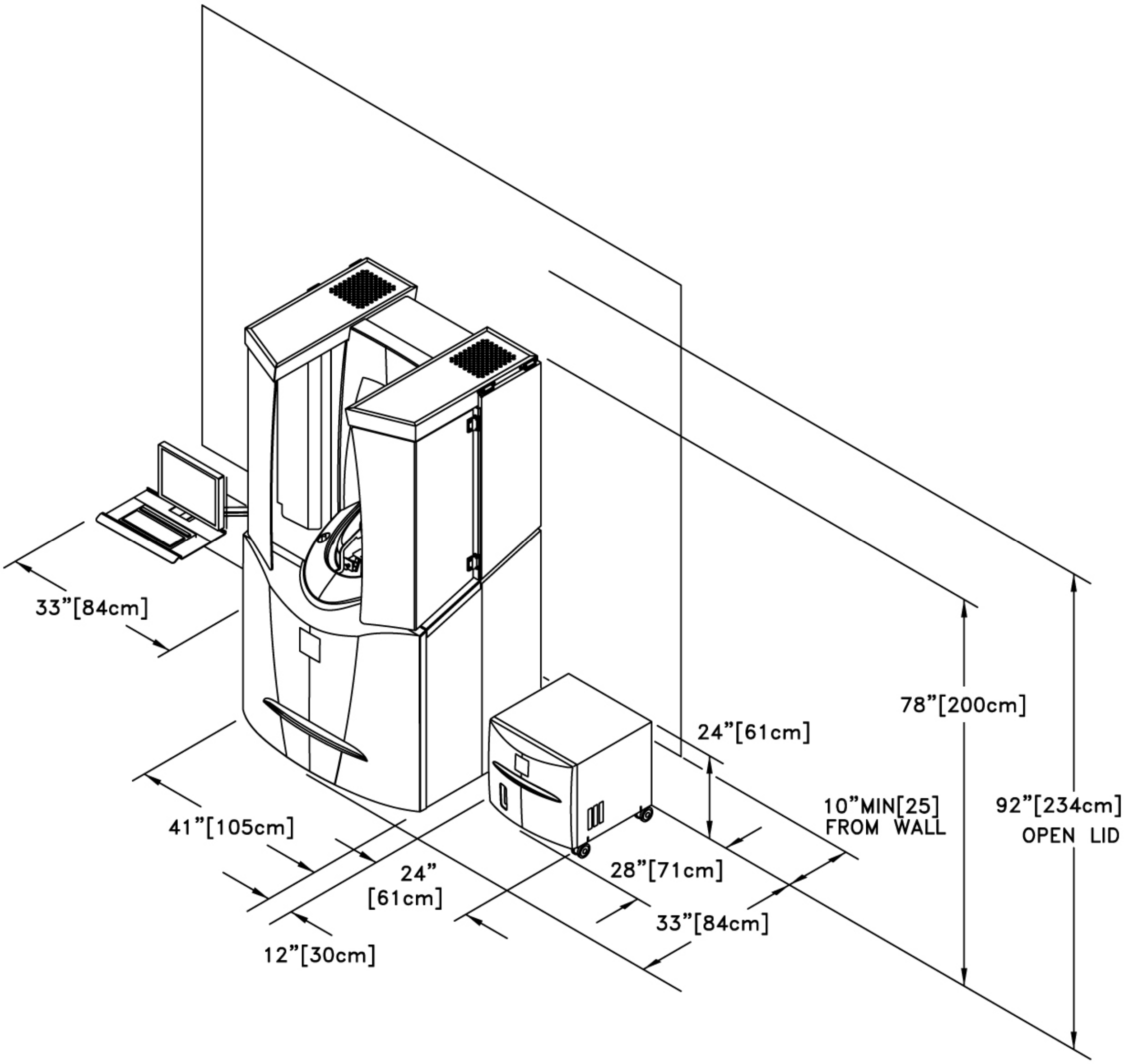
Physical Dimensions:
Main Cabinet (excl. keyboard arm and compressor hoses): ~ 84 x 104 x 199 cm3 (L x W x H). Weight: ~ 400 kg.
Pump Console: ~ 71 x 61 x 61 cm3 (L x W x H). Weight: ~ 65 kg.
Compressor: ~ 46 x 48 x 62 cm3 (L x W x H). Weight: ~120 kg.
Compressor hoses (pair): ~ 12 or 30 m length. Weight: 34 kg (pair).

Compressor Power Requirements:
3 Phase 220/230VAC 27A max @ 60 Hz;
3 Phase 460VAC 13A max @ 60Hz;
3 Phase 380/420VAC 16 A max @ 50 Hz;
Power requirement of 9 kW max with a typical consumption of 7.2 kW

Cooling water Requirement (Water-cooled compressor):
≥9 liters/min @ 28 °C and ≥3 liters/min @ 10 °C.

Maintenance Time on Compressor: After 20,000 operational hrs (Operational hours recorded by timer on compressor)

Maintenance Time on Cold Head: ~every 40,000 to 60,000 operational hrs



Laboratory layout of the MPMS SQUID VSM