Operation Manual for

MS2 Magnetic Susceptibility System

Bartington®
Instruments

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1. About this Manual

This manual describes the operation of the MS2 range of magnetic susceptibility measurement instruments.

It should be read in conjunction with the magnetic susceptibility product brochure DS0020 and operation manual OM1131 (Multisus for Windows), both of which are available on the MS2/MS3 product page on the Bartington Instruments at www.bartington.com/ms3.html.

Outline drawings of the MS2 meter and sensors are also available on the product page.

Following the instructions in this manual will enable the optimum operation for which your equipment is designed. Failure to follow these instructions may invalidate your warranty.

1.1. Symbols Glossary

The following symbols used within this manual call your attention to specific types of information:

WARNING: Indicates a situation in which serious bodily injury or death could result if the warning is ignored.

Caution: Indicates a situation in which bodily injury or damage to your instrument, or both, could result if the caution is ignored.

Identifies items that must be disposed of safely to prevent unnecessary damage to the environment.

Note: Provides useful supporting information on how to make better use of your purchase.

2. Safe Use

WARNING: While the MS2 meter usually runs off internal batteries, it can also be powered by mains electricity. Ensure that the unit is properly earthed at all times. When using the mains power supply, ensure that the mains adaptor is correct for the local AC mains voltage (110V or 240V). Do not open the casing or have contact with any internal parts.

WARNING: In addition to the above, ensure that the mains selector on the MS2WFP sensor is set to the local AC mains voltage (110V or 240V).

WARNING: These products are not qualified for use in explosive atmospheres or life support systems. Consult Bartington Instruments for advice.

3. Introduction

The MS2 Magnetic Susceptibility System comprises a variety of sensors together with a field portable measuring instrument, either the MS2 meter or the MS3 meter.

The MS3 meter is a more compact instrument than the MS2 meter, of higher range and lower noise, with a primarily USB interface for use in conjunction with a Windows computer or PDA. It can be used with all of the MS2 sensors in place of the MS2 meter. As it is the subject of its own operation manual (OM3227), available from the product page, it will not be discussed further here.

The range of equipment described in this manual in addition to the MS2 Meter is as follows:

- MS2B dual frequency sensor
- MS2C core scanning sensor
- MS2E high resolution surface scanning sensor
- MS2 handle for use with probes type MS2D and MS2F
- MS2D probe
- MS2F probe
- MS2G single frequency sensor
- MS2H down-hole probe
- MS2K high stability surface scanning sensor
- MS2W water jacketed sensor
- MS2WF furnace sensor
- MS2WFP power supply/temperature controller

All sensors are described in the product brochure.

Each MS2 sensor is designed for a specific application and sample type, and is connected to the MS2 meter via a simple TNC-TNC coaxial cable that is supplied with the order. The meter displays the magnetic susceptibility value of materials when these are brought within the influence of the sensor.

An RS-232 serial interface allows the instrument to operate in conjunction with custom software, Multisus or Bartsoft, running on a portable data logger or PC. Interfacing commands are provided should there be requirement for an alternate interface.

The MS2 meter is powered by internal rechargeable batteries.

The circuitry within the MS2 meter powers the sensors and processes the measurement information produced by them. The measurements are obtained digitally using a time dependent method. This results in precise and repeatable measurements. The sensors are independently calibrated and are therefore fully interchangeable between MS2 meters.

4. General Information

4.1. Measuring Magnetic Susceptibility

Magnetic susceptibility corresponds to the ability of a material to be magnetised in an external field. Bulk (volume) susceptibility χ_{vol} can be directly related to the relative permeability (μ_r) of a material: $\chi_{vol} = \mu_r - 1$ and where μ_r is the ratio of permeability of material/permeability of vacuum.

The MS2/3 instruments rely on the change of inductance in an inductor when the permeability of its core is changed.

The reference state is measured when the sensor contains only air (the permeability of air is approximated as the permeability of a vacuum). Taking a reading with a sample will then give the permeability of the material.

Any thermally induced sensor drift needs to be eliminated by occasionally obtaining a new 'air' value, to re-establish the zero reference. This is done by pressing the 'Z' button on the MS2 meter (see Front Panel Controls).

The magnetic susceptibility value is displayed digitally and output via a serial interface.

For further information on calculating the magnetic susceptibility and how it is related to magnetic permeability, see Appendix 5. Calculating Magnetic Susceptibility.

4.2. The Sensors

Each sensor subjects the sample to a non-saturating field that has the advantage of measuring initial susceptibility without destroying any sample magnetic remanence. When measuring non-metallic samples, the sensors are particularly insensitive to sample conductivity.

The sensors can be broadly divided into laboratory and field survey sensors:

Type	Sensor	Purpose
Laboratory sensors	MS2B	Measurement of magnetic susceptibility of soil, rock and sediment samples.
	MS2C	High resolution volume susceptibility measurements on whole cores.
	MS2E	Measurements with high spatial resolution along split cores or suitably prepared geological specimens.
	MS2G	Measurements of powder or liquid samples.
	MS2W	Measuring temperature dependency of magnetic susceptibility.
Field survey equipment	MS2D	Assessment of the concentration of ferromagnetic materials in the top 100mm of the land surface.
	MS2F	Stratigraphic study of exposed geological and archaeological sections.
	MS2H	Down-hole sensor for sub-surface measurements of volume magnetic susceptibility of strata.
	MS2K	Highly repeatable measurements of the volume magnetic susceptibility of moderately smooth surfaces.

The full range, specifications and functions of the sensors available for use with the MS2 meter are given in the product brochure.

4.3. Operating Environment Considerations

The following environmental factors should be taken into account when using the MS2 system.

4.4.1. Temperature Induced Drift

The MS2 sensors operate on the principle of comparison between the magnetic permeability of air and the relative permeablility obtained with the contribution of the sample magnetic permeability. In order to do this the sensors are required to measure the magnetic permeability to a high resolution. This can be a very demanding requirement as any change in temperature can lead to a slight distortion of the coil shape, causing an apparent change in permeability, and therefore in susceptibility.

Each sensor employs its own technique for temperature compensation to minimise any temperature induced drift. A facility for automatic correction of temperature drift at the end of a measurement sequence is also provided by the Multisus and Bartsoft software packages. This drift correction is worked out by taking a zero (or blank) reading at the start, and then taking a second blank reading (not a zero) after the sample measurement.

The best precaution is to ensure that the operating temperature is constant during measurements, and preferably cool, and that sensor and samples have time to reach an equilibrium temperature. This may be more difficult when operating in the field.

4.4.2. Wet Conditions

Caution: These instruments are protected against the ingress of moisture but operation in very wet conditions should be avoided.

Note: Some sensors can be operated while submerged in water: see product brochure for further information.

4.4.3. Noise and Interference Check

Caution: These instruments should not be operated close to high power radio transmitters, heavy electrical machinery, computers, or other electrical or magnetic equipment.

Note: The unit is unlikely to be affected by interference from other equipment in the normal operating environment. However, by their nature the sensors are susceptible to electromagnetic interference and operation close to a radio frequency source with a frequency close to the operating frequency of the sensor should be avoided. It is important to position the sensor to minimise interference and obtain the best performance.

Select the normal sensitivity, x1.0 range. With no sample present, first press the 'Z' button and then select continuous measurements on the 'M' toggle switch. If fluctuations of greater than ±1 least significant digit per reading appear on the display then external electrical noise should be suspected. In this case the only solution is to re-site the equipment.

Before using the laboratory sensors, first check the selected area for freedom from large ferrous objects by moving the sensor and watching for any changes on the display.

4.4.4. Electromagnetic Compatibility

The MS2 meter and sensors contain no high frequency electronics likely to cause emissions that could affect other apparatus. Emissions are minimised by the use of a rechargeable battery charged from a mains adaptor and decoupling of the internal switched mode power supply. The sensors generate a small magnetic field so very sensitive equipment such as SQUID magnetometers will be affected if placed in close proximity.

4.4. Software

The available software is described in the product brochure and is supplied with individual operation manuals. **Bartsoft** is the most up to date software package and can be used to operate both the MS2 and MS3 meters. **Multisoft** is an older software package that is only compatible with the MS2 meter. The **Geolabsoft** software is intended for use only with the MS2 X/T Temperature Susceptibility System.

4.5. SI and CGS units

The instrument may be pre-set to display the susceptibility value directly in either SI or CGS units. The table below shows the basic mass or volume specific unit thus produced.

Mass and volume in SI and CGS units		
	Mass (χ_{mass})	**Volume (χ_{vol})**
SI	10^{-8} (m^3/kg)	10^{-5}
CGS	10^{-6} (cm^3/g)	10^{-6}

Numerical conversion from SI to CGS units is accomplished by dividing the SI value by 4π, i.e. $\chi_{CGS} = \chi_{SI}/4\pi$. The MS2 meter performs this function internally but by using the constant 0.4π to keep the numbers in a similar range of magnitude.

4.6. Range Selection

The instrument may be pre-set to display the susceptibility value in either the 1.0 or 0.1 range. The table below shows the the exponent value of the least significant digit (i.e. the last digit on the LCD) for each range. The units in the table below for volume susceptibility.

Exponent values for least significant digit in 1.0 and 0.1 ranges		
	SI	**CGS**
1.0	10^{-5}	10^{-6}
0.1	10^{-6}	10^{-7}

On the 0.1 range a decimal point will be displayed, effectively moving all the digits on the LCD to the left when compared with the 1.0 range. It should also be noted that one measurement in the 0.1 range will be an average of multiple readings taken over a period of 10 seconds.

4.7. Calibration

All sensors are calibrated either directly or indirectly to the diamagnetism of water (H_2O), where density ρ (rho) = 1.

χ_{mass} (mass susceptibility of H_2O) is -0.72×10^{-6} CGS

Therefore, for H_2O, $\chi_{vol} = \rho \times \chi_{mass}$

$= 1 \times -0.72 \times 10^{-6}$ CGS.

Precise mass specific measurements are only possible using the MS2B sensor where the sample volume is accurately defined.

5. MS2 Meter

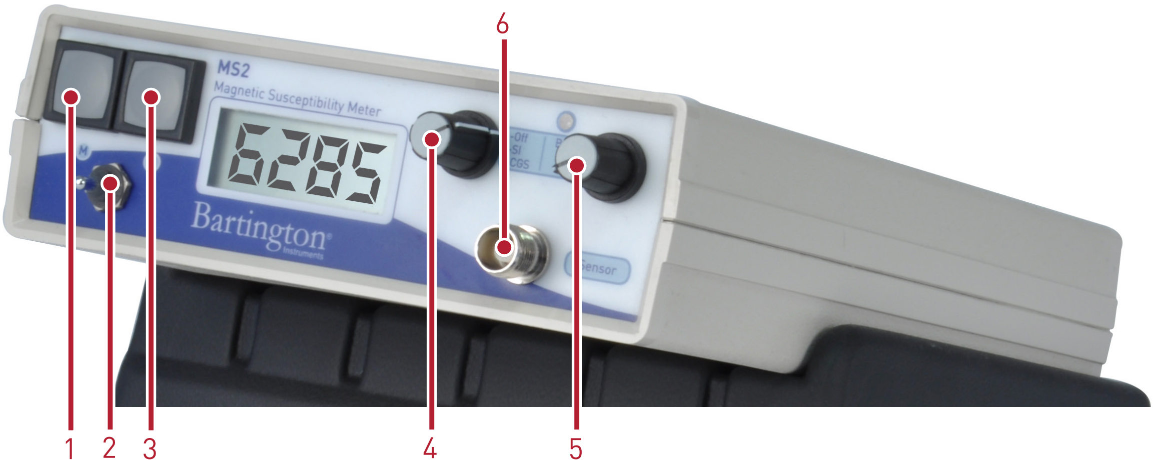

Figure 1a. MS2 meter, front panel.

Key to Figure 1a

1. 'Measure' ('M') push button
2. Toggle switch
3. 'Zero' ('Z') push button
4. On/Off Switch
5. Range multiplier switch
6. Socket for coaxial cable connection to sensor

5.1. Front Panel Controls

There are five front panel controls.

1. 'Measure' push button, labelled 'M': permits sample readings to be taken.
2. Toggle switch: performs the same function as the push button but permits continuous measurements.
3. 'Zero' push button, labelled 'Z': permits 'air' readings to be taken. By performing a measurement to 'air' this control re-sets the instrument and brings subsequent measurements within the range of the display.
4. On/Off Switch: controls the internal battery supply and also permits the selection of either SI or CGS units.
5. Range multiplier switch: allows selection of either x1 or x0.1 sensitivity range. In the second case the result is shown to the first place of decimal and a 10-fold increase in measurement time provides additional noise filtering. The switch also activates the battery indicator.

5.2 MS2 Meter Rear Panel

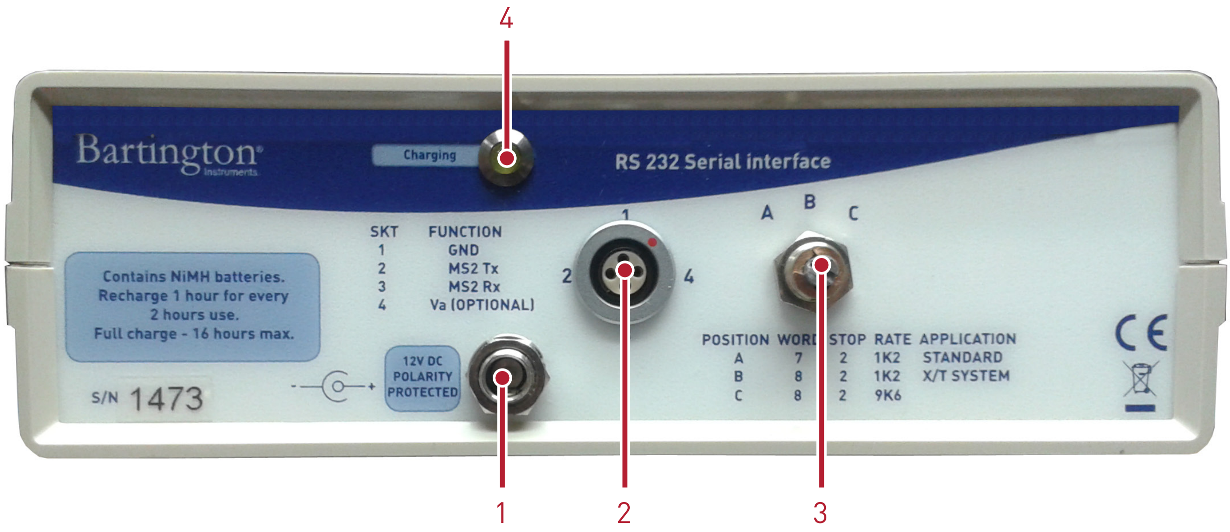

Figure 1b. MS2 meter, rear panel.

Key to Figure 1b

1. Power supply connector
2. RS-232 serial interface
3. Three-way rotary switch
4. Charging light

5.3. Rear Panel

The rear panel contains the following features:

1. Power supply connector: the power adaptor plug should be inserted here. For more information see Internal Batteries.
2. RS-232 serial interface: an MS2 RS-232 cable can be inserted here and connected to a computer to allow control and communication using Bartsoft or Multisus software. For more information see Serial Interface.
3. Three-way rotary Switch: allows the user to select one of three RS-232 communication settings options. For more information see Serial Interface.
4. Charging light: this LED will light up when power is connected and the MS2 battery is being charged. For more information see Internal Batteries.

5.4. Connecting a Sensor

Connect the sensor to be used to the front panel socket of the MS2 meter with the supplied 50Ω TNC-TNC cable, and switch on by selecting either SI or CGS units.

5.5. Taking Measurements

Set the meter to the 1.0 range for the initial measurement of any sample, to establish the approximate result, before switching to the more sensitive 0.1 range. If the value of a sample is greater than 1000 then the most significant digit will not be seen if measured on the 0.1 range, leading to an apparent gross error in the result.

Irrespective of the type of sensor being used, measurements are accomplished using the following procedure.

1. Take an 'air' reading by pressing the 'Z' push button with the sample to be measured away from the influence of the sensor. The display will appear blank and a colon will appear to show the instrument is 'busy'. The completion of a Z cycle will be announced by a bleep and the display will show all zeros.

2. Place the sample within the influence of the sensor and press the 'M' button. The 'busy' colon will appear and the display will show the previous reading until updated at the completion of the current measurement period. This is announced with a beep. At this time serial data will be transmitted.

3. If either push button is enabled at the completion of a cycle then a repeat measurement will be taken.

4. To measure weakly magnetic material, select the more sensitive x0.1 range and compensate for any thermally induced drift by making a series of measurements:

   a) Zero to air by pressing 'Z' button = R_0 (= 0)

   b) Measure samples = R_1 , R_2 ....

   c) Measure 'air' = R_{Final}

   The mean of an 'air' measurement before and after the sample is subtracted from the n^{th} sample measurement R_n:

   Corrected value $R_k = R_n - n \times (R_{Final} - R_0)/N$

   where N is the total number of measurements after the initial zero (including R_{Final})

   In the case that only one sample measurement is taken: $R_k = R_1 - (R_{Final} - 0)/2$

   When taking manual measurements, attempt to keep the time between measurements as consistent as possible. If recording values by hand then the previous value can be read whilst the current measurement is taking place, thus saving time and improving precision.

   The drift correction can be done automatically using Multisus or Bartsoft where the time of each measurement is recorded, and the is drift applied linearly as a function of time.

The magnetic susceptibility of common rocks is shown in Appendix 1.

5.6. Serial Interface

An RS-232 compatible serial interface, which permits data logging in the field and data processing in the laboratory, is included within this unit. The instrument produces a serial output of each meter reading, whether triggered by a signal on the serial interface or by a manual push button operation. A zeroing operation produces no serial output.

Via the four-way connector on the rear panel of the instrument, the RS-232 serial interface allows data communication between the MS2 meter and a computer with custom designed software. For reasons of economy of battery drain, the interface is restricted to operate over a maximum cable length of 50 metres.

An RS-232 connecting cable is provided with the MS2 for connection to a computer via a 9-way D-type connector. No hardware handshaking is provided.

The 'Z' and 'M' functions can be controlled externally by sending the ASCII character Z (Zero) or M (Measure) to the MS2 from the computer. To zero the instrument once, therefore, it is necessary to send Z followed by carriage return. Sending M followed by carriage return will cause a single measurement to be made. To return the instrument to the IDLE mode, any other character can be sent.

Data is only transmitted from the MS2 following the instruction to measure. The delay between the instruction being received and the data being transmitted will be equal to the measuring period, which depends on the sensor type (see relevant specification in the product brochure) and the range selected. The time taken to reset the meter to zero is the same as that required to take a measurement. Software should allow sufficient time for a response before issuing the next command.

The RS-232 interface operates in one of three modes as set by the screwdriver-operated rotary switch on the rear panel. The options are:

A. Standard operation 1200 baud with a 7 bit word (for use with Multisus software).

B. X/T system operation 1200 baud with an 8 bit word (for use with GeoLab software).

C. Operation at 9600 baud with an 8 bit word.

See Data Transmission for further information.

5.7. Internal Batteries

The instrument is powered by internal maintenance-free rechargeable Ni-MH batteries. Recharging can be carried out from either a mains electricity supply or a vehicle power socket.

WARNING: When using the mains power supply, ensure that you are using a mains adaptor that is correct for local AC mains voltage (110V or 240V).

To recharge the batteries, connect either the 12V mains power supply adaptor or the vehicle power socket cable to the 2.1mm connector on the rear panel of the instrument where a yellow LED will indicate that charging is taking place. The rate of charge will depend on whether the instrument is switched ON (trickle charge) or OFF (full charge).The charger input is polarity protected and any DC source as specified in the product brochure can be used.

Note: To maintain the full capacity of the batteries it is necessary to completely discharge and recharge them not more than every six months.

5.6.1. Battery Charging: Laboratory Use

When the instrument is switched on and connected to the mains supply via the battery charger, the batteries receive a trickle charge and therefore continuous use from the power supply is permitted.

5.6.2. Battery Charging: Field Use

Note: For field use, the batteries will need to be charged overnight for use the following day. A full recharge will take 16 hours with the instrument switched off and connected to an external mains supply or vehicle power socket.

Caution: To prevent overcharging, do not continue charging for more than 16 hours.

5.6.3. Battery Check

The condition of the batteries can be checked by selecting 'BATT' on the range multiplier switch. The battery indicator lamp will appear:

- Green: charge acceptable.
- Yellow: re-charge soon.
- Red: re-charge immediately.

Note: Use of the instrument when the battery voltage is low will cause excessive measurement drift and serial communication may fail.

5.6.4. Replacing the MS2 Meter Battery

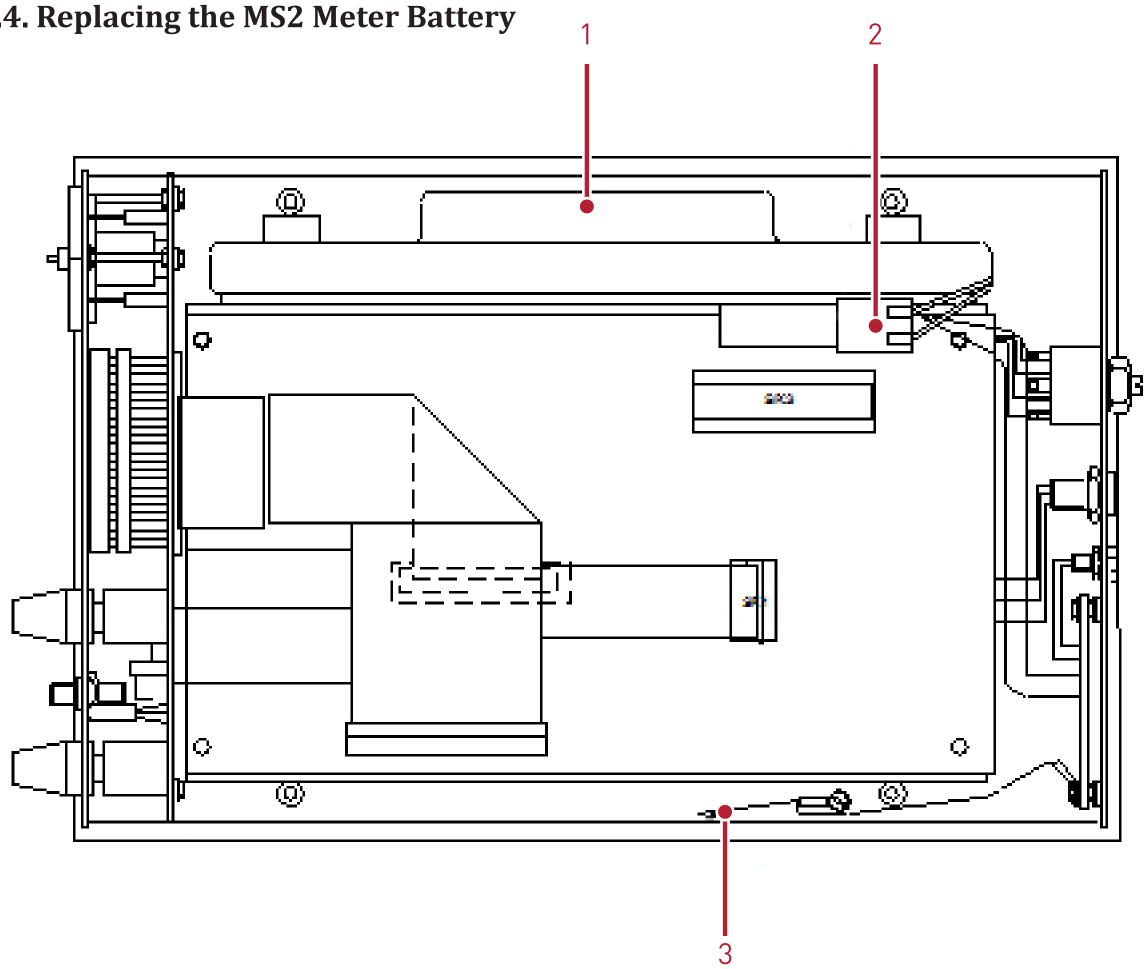

Figure 2. Replacing the MS2 battery.

Key to Figure 2.

1. NiMH battery pack
2. Two-way connector
3. Earth lead to earth point in the upper enclosure

For MS2 meters purchased prior to 1st January 2006, scrape away the wax coating over the four slotted nuts in the base of the unit and undo the nuts with a 6mm wide split screwdriver.

Figure 3. Screws in the base of the MS2 meter.

For units purchased after 1st January 2006, the holes are no longer filled with wax. A small Philips screwdriver must be used to release the enclosure halves. The top half of the enclosure can now be carefully lifted away from the unit.

Caution: Before opening the enclosure, ensure that the instrument is turned off and not connected to the mains power.

Caution: Take care not to disconnect the earth lead between the two halves of the enclosure.

Note: It is recommended to disconnect and lift PC7 off (4 screws), and lift rear panel out while assembling the new battery pack.

Disconnect and remove the battery. On later batteries the connection is via a two-way connector.

On older units the connection is via a terminal block with screw terminals. The terminal block forms part of the battery assembly, and must be removed with the battery to avoid the possibility of shorting the battery and creating a potential fire risk. Once the battery has been disconnected, remove the terminal block: this will be used on the replacement battery.

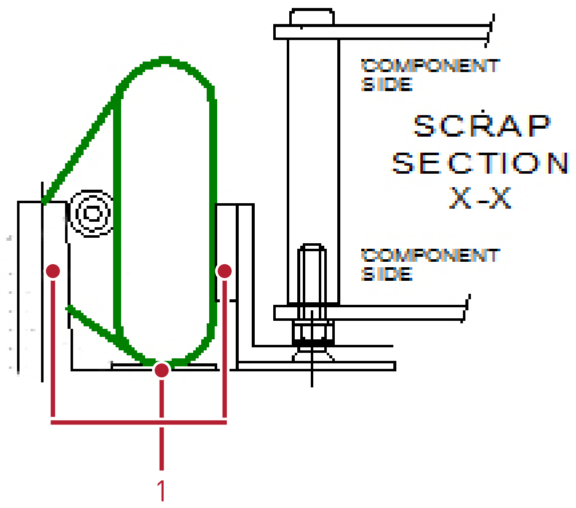

Figure 4. Double-sided insulation foam.

Key to Figure 4

1. Double sided foam

Note: The double-sided adhesive foam that holds the battery in place should be replaced when the battery is replaced. The old foam can be removed using isopropanol cleaning solvent.

WARNING: On no account use acetone as this will dissolve the enclosure.

Once dry, apply new strips of double sided foam (supplied with the replacement battery).

Insert the replacement battery and reconnect.

For older units, it will be necessary to remove the two-way plug from the replacement battery, cutting each wire separately so as not to short the battery. Assemble the terminal block onto the battery wires, then reconnect being careful to connect black to black and red to red.

Re-assemble top half of enclosure and secure with the appropriate screws or slotted nuts.

Dispose of the old battery in an approved disposal facility.

5.8. Data Transmission

Two-way transmission of data may be accomplished over a screened cable up to 50 metres.

A 2-metre cable with a 9-way 'D' type connector is provided.

The baud rate and bit format are set by a rotary switch on the rear panel as follows:

A. Standard serial interface	
Baud rate	1200
Bits per character	1 start, 7 data, 2 stop, no parity
Number of characters	5 + carriage return
Character format	Sign, four digits, CR
Control lines	Inactive
Code	ASCII

B. Serial interface for κ/T system operation (Used for compatibility with the temperature meter)	
Baud rate	1200
Bits per character	1 start, 8 data, 2 stop, no parity
Number of characters	5 + carriage return
Character format	Sign, four digits, CR
Control lines	Inactive
Code	ASCII

C. Serial interface for 9600 baud option	
Baud rate	9600
Bits per character	1 start, 8 data, 2 stop, no parity
Number of characters	5 + carriage return
Character format	Sign, four digits, CR
Control lines	Inactive
Code	ASCII

MS2 serial interface cable for connection to PC		
MS2 4-Way Fischer	**9-Way D-type connector**	**Function**
Pin 2	Pin 2	MS2Tx
Pin 3	Pin 3	MS2Rx
Pin 1	Pin 5	COMMON
	Pin 4 and 6	RTS, CTS
	Pin 7 and 8	DSR, DTR

5.9. Power Supply Accessories

The following accessories are supplied with the equipment:

- Fully isolated 240V or 110V to 12V DC 2.1mm centre-positive plug, thermally protected input and output.
- Vehicle DC – DC converter cable; 2 amp regulated 12V output to 2.1mm centre-positive plug.

Connection is via the rear panel socket.

6. MS2B Dual Frequency Sensor

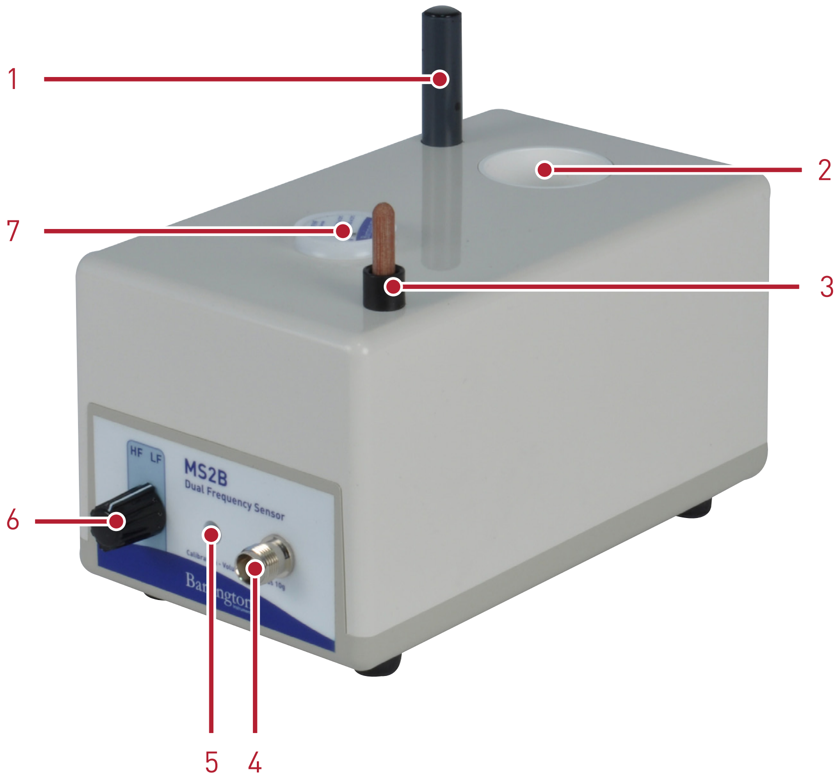

Figure 5. MS2B dual frequency sensor.

Key to Figure 5

1. Sample insertion mechanism & height adjustment screw
2. Sample cavity
3. Flat bladed adjuster tool
4. TNC connector for connection to MS2 meter
5. HF calibration screw
6. Operating frequency selector
7. Calibration check sample

6.1. General Description

The MS2B dual frequency sensor is a laboratory sensor designed to measure samples in containers that are placed into the sample cavity.

The sample containers accommodated by this sensor are those commonly in use in most palaeomagnetic and mineral magnetic laboratories; thus measurements of NRM (natural remanent magnetisation), IRM (induced remanent magnetisation), ARM (anhysteric remanent magnetisation) etc. can be carried out without any further sample treatment.

The sensor characteristics are optimised to produce no measurable response to sample conductivity in, for example, even 25% saline solution. Even metallic conducting material can be measured provided it is divided into a granular form to reduce the apparent diamagnetic contribution that might otherwise result due to eddy currents.

Sample insertion and removal is facilitated by a hand operated platen. It is normally fitted with a moving platen with a 27.5mm stem. For measurements of anisotropy of magnetic susceptibility (see Appendix 3. Anisotropy of Magnetic Susceptibility Measurements) the alternative 18.5mm stem supplied must be fitted.

6.2. Dual Frequency Measurements

Fine grained materials exhibit frequency dependent susceptibility. This is especially significant where grains of the single domain order are present (around 0.03 µm diameter), where very rapid changes in frequency dependency occur with relatively small changes in diameter. In naturally occurring materials, these grains are widely distributed in size and give rise to a fairly uniform frequency dependency of susceptibility in the low kHz range in which the MS2 operates. The coefficient of frequency dependency (χ_{FD}) can be expressed as the change in susceptibility per decade frequency divided by the low frequency susceptibility (χ_{LF}), where the low frequency susceptibility will always have the higher value.

$$\chi_{FD}\,\% = 100 \text{ x } ((\chi_{LF} - \chi_{HF}) / \chi_{LF})$$

where the frequencies used for LF and HF are in the ratio 1:10.

The frequencies used by the MS2B sensor are given in the product brochure. The LF frequency is carefully chosen to avoid interference from the ninth harmonic of 50Hz, and from the eighth harmonic of 60Hz electrical mains supplies. For further information regarding frequency dependance and the use of dual frequency measurements, please refer to OM0409 John Dearing Handbook, available from Bartington Instruments.

6.3. Single Frequency Measurements

When dual frequency measurements are not required, the LF (low frequency) range should always be selected as this will give results to the best precision.

6.4. Setting up the Sensor

Before any measurements can be taken, the MS2B must be plugged into the connector on the front of the MS2 meter via a TNC-TNC cable and the MS2 should be turned on. Ensure that the sensor is not situated on or near any materials with high magnetic susceptibility or those that are electrically conductive.

6.4.1. Centring

Perfect centring of the sample within the sample cavity is accomplished by adjusting the rest position of the moving platen. To reveal the nylon adjustment screw, remove the cap at the top of the sample insertion mechanism handle.

For standard 10cc samples the calibration sample, stored in the top of the sensor, should be used as a reference to find the centre point. While taking continuous measurements of the calibration sample, adjust the nylon screw with the non-magnetic adjuster tool, also located in the top of the sensor, until a maximum value is obtained.

For non standard sample volumes, the sample being tested should be used as a reference, and the height adjusted to achieve the maximum value.

The maximum adjustment of the height of the platen is ±10mm. For further information and illustrations see Appendix 4. Adjusting the MS2B Platen Height.

6.4.2. Calibration Check

A calibration sample is provided which contains a type B2 ferrite specimen located at the centre of an acetal cylinder. The sample is located in the top of the sensor, this can be removed and placed in the sample cavity for checking.

Note: The calibration sample can sometimes be difficult to remove.

The magnetic susceptibility value is marked on the sample. This material exhibits a negligible frequency dependency, and may be used to check the sensor accuracy periodically.

Note: The sample should not be exposed to high magnetic fields or demagnetising fields.

6.4.3. HF/LF Cross Calibration

The high frequency HF calibration can be adjusted relative to the low frequency LF calibration to within 0.05% as follows.

1. Select LF, set zero, and check the calibration sample on this range.
2. Switch to HF, wait 10 seconds, set zero, and then measure the calibration sample again.

If the HF value is greater or less than the LF value by more than 0.05% then the error can be removed by adjusting the HF trimmer control through the hole in the panel located in the top of the sensor, using the non-magnetic screwdriver. Clockwise rotation will increase the HF scaling, and counter clockwise decrease it. Perform a complete Z and M sequence following each adjustment. The maximum adjustment range is ± 0.13%.

Note: Although unlikely to change, it is advisable to carry out these quick checks before any set of measurements.

6.5. Preparation of Samples

Natural samples will never occur in such a form that the textbook value will be obtained. For example, the material of interest may be involved in a matrix of organic material of no interest, or be suspended in water. The true density of the analytic fraction is seldom known. Therefore, no strict instructions can be given for every situation. Each situation must be judged on its own merits and an appropriate sample collection and preparation regime planned. However, the following general points must be observed.

1. For most surveys, precise inter-sample comparability is of more interest than absolute values. This can only be assured where more importance is attached to consistency of the method of sample collection than to rigorous laboratory after-treatment.

2. Samples can safely be dried in air at temperatures up to 40°C to reduce the mass contribution of water.

3. The sensor is calibrated to a secondary standard derived from a primary standard of 10cc H_2O. The standard applies for a sample shape defined by the 10cc sample pot. Some variation in accuracy will result when other sample volumes are employed: see Table 2.

   Note: It is particularly important that sample containers are accurately filled or calibration will be impaired.

Table 2. Volume correction factors in sample preparation.

Description	Volume ml (cc)	Volume correction factor. Multiply κ by:	Accuracy
10 ml cylindrical bottle	10	1.0	1%
20 ml cylindrical bottle	20	0.5	2%
1′ length x 1′ dia. core	13.27	0.81	1%
23mm cubic sample	7.18	1.4	2%
1′ cube	13.16	0.82	1.5%

When using an unusual size of sample pot, see Centring for guidance on centring.

6.6. Sample Holder Effects

Note: Only sample containers constructed in electrically insulating materials should be used with this sensor.

Note: When operated on the x0.1 range, the diamagnetic contribution (-ve sign) may become significant due to the material of the sample holder. This should be measured separately for an empty container, and the value subtracted from subsequent readings.

i.e. $R_{sample} = R_{meas} - R_{container}$

6.7. Mass and Volume Specific Measurements

The density of most sample materials will be their bulk density. Due to their granular nature and the inclusion of air, this will almost always be less than the 'true' density.

Except in the case of rock samples, conversion from mass to volume units is not possible unless the true density can be established by, for example, compacting the material to a solid at great pressure.

6.7.1. Mass Specific Measurements

The sensor is calibrated for a sample mass of 10g. Mass specific measurements are the preferred method of expressing measurements using this sensor. For dry materials, and for materials of unknown density, this provides the most useful measurement because simple weighing of the material is all that is required. Where sample mass departs from calibration mass the corrected value will be:

χ = measured value x calibration mass/sample mass

Therefore it will be usual to weigh the samples carefully prior to taking measurements.

Example: cal. mass = 10g., sample mass = 12g. $\chi_{true} = \chi_{meas.}/1.2$

6.7.2. Volume Specific Measurements

Where comparison only between identically prepared samples is required, or where it is not desired to dry out wet samples, then 'volume' susceptibility can be recorded directly. Where sample volume departs from calibration volume, the corrected value will be:

κ = measured value x calibration volume/sample volume. (See Table 3 below.)

6.8. Taking Measurements

At this stage the samples should have been correctly labelled and weighed, and the operator should be familiar with the calculations given in the previous section.

Note: Time should have been allowed for the samples and sensor to thermally equilibrate to room temperature.

Correctly position the sensor, and if possible immobilise it on the bench using bench recesses. Connect up, switch on, and allow a 10-15 minutes warm-up time before taking measurements.

If dual frequency measurements are to be performed on a batch of samples then they should all be measured first at one frequency, then at the other. This avoids rapid switching between HF and LF ranges with insufficient settling time between range selections.

6.8.1. Sample Insertion Procedures

To insert a sample, first raise the moving platen using the pillar on the top of the sensor. Position the sample accurately within the recesses of the platen, and lower the sample into the sample cavity to perform a measurement.

> **Note:** When performing zero or blank measurements on the x0.1 sensitivity range, the platen must be in the lowered (resting) position to eliminate the possibility of errors arising from its diamagnetism.

6.8.2. Selecting the Measuring Range

Choose one or two samples from the batch to be measured and obtain, if possible, the typical batch susceptibility value using the x1 range. If the value obtained is less than 20 then the entire batch should be measured using the x0.1 measurement range on the MS2 meter. This is particularly important if the coefficient of frequency dependency is of interest.

> **Note:** When using the x0.1 range, the measurement procedures for drift cancellation that are described in Taking Measurements should be adopted.

> **Note:** Some highly susceptible samples may saturate the MS2 meter, which is designed primarily for weakly magnetic sediments. However, excellent accuracy can be obtained with this sensor by reducing the sample quantity and then applying volume or mass corrections.

6.9. Calibration Notes

The sensor is calibrated using a cylindrical 10 ml sample of water where:

$\chi_{vol}(H_2O) = -0.719 \times 10^{-6}$ CGS

$\chi_{vol}(H_2O) = -0.903 \times 10^{-5}$ SI

Note: Use only distilled, de-ionised water.

Note: Values obtained for other sample sizes will be in proportion to the sample volume.

7. MS2C Core Scanning Sensor

Figure 6. MS2C core scanning sensor.

Key fo Figure 6

1. TNC connector for connection to MS2 meter

7.1. General Description

The MS2C sensor is a core sensor with a large aperture through which to feed the sample (See Figure 6). The aperture is centred within the sensor coil, which has a diameter 8mm greater than that of the aperture. The full range of diameters available is given in the product brochure.

The MS2C is designed for volume susceptibility measurements of sediment, peat or soil cores, made in plastic, Perspex or similar non-magnetic tubes, trays or liners. The high spatial resolution of the sensor permits cores to be logged at intervals down to circa 20mm.

The sensor can be mounted either on a vertical or horizontal surface. Where it is necessary to preserve the water sediment interface, e.g. in lake cores, horizontal logging is preferred.

> **Note:** For highest resolution and sensitivity, select a sensor with a loop diameter approximately 5mm larger than the core.

A manual core conveyor is available for use with the MS2C.

7.2. Operating Instructions

Note: Select a suitable site away from any possible sources of electromagnetic interference.

Note: Avoid situations where the sensor might be subject to large temperature fluctuations or direct heating by the sun's rays.

Switch on the instrument and allow ten minutes settling time before commencing measurements.

7.2.1. Calibration Check

A calibration check core is provided. The serial number of the MS2C sensor appears on the calibration core supplied. The value for the core, when used with the specified diameter sensor, is printed around the middle of the core.

The stability of the sensor over time has been shown to exceed that of any core material which might be used routinely to check the calibration. Therefore, the core should be used only to identify when some catastrophic calibration error has occurred. If the sensor is within its factory set calibration then the value obtained should be within 5% of the value printed on the core.

7.2.2. Calibration Notes

Appendix 2 provides calibration graphs that may be helpful when:

- estimating true values of susceptibility (χ_{vol}) for narrow strata
- compensating for end of core effects
- compensating for different core diameters.

When taking prolonged core logging sequences, a blank or 'air' value should be obtained before and after logging. These values are used to obtain a base line correction when plotting the results. Any drift can be assumed to have been linear up to 30 minutes.

8. MS2E High Resolution Surface Scanning Sensor

Figure 7. MS2E high resolution surface scanning sensor.

Key to Figure 7

1. Ceramic enclosure containing sensing area
2. TNC connector for connection to MS2 meter

8.1. General Description

The MS2E sensor is a surface sensor that can be held by hand or fixed into a core measurement system. The sensing surface is at the end of a ceramic tube, which is mounted on a metal enclosure that houses the electronic circuitry (See Figure 7). The sensing surface should be held in contact with the sample during use. The coil itself is elliptical in shape, giving an improved spatial response. The user should therefore be aware of the sensor orientation, denoted by two black marks on either side of the tube.

The MS2E sensor is designed to perform high resolution measurements of magnetic susceptibility along flat surfaces that have a roughness less than 1mm. Each sensor is individually calibrated to measure true χ_{vol} when measured against a flat surface greater than 10mm depth, and also individually calibrated to compensate for temperature induced drift. The sensor connects directly to the MS2 meter via a TNC-TNC coaxial cable that can be up to 30 metres in length.

The sensor and calibration sample are supplied in a polycarbonate, foam filled box.

8.2. Characteristics

8.2.1. Spatial Response

The response to magnetic material within the vicinity of the sensing area, when measured in the plane of the sensor, shows a rectangular profile with a long axis and a short axis. The long axis direction is marked on the circumference of the ceramic enclosure and the direction is also shown symbolically on the sensor label. The rectangular response permits two modes of operation.

- With the long axis parallel to narrow strata, the maximum spatial sensitivity is obtained for detailed measurements.
- With the long axis perpendicular to the strata, the measurement is integrated over a longer interval and an average value is obtained.

A detailed description of the spatial response is shown in Figure 8.

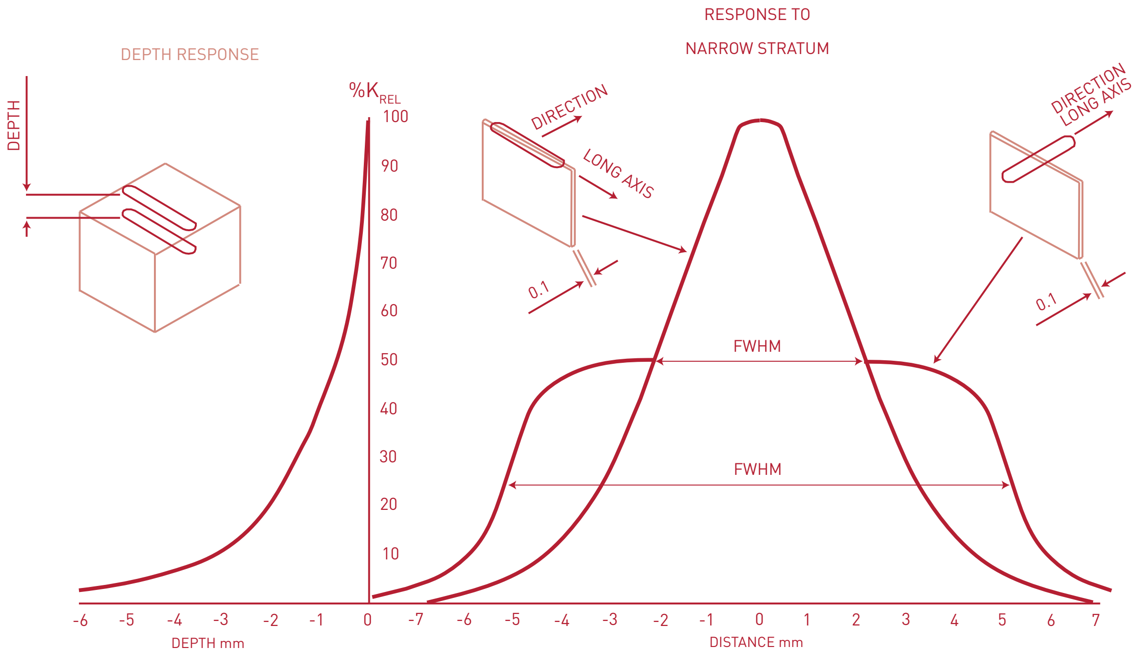

Figure 8. MS2E response characteristics.

Two response characteristics are given:

1. **Response to narrow stratum (in the plane of the sensor).** This shows the full width at half maximum (FWHM) response to be circa 11.5mm with the long sensing axis perpendicular to the stratigraphy, and circa 3.8mm with the long sensing axis parallel to the stratigraphy.
2. **Depth response (normal to the plane of the sensor).** This shows the rate at which the relative response falls off with depth below the surface of the sensor. The response is reduced by approximately 50% at a depth of 1mm.

This shows the rate at which the relative response falls off with depth below the surface of the sensor. The response is reduced by approximately 50% at a depth of 1mm.

8.2.2. Conductivity

> **Note:** Measurement of conductors by the sensor is restricted to those which are relatively poor, or are in shapes which do not form a conductive loop.

This is because the sensor's relatively high operating frequency of 2kHz can generate eddy currents within the conductor, which in turn can cause inaccuracies in the susceptibility measurement. If a good conductor forms a conductive loop, is larger than the FWHM outline and is more than 0.2mm thick, then apparent negative susceptibility values will be measured.

> **Note:** For this reason cores cannot be measured in split aluminium cladding or trays.

8.2.3. Calibration

The sensor is calibrated to read true volume susceptibility where the sample is effectively infinitely large. The value χ_{vol} displayed on the MS2 on the x1 and CGS range is therefore equivalent to that which would be obtained for 1cc, and is therefore equal to χ_{vol} x 10^{-6} CGS.

For further guidance on dimensional systems, refer to MS2B Dual Frequency Sensor.

A calibration sample is provided and should be used periodically to check that the sensor is working correctly.

> **Note:** Never expose the calibration sample to high magnetising fields as these can alter the calibration value. Keep the sample with the sensor at all times.

> **Note:** The correct face of the calibration sample must be aligned with the MS2E sensor face. This is its black face, which is the actual sample material.

> **Note:** The black lines either side of the calibration sample label should be orientated with the marks on the MS2E sensor head that indicate its long axis

Figure 9 shows the correct position of the calibration sample aligned with the MS2E sensor face. The calibration label is uppermost so that the black sample face is aligned with the sensor face.

Figure 9. MS2E calibration sample: correct orientation.

> **Note:** Figure 9 is for illustration of the sample orientation only, when the cable is attached to the sensor it will be easier to measure with the MS2E held in a different position.

8.3. Operating Instructions

This sensor is designed for measuring the susceptibility of split cores. The following describes the method of obtaining measurements by hand, both in the field and laboratory.

> **Note:** Automatic core logging systems are also available, together with data logging software.

8.3.1. Connecting Up

Connect the MS2E sensor to the MS2 meter via the supplied TNC-TNC coaxial cable. Select the desired operating range on the MS2 meter. After a 10 minute warm-up time, the sensor will be ready to take measurements.

8.3.2. Taking Measurements

The sensor is zeroed to 'air' by pressing the 'Z' button. When the zero period is completed, gently place the sensor against the surface to be measured and press the 'M' button.

> **Note:** During the zeroing period the sensor should be raised at least 2cm above the measurement surface.

Prior to use, a measurement of the calibration sample should be made to ensure that the sensor is working correctly.

8.3.3. Siting the Sensor

Choose a suitable site for the measurements.

> **Note:** Measurements of cores should only be performed on a non-conducting surface such as a wooden bench. Although the sensor takes measurements only in the vicinity of the probe surface, its very high sensitivity makes it susceptible to the influence of large electrical conductors or magnetic materials at several centimetres from the probe.

> **Note:** As a precaution, take measurements at different points over the surface of the bench and at different heights above it to check its suitability.

> **Note:** The sensor has good immunity to interference from external electromagnetic sources. However, avoid operating it near to electrical machines, transformers etc.

8.3.4. Preparing the Core

Prepare a soft sediment core, suitably clad and stabilised in a suitable cradle, by covering it with thin PVC film. The film will prevent contamination of the sensor measuring surface and therefore prevent errors from this source. Kitchen film has a thickness of approximately 0.02mm and the reduction of the scale factor due to this distance can be ignored. If a thicker film is used then allowance should be made for the reduction in the scale factor. For example, at 0.05mm, values must be multiplied by 1.04 to correct for this reduction.

Figure 10. Using a non-magnetic ruler with MS2E sensor.

A non-magnetic (plastic) ruler (Figure 10) can be fixed or supported along the core to gauge the measurement interval, which might typically be 5cm. For closer measurement intervals, e.g. 3mm, it may be more convenient to prepare a marker tape, stepped off and numbered for each measurement point.

8.3.5. Core Logging

> **Note:** Allow the core and sensor to reach the same temperature before attempting measurements.

After zeroing to 'air', obtain the first measurement. Then move on to the next point and take a second measurement. Check the baseline drift by performing a measurement to 'air'. If the drift level is unacceptable then further time for temperature equilibration should be allowed.

Five or so measurements should normally be possible before the need to re-zero. Drift compensation is accomplished automatically using Multisus software.

The choice of orientation of the sensor relative to the core will depend on whether detailed examination of core lamination is to be attempted or not.

8.4. Care of Sensor

⚠ **Caution:** The sensor is ruggedly constructed. However, the sensing surface is constructed of a very thin layer of alumina (aluminium oxide) which can be fractured if it receives a heavy blow from a sharp object. Therefore, every precaution should be taken not to drop the sensor and, when not in use, it should be stored together with the calibration sample in the box provided.

Caution: The sensor should be cleaned only with weak detergent and water, should this be necessary.

9. MS2 Probe Handle for Use with Probes Type MS2D and MS2F

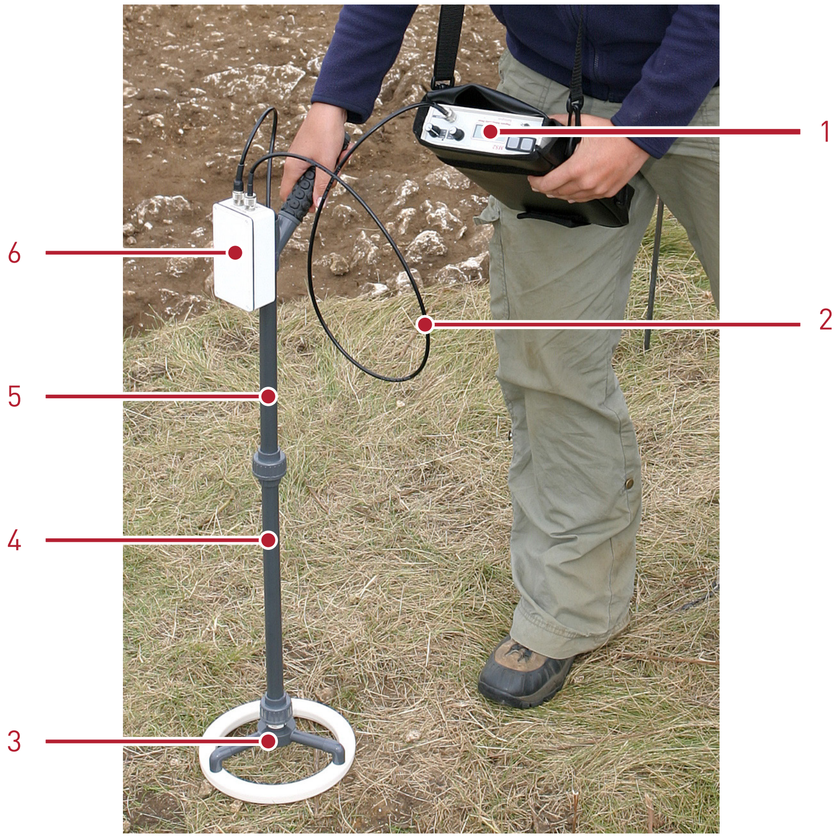

Figure 11. MS2 probe handle for use with probes type MS2D and MS2F

Key to Figure 11

1. MS2 meter
2. TNC coaxial cable
3. Probe
4. Lower extension tube
5. Upper section, with handle
6. Electronics module

9.1. General Description

The MS2 probe handle is for use with the MS2D and MS2F field probes, it is not compatible with any other sensors. The handle provides the measurement electronics for the sensors, as well as giving extra reach to the user when taking measurements.

The handle comprises an upper section, which includes an electronics module, and a lower extension tube. Correct connections are clearly marked on the electronics unit.

The probe is connected to the handle electronics module via the supplied 50Ω TNC-TNC cable which passes up the inside the tubular parts and emerges at the top through a liquid tight rubber gland. If required the cable can be retracted to facilitate connection of a probe to the top section of the handle alone.

The probe cable can be replaced by removal of the rubber gland and a replacement part fitted.

The handle is submersible in water up to the electronics unit (0.6 metres). Extension tubes can be provided for a limited increase in length.

Caution: Probe types MS2D and MS2F must be used in conjunction with the handle. Accidental direct connection of a probe to the MS2 meter will result in excessive current drain but will not cause permanent damage.

10. MS2D Probe

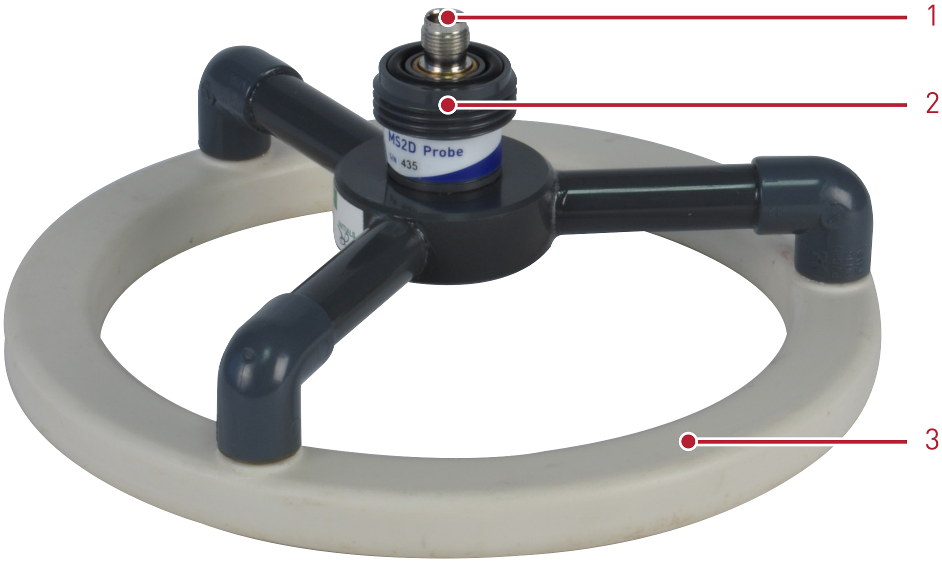

Figure 12. MS2D probe.

Key to Figure 12

1. TNC coaxial cable connector
2. Screw-in connection to MS2 handle
3. Sensor loop

10.1. General Description

The field survey MS2D is a circular sensor, with a large effective measuring volume. It is intended for use on flat surfaces where pinpoint accuracy is not required. It is used with the MS2 probe handle and will not function without it.

The probe is specially constructed to tolerate the moderate stresses encountered when it is pressed against surfaces. It is designed to perform equally well on land or when submerged in water.

The sensor provides a method for surveying and plotting the concentration of ferromagnetic minerals in the top circa 60mm of the land surface. It is especially well suited for use on plane surfaces such as beaches and poorly vegetated slopes.

> **Note:** Surface roughness in the form of tussocky vegetation, or variable thickness of organic leaf litter, limits the accuracy of the MS2D probe. The MS2F probe may be more appropriate for these conditions.

10.2. Calibration Notes

This sensor is calibrated to read 0.5 χ_{vol} on rough soils and will give about 0.75 χ_{vol} on smooth surfaces.

11. MS2F Probe

Figure 13. MS2F probe.

Key to Figure 13

1. TNC coaxial cable connector
2. Screw-in connection to MS2 handle
3. Sensing area

11.1 General Description

The MS2F probe is the second probe that is used with the MS2 probe handle. It is a point sensor, with a much smaller effective volume than the MS2D, allowing more accurate measurements over rougher surfaces. It is light and small enough to penetrate surface vegetation, or to allow logging of soil profiles and geological sections and exposures. It can be used either with the upper section of the MS2 probe handle alone (the cable can be retracted and coiled up at the top of the handle) or with the extension tube for ground level use.

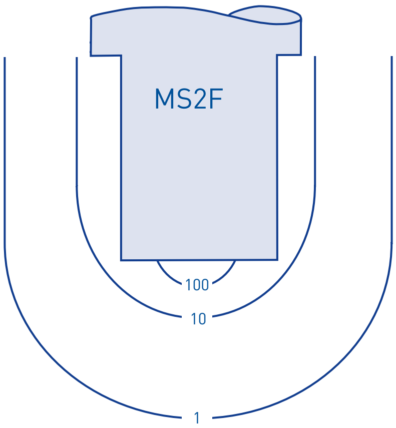

Figure 14. Relative variation in sensitivity around the MS2F probe.

The probe provides a series of comparable and repeatable contact readings.

The value of the readings obtained will be approximately 0.5 χ_{vol} with the sensor placed against a flat surface and 1 x χ_{vol} when buried up to the shoulder. See Figure 14 for the variation in sensitivity around the MS2F probe head.

Note: The whole of the sensor end must be placed against a flat surface for accurate readings.

11.2. Operating Instructions

11.2.1. Connecting the Probe to the Handle Electronics Unit

1. Inspect the 'O' ring seals on the handle and extension tube to ensure that they are in contact.

2. Correct connections are clearly marked on the electronics unit. Accidental direct connection of a probe to the MS2 unit will result in excessive current drain, but will not cause permanent damage. Connect the probe to the handle electronics module using the supplied 50Ω TNC-TNC cable which passes up the inside of the tubular parts and emerges at the top of the handle through a liquid tight gland.

3. If required, the cable can be retracted to facilitate connection of the probe to the top section of the handle alone.

11.2.2. Taking Measurements

1. Switch on and allow a 10 minute warm-up time.

2. Select the x1 sensitivity range on the front panel of the MS2.

3. With the sensor at least 100 cm away from the material to be measured, press the 'Z' button on the front panel of the MS2 to zero the instrument.

4. Place the probe in firm contact with the material to be measured and take a reading.

   Note: For materials with susceptibility values less than 5-10 CGS (10 on the LCD readout), it will usually be necessary to zero the instrument between each reading.

12. MS2G Single Frequency Sensor

Figure 15. MS2G single frequency sensor.

Key to Figure 15

1. TNC coaxial cable connector
2. Calibration sample
3. Height setting screw
4. Sample measurement cavity
5. Retaining nut

12.1. General Description

The MS2G sensor type is intended for use with a 1cc volume sample vial. It comprises a metal enclosure containing the electronic circuitry, at the end of which is mounted a rectangular block containing the measurement cavity.

Connection to the MS2 meter is via the standard TNC-TNC coaxial cable. Samples are inserted into the top of the cavity. An adjustable mechanical stop can be set to centralise the sample material within the measurement zone. This permits a sample volume down to 0.2cc to be used. Markings on the front of the cavity show the position of the measurement zone. The sensor operates at a single frequency. A calibration check sample is provided.

12.2. Setting Up

Choose an operating site well away from sources of electrical and radio interference. The site should also be free from magnetic materials and large non-magnetic sheets of electrically conductive material, e.g. aluminium bench tops.

Note: A reasonably stable room temperature is desirable.

12.3. Sample Height Adjustment

If possible a full 1cc sample container should be used. However, satisfactory measurements are possible with a sample volume of less than 1cc provided the sample material is positioned at the correct height and the appropriate correction factor, given in Calibration, is applied.

Note: For best accuracy, each sample vial should be uniformly filled.

Place the vial in front of the sensor block and gauge the appropriate sample height for which the sample material is symmetrically within the two horizontal lines. Adjust the sample height setting screw, located below the cavity, to achieve the same sample position for when the sample is within the cavity. Tighten the locking nut. The adjustment mechanism may be removed by undoing the brass retaining nut.

12.4. Calibration

The measuring zone is 5mm in height and senses only over a small portion of the sample. For this reason the sample appears infinite and volume susceptibility units apply.

The density of the sample material should be controlled, wherever possible, by compressing the sample material in the bottom of the vial. The sample may be weighed to establish the density. The tare weight of the vial is 0.69 g.

The vial has a constant internal area of 0.33 cm^2, so the fill height and volume are linearly related. The vial has a diamagnetic value of -0.55×10^{-6} CGS which is constant at all practical measurement positions. This value (or its SI equivalent) should be subtracted from the measured value to give the correct value.

12.4.1. Fill Height/Volume Correction Factors

Table 3. Fill height/volume correction factors.

FILL HEIGHT (mm)	VOLUME (cc)	CORRECTION FACTOR
5.0	0.165	1.46
5.5	0.1815	1.40
6.0	0.198	1.35

6.5	0.2145	1.295
7.0	0.231	1.26
7.5	0.247	1.214
8.0	0.264	1.185
11.0	0.33	1.098
16.0	0.5	1.032
21.0	0.66	1.015
Full	1.0	1.0

Multiply measured value by the correction factor.

12.5. Taking Measurements

Allow circa 5 minutes settling time before taking measurements to allow the sensor to warm up.

> **Note:** Samples should be allowed to equilibrate to room temperature prior to attempting measurements, this step is especially important when using the x0.1 range.

Check that the sensor is functioning correctly by performing a calibration check using the 1cc check sample located on the side of the sensor. The value obtained should be within 1% of the stated value.

When measuring on the x1.0 range, first press 'Z' and measure ‘air’. Then insert the vial and obtain its value by pressing 'M'.

When measuring on the x0.1 range, take three measurements by pressing 'M': first to ‘air’, then with the sample, and then to ‘air’ again. Record the three values obtained. The drift corrected value will be equal to the sample value minus the average of the two ‘air’ values.

13. MS2H Down-Hole Probe

Figure 16. MS2H down-hole probe.

Key to Figure 16

1. TNC coaxial cabler connector
2. Screw conenctor to extension tube
3. Probe head
4. Centre of measurement
5. Markings engraved on probe at 10mm intervals

13.1. General Description

The MS2H down-hole probe is designed for sub-surface measurements of volume magnetic susceptibility of strata in a nominal 25mm (1') diameter auger hole.

The probe is calibrated for a 22mm hole, but can be used on any hole diameter from 22mm to 25.4mm. (See Table 4 below for scaling factors.)

The sensor consists of a probe head attached to a tube, which is lowered into the test hole. The head and tube are graduated to allow the sensor depth to be determined accurately. As the probe is lowered into the hole, additional extension tubes can be attached to allow the probe to be inserted to any practical depth.

The probe and tube have threaded couplings with waterproof seals.

The sensor electronics are integrated into the probe head, which is directly connected to the MS2 meter. The connecting cable is routed through the hollow extension tubes. The sensor is supplied with cables as described in the product brochure.

The sensing coil position is indicated by the lowest graduation mark ('0') on the probe head.

13.2. MS2H Equipment List

The MS2H probe is supplied with:

- 1 x MS2H probe head
- 1 x 0.9m lower extension tube (attaches to probe head)
- 1 x 1.0m extension tube
- 1 x 5m cable (or 10m if additional extension tubes are purchased)
- 1 x rubber boot for cable protection and shower proofing
- 1 x calibration sample
- 1 x pack of spare 'O' rings

13.3. Operating Procedure

13.3.1. Probe Assembly

1. Connect the cable to probe head.
2. Thread the free end of the cable through the short (0.9m) extension tube.
3. Connect the probe head to the short extension tube by screwing together.

    Note: To avoid twisting the cable whilst doing this, or when adding extra tubes, hold the probe head still and only rotate the extension tube.

    Caution: Do not over-tighten or the sealing ring may be damaged. Light-hand pressure is sufficient. The assembly is correctly tightened when the sealing ring is just clamped between the tubes, and the graduated scale on the probe head and the tube are exactly aligned.

4. If not already fitted, feed the cable through the threaded end of the rubber boot, and screw the boot into the extension tube.
5. Connect the cable to the MS2 meter and switch on.

13.3.2. Assembly for Deep Holes

If the hole under investigation is deeper than ~1m then additional extension tubes should be added at step (3).

Note: For holes deeper than 3m, to avoid having a very long sensor assembly above ground, thread all the required tubes onto the cable at the start but do not connect them all together. Connect each tube into the assembly in turn as the probe is lowered into the hole.

13.3.3. Taking Measurements

13.3.3.1. Measurement Range

Note: Set the meter to the 1.0 range for measurements with the MS2H probe.

Note: The probe is not intended to be used on the 0.1 high resolution setting.

13.3.3.2. Temperature Drift Effects

The sensor is compensated to minimise temperature variation, but some drift is inevitable. For best results, allow the probe temperature to stabilise at the test hole temperature before commencing readings.

Note: Allow at least 30 seconds settling time for every °C difference between initial probe temperature and test hole temperature.

In addition, to allow adequate settling time, take 'air' readings as the first and last measurements, and compensate for any drift during the measurement run.

Note: If the Multisus or Bartsoft PC softwares are being used then the readings can be corrected automatically to include drift compensation at the end of the run.

13.3.3.3. Using Multisus Software

Multisus software for a Windows PC simplifies use of the MS2H probe by automatically logging data from the MS2 meter and correcting readings for temperature drift. The software is provided with the meter.

Note: Multisus v2.4 is needed or later for full support of the MS2H down-hole probe.

Note: Bartsoft is a newer software that can also be used with the MS2H.

A separate manual for using Multisus is provided with the purchase, giving full details of the features for the MS2H probe. A summary of the measurement procedure is as follows.

1. Follow the earlier procedure to assemble the probe and connect to the meter. Connect the meter to the PC, start the Multisus program and ensure the meter and PC are communicating correctly (see Multisus manual for details).
2. Using the file menu, select a new data file for the MS2H probe.
3. Select SI or CGS, and 1.0 range on the MS2 meter.

Note: For the MS2H probe, the 0.1 range is not recommended.

4. Enter setup data for measurement depth interval, drift warning level and auger hole reference, and select SI/CGS and 1.0/0.1 range to match the meter settings.

5. Insert the probe into the test hole and allow time for probe temperature to settle. (See Temperature Drift Effects.)

6. Remove probe from hole, clean probe, and hold in air, clear of the ground and surrounding objects. Click on OK to perform the first 'air' zero reading.

7. Insert the probe into the hole so that the lowest (sensing) graduation mark is at ground level (i.e. depth = 0mm) and click Measure (or press F9) to perform a reading. Hold the probe steady until the meter beeps to indicate that the reading has been taken.

8. Lower the probe by the desired reading depth interval (using the graduated depth scale on the probe/tube) and click Measure to take the next reading. Continue this process until all readings to the desired depth have been recorded. Readings can also be taken as the probe is extracted from the hole.

9. Click on Apply Corrections. You will be prompted to remove the probe from the hole, clean it, and perform another 'air' zero reading. The software will then automatically calculate zero drift over the time of the measurement run and apply corrections based on the time of each reading (a linear zero drift with time is assumed).

10. Data can be saved to file and/or plotted (see Multisus manual for details).

13.3.3.4. Using the MS2H Probe Without a PC

It is possible to use the probe and meter without a PC, but all readings must be made and zero drift corrections applied by hand, as there is no logging facility within the MS2 meter.

The procedure is as follows.

1. Follow the procedure above to assemble the probe and connect to the meter.

2. Select SI or CGS and 1.0 range on the meter.

   Note: For the MS2H probe, the 0.1 range is not recommended.

3. Insert the probe into the test hole and allow time for probe temperature to settle. (Temperature Drift Effects.)

4. Remove probe from hole, clean probe, and hold in air clear of the ground and surrounding objects. Press the 'Z' button to zero the instrument.

5. Insert the probe into the hole so that the lowest (sensing) graduation mark is at ground level (i.e. depth = 0mm) and press 'M' to perform a reading. Hold the probe steady until the meter beeps to indicate that the reading has been taken. Record the reading against 'depth = 0' on your results table.
6. Lower the probe by the desired reading depth interval (using the graduated depth scale on the probe/tube) and press 'M' to take the next reading. Record the reading on your results table.
7. Continue this process until all readings to the desired depth have been recorded.Readings can also be taken as the probe is extracted from the hole.
8. Remove the probe from the hole, clean it, and perform a final reading in air. Record this reading as the end of measurement zero drift. For best accuracy results, you should now calculate a drift correction for each reading, assuming that the 'air' zero reading has drifted linearly with time from 0 (at the start) to your final 'air' reading.

13.4. Checking Calibration

A sample is provided to allow an approximate check on the calibration of the probe.

To use the sample, select 1.0 range and SI on the meter.

Put meter toggle switch to the centre position, hold the probe in air clear of other objects, and press the 'Z' button to zero the meter.

If meter correctly zeroes, put the toggle switch to the left (M) position. The meter will start continuous measurements. Insert the probe into the calibration sample and slowly vary the depth to obtain a maximum reading. The maximum reading should be within the ± tolerance range printed on the sample label.

13.5. Scaling Factors

The sensor is calibrated to display volume magnetic susceptibility (χ_{vol}) for a 22mm hole.

For larger hole diameters, the displayed value will be lower than true χ_{vol}. An approximate value of χ_{vol} can be obtained by multiplying the displayed reading by the scale factor in Table 4.

Table 4. Scaling factors for χ_{vol}.

Hole diameter (mm)	Scale factor * for χ_{vol}
23.0	1.000
24.0	1.418
25.4	1.739
* Average value determined by tests on 20 samples.	

14. MS2K High Stability Surface Scanning Sensor

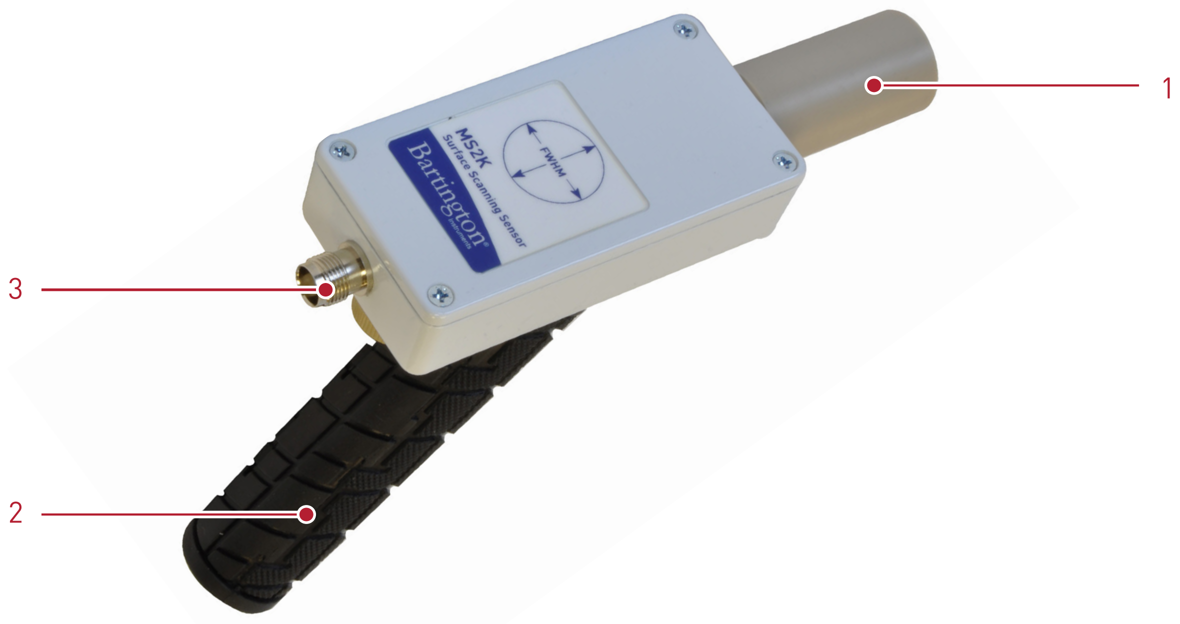

Figure 17. MS2K high stability surface scanning sensor.

Key to Figure 17

1. Sensing area
2. Pistol grip
3. TNC axial cable connector

14.1. General Description

The MS2K sensor is designed to provide highly repeatable measurements of the volume magnetic susceptibility of moderately smooth surfaces. Key applications are description of magnetic stratigraphy and identification of horizons. Characterisation of outcrops and logging of split cores are also possible.

Although similar in design to the MS2E, the MS2K coil shape is more circular, offering a greater depth of penetration, with slightly lower spatial resolution.

Each sensor is individually calibrated to measure true χ_{vol} when measured against a flat surface greater than 10mm depth, and also individually calibrated to compensate for temperature induced drift.

The sensor is housed in a lightweight enclosure and is fitted with a pistol grip. The active region of the sensor is 25mm in diameter at the tip of a cylinder and is protected by a wear-resistant ceramic disk. The isotropic 25mm diameter response pattern gives good surface integration without sacrificing resolution, as shown in Figure 18.

The sensor connects to the MS2 meter via the supplied TNC-TNC 1 metre length co-axial cable. Measurements are accomplished to 1 x 10^{-6} CGS in one second on the x1.0 range on the MS2 meter.

> **Note:** Do not use this sensor within 100mm of large conductors or magnetic structures. Aluminium clad cores are therefore excluded.

The sensor, calibration sample and cable are supplied in a polycarbonate carrying case.

14.2. Characteristics

14.2.1. Sensitivity

A detailed description of the FWHM response is given in the diagram in the product brochure. The response is reduced by approximately 50% at 3mm depth.

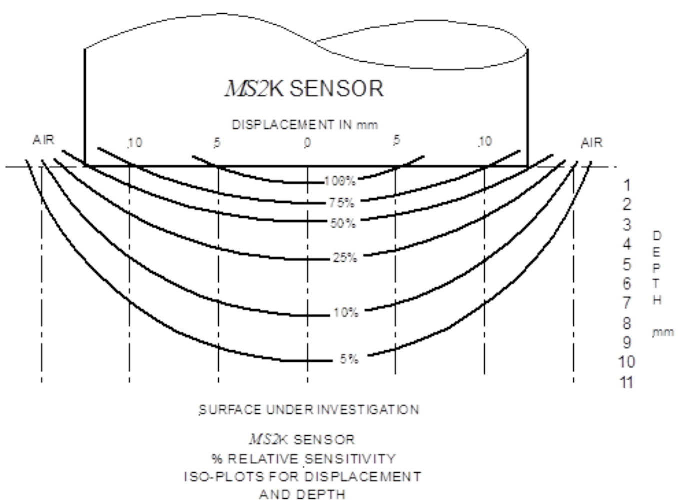

Figure 18. MS2K depth response

14.2.2. Conductivity Effects

A low operating frequency, f, and the ability to be positioned at the point of interest make the MS2K sensor a good choice for the measurement of the magnetic properties of poorly conducting metals, e.g. stainless steel.

The resistivity, ρ, and relative permeability of the specimen, μ_r, will also determine the depth of penetration of the sensor's magnetic field where:

Depth $S = \sqrt{(\rho/\pi\mu f)}$ where $\mu = \mu_0\mu_r$

and is defined as that depth at which the flux diminishes by a factor of $^1/e$ (0.37). From the examples given below it is apparent that at a frequency of 1kHz the skin depth for stainless steel is compatible with measurements performed using the MS2K sensor:

Cu, Ag	S = approx. 2mm
Fe	S = approx. 0.2mm
Stainless steel	S = approx. 14mm

Note that for Fe the high value of mr = 500 accounts for the significantly low value of S, as does the low resistivity of Cu and Ag.

14.2.3. Calibration

The sensor is calibrated to read true volume susceptibility where the sample is effectively infinitely large. The value χ_{vol} displayed on the MS2 on the x1 and CGS range is therefore equivalent to that which would be obtained for 1cc, and is therefore χ_{vol} x 10^{-6} CGS.

For further guidance on dimensional systems, refer to MS2B Dual Frequency Sensor.

A calibration sample is provided and should be used periodically to check that the sensor is working correctly.

> **Note:** Never expose this calibration sample to high magnetising fields as these can alter the calibration value. Keep the sample with the sensor at all times.

14.3. Operating Instructions

14.3.1. Connecting Up

Connect the MS2K sensor to the MS2 meter via the supplied TNC-TNC coaxial cable. Select the desired operating range on the MS2 meter and, after a few minutes warm-up time, the sensor will be ready to take measurements.

14.3.2. Taking Measurements

The sensor should be allowed to acclimatise before taking measurements. Prior to use, always measure the calibration sample to ensure that the sensor is working correctly.

The sensor is zeroed to 'air' by raising the sensor about 20mm above the measurement surface and pressing the 'Z' button. (See figure 18 for the MS2K depth response). When the zero period is completed, the sensor can be gently placed against the surface to be measured and the 'M' button pressed.

Move on to the next point and take a second measurement. Check the baseline drift by performing a measurement to air.

> **Note:** If the drift level in unacceptable then further time should be allowed for temperature equilibration.

> **Note:** Drift compensation is automatically accomplished using Multisus software.

14.3.3. Maintenance

Ensure that the connector is kept clean at all times, and inspect the connecting cable occasionally for signs of wear.

15. MS2/MS3 Susceptibility/Temperature System

The measurement capability of the MS2/MS3 system can be extended to include the measurement of the magnetic susceptibility of materials as a function of temperature. There are five additional items required for this.

1. **Water-jacketed sensor type MS2W:** Magnetic susceptibility sensor, with special cooling and temperature compensation. See MS2W Water Jacketed Sensor.

2. **Furnace type MS2WF:** Heating furnace with an integral temperature display module, internal thermocouple, and external thermocouple socket. See MS2WF Furnace Sensor.

3. **MS2WFP power supply:** Power supply unit for the system, with controls for heating and pump operation, and communication connections to a PC. See MS2WFP Power Supply/Temperature Controller.

4. **A water supply of 2 litres/minute:** Protects sensor from high temperatures of the furnace

5. **A computer (supplied by the user) with an RS-232 serial port running the GeoLab for Windows software:** Software is supplied with the system, for plotting the results in real time.

This equipment can be used to perform magnetic susceptibility measurements on small samples (e.g. soil, rock, powder) over a temperature range from -250 to 850 °C. The system includes everything required to heat samples from room temperature, at a controlled rate. For cooling below room temperature, a facility to cool samples is required (e.g. liquid nitrogen dewar). The measurements can be taken manually, or automatically logged using a PC.

The system name is abbreviated to the “MS2 X/T System”.

15.1 MS2/MS3 Susceptibility Temperature System Cables

The following interconnection cables are provided with the MS2/MS3 Susceptibility/Temperature system:

- MS2WFP to computer (RS-232 serial interface: 9-way ‘D’ type).
- MS2/MS3 meter to MS2WFP (RS-232 serial interface: 9-way ‘D’ type).
- MS2/MS3 meter to MS2W sensor (TNC-TNC coaxial cable).
- MS2WF to MS2WFP (8-way cable: circular multipole type).
- Mains to MS2WFP (mains cable: IEC 3-pole to service outlet as requested).

16. MS2W Water Jacketed Sensor

Figure 19. MS2W water jacketed sensor.

Key to Figure 19

1. TNC axial cable connector
2. Water in
3. Water out
4. Sample cavity

The MS2W has a 30mm internal diameter sample cavity. The highly stable sensing coil and the precision oscillator electronics within the sensor enclosure are cooled by a flow of cold water which completely screens the sensor from extremes of temperature occurring within the sample cavity. The special circuitry compensates for small changes in temperature arising from the influence of the furnace or changes in the cooling water temperature.

The glass cavity is 65mm high x 30mm internal diameter and is painted on the outer surfaces with a special reflecting paint. The sensor can be mounted on a retort stand in any position, but will be vertically orientated when used in conjunction with the furnace. The probe is calibrated to accept a 10cc sample. The operating frequency of 696Hz is chosen to be sufficiently low so that measurements are essentially independent of sample conductivity.

For low temperature measurements the maximum sample diameter of 25mm can be used, in which case it is usual to cool the sample in liquid nitrogen (-196°C) and insert it within the cavity, and record susceptibility changes as the sample recovers to room temperature.

WARNING: The MS2W sensor glass tube may be damaged if a tightly fitting sample is inserted. When making low temperature measurements, use only the recommended sample size and, if other components or objects are to be placed within the cavity, ensure that they will not expand on recovery to room temperature and damage the glass.

WARNING: Catastrophic damage will occur if the MS2W sensor is exposed to temperatures above the ambient temperature without the recommended water flow. The MS2W sensor will also be damaged if the water flow is interrupted when the furnace is operating inside the sensor. A flow indicator is provided to be fitted in the water outlet from the sensor.

WARNING: If low temperature measurements are made as suggested using liquid nitrogen, the operator must take the necessary precautions involved with using liquid nitrogen.

16.1. Calibration Note

This sensor is calibrated to read χ (H_2O for 10cc cylindrical sample). (See Range Selection.)

17. MS2WF Furnace Sensor

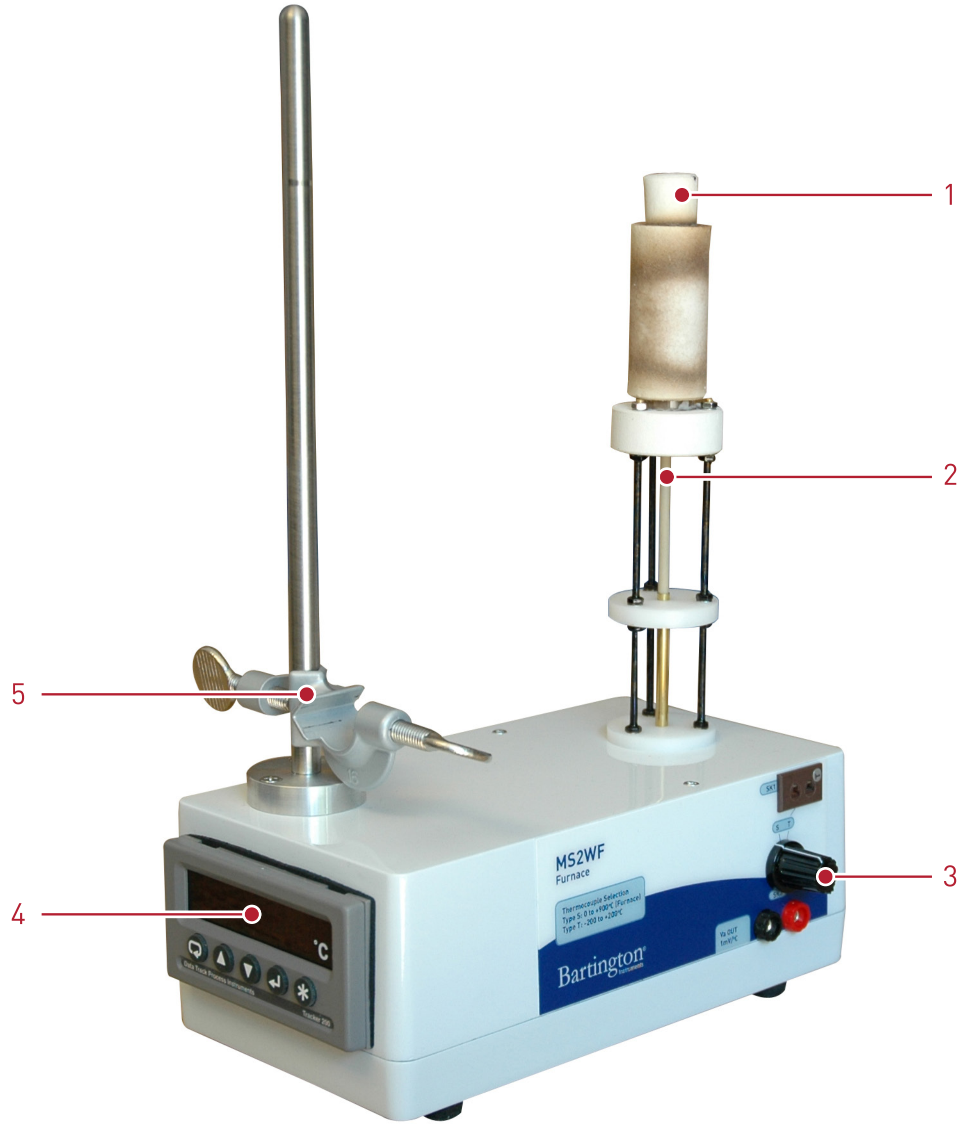

Figure 20. MS2WF furnace.

Key to Figure 20

1. Crucible (silica tube containing heating element)
2. Thermocouple
3. Thermocouple selector switch
4. Digital multimeter (buttons have no function)
5. Retort stand to hold MS2W sensor

This furnace has been specially designed for use with the water-jacketed MS2W probe to facilitate susceptibility/temperature measurements up to 850°C.

It comprises a non-inductively wound platinum wire furnace, with a maximum operating temperature of 900°C and a maximum sample capacity of 15mm diameter. The furnace is mounted on a substantial metal base which contains serial interface circuitry and a digital panel meter (DPM). Temperature information is obtained from either the internal type 'S' thermocouple or an external type 'T' thermocouple. The base includes a retort stand for mounting the MS2W sensor around the furnace (or any other experimental hardware).

Temperature information is available as a 4 digit LED display, 1 mV/°C analogue output and RS-232 compatible serial data for computer interfacing. The panel meter has an RS485 interface and this is converted to RS-232 within the furnace unit.

WARNING: The thermocouples are not electrically isolated and must not be connected to ground potential or errors will occur.

WARNING: The outside surface of the furnace will become hot during measurements and the interior will remain hot for a considerable time after the unit is switched off.

WARNING: The MS2WF furnace is powered by a current-limited low voltage supply. The furnace support pillars carry the current to the furnace and should not be shorted together.

WARNING: The black heatsink on the rear of the MS2WFP will become very hot when the furnace is heating.

17.1. Operation

The base is fitted with a retort stand for mounting the MS2W probe and contains a digital multimeter for temperature indication.

The MS2W probe is mounted on the retort stand such that its sample cavity fits over the crucible on the MS2WF. The switch [3] on the side of the furnace is used to select the appropriate MS2WF thermocouple. The GeoLab software supplied requests the operator to identify the thermocouple in use and communicates this to the meter, which provides the appropriate scaling, cold junction compensation and linearisation.

Note: The meter is pre-set for normal operations and the front panel manual controls should not be used if the equipment is operated with a computer running GeoLab. For stand-alone applications without a computer, the front panel controls should be used to select the thermocouple type to be the same as set by the manual switch on the side of the furnace unit. Bartington Instruments is unable to advise on this latter mode of operation.

The MS2WF furnace and MS2WFP power supply are connected via an 8-way cable for the transmission of data and power.

17.2. Construction

The 17mm internal diameter silica tube is non-inductively wound over a 45mm length with a platinum wire heating element which, when supplied with current, will uniformly heat a sample placed at its centre. Stray magnetic fields within the furnace are extremely small. A 4mm layer of silica fibre insulating material reduces the surface temperature to approximately 100°C max., making the furnace suitable for use within the sensor cavity. The refractory materials used in this furnace are free from magnetic contaminants and contain no asbestos.

Note: The recommended sample size to obtain uniform heating is 15mm diameter x 15mm length.

17.3. Pt/Pt.Rh type 'S' thermocouple

This is housed in a 4mm x 160mm mullite sheath which can be clamped, using a 3mm diameter locking screw, at any height within the furnace.

The sample is placed in close contact with the tip of the Pt/Pt.Rh type 'S' thermocouple. In this way, very accurate temperature measurements of the sample are accomplished.

Note: To minimise the generation of sample thermal gradients, the sample should not come into contact with the furnace wall. The sample should therefore be drilled and mounted on the tip of the type 'S' thermocouple pillar. A hole depth of one third of the sample length is suggested for good thermometry.

Ceramic crucibles with an internal diameter of 13mm and a depression in the base to fit on the thermocouple are supplied with the system for the measurement of granular samples.

Silica fibre insulating plugs are fitted at the ends of the heated section. These are essential for the achievement of high sample temperatures with low thermal gradients, and can be re-made and replaced by the user to maintain good magnetic hygiene.

The furnace is guaranteed to perform to its full specifications for 1000 hours cyclical use. The heating element is cemented into place using caked alumina to tolerate the stresses induced by frequent heating and cooling cycles.

Note: The type 'T' thermocouple is for low temperature measurements and is not recommended for use in conjunction with the furnace.

18. Maintenance of MS2WF Furnace

To maintain good magnetic hygiene and efficient heating, the plugs at the top and bottom of the furnace should be replaced when they appear to become fragile or dirty. Contamination of the furnace can be evaluated by occasionally performing a temperature measurement sequence with no sample in place. In the absence of contamination, no magnetic transition behaviour will be observed.

18.1. Preparation of Plugs

The efficient performance of the furnace depends, to a very great extent, on the quality of the insulation material provided. The insulating material is a low cost, silicate fibre fabric which can be wound into a regular shape.

WARNING: When the furnace is first heated, or first heated after renewing the insulation, the binder material in the insulation is burnt off and produces unpleasant fumes. Some samples may also produce fumes during heating. Ensure good ventilation is provided at all times and avoid breathing the fumes.

Thermal plugs are fitted at the top and bottom of the heated section of the furnace. The thermocouple probe passes through the lower plug.

Plugs should be prepared in the following manner.

1. Cut a 400mm x 30mm strip of the insulating material provided using a ruler and scalpel, and wind into a cylindrical shape. The lower plug should be wound round a 4mm former (e.g. 4mm drill) to provide entry for the thermocouple. The end of the winding should be secured in place with Fortafix Light Grade High Temperature Cement to prevent the plug from unwinding.

2. Push the lower plug down into the furnace until it is flush with the base of the furnace silica tube.

The upper plug need only be pushed in half way whilst performing high temperature measurements and will require frequent replacement.

18.2. Furnace Outer Insulation

This should seldom need to be replaced. If it does, proceed as follows:

1. Remove the old insulation.

Caution: Do not use sharp objects as they may damage the heating element or the furnace tube.

2. Rewind the insulation from a strip of the fabric provided, 500mm x 60mm. It is necessary to burn off the binding material from the silica fabric. To do this, retain the fabric in place with aluminium foil whilst heating the furnace to 800°C.

WARNING: When using aluminium foil, do not allow it to come into contact with the threaded brass support rods which carry current to the furnace.

3. Carefully remove the foil, and the furnace will be ready for use.

18.3. Thermocouple Installation

The type 'S' thermocouple base is clamped by a screw within the furnace assembly. The thermocouple tip can therefore be positioned at the desired height. The centre of the heating zone is 35mm from the top of the silica tube, or approximately 147mm from the top of the furnace base.

19. MS2WFP Power Supply/Temperature Controller

Figure 21. MS2WFP power supply/temperature controller.

Key to Figure 21

1. 10-turn dial
2. Power socket
3. MS2WFP on/off switch
4. Water pump on/off switch
5. Water pump flowmeter sockets
6. MS2WF connection socket
7. PC serial connection socket
8. MS2/3 connection socket
9. Current meter
10. Control switches

This unit performs two basic functions.

1. Thermostatic power control of the MS2WF furnace. It supplies electrical power to the furnace and provides either pre-set thermostatic control of temperature, or slowly varying linear increase or decrease of temperature. The ramp rates can be controlled manually.

2. Routing data transmissions. Serial interface connection between the user's computer, the MS2/MS3 meter and the digital thermometer is via this power supply unit.

19.1. Internal Power Distribution

Filtered mains supply is rectified and smoothed, and supplied to transistors which control the voltage supplied to the furnace. Furnace current is monitored by a meter on the front panel. A DC regulated supply is provided for the internal circuitry. A DC supply is fed to the digital panel meter and associated circuitry, and a precision reference voltage is provided for temperature offset and control purposes.

19.2. Temperature Control

Temperature is controlled in two ways.

1. Temperature is pre-set on the 10-turn dial, thermostatically maintained.

2. Temperature is programmed to increase or decrease with time in a linear fashion at a rate pre-selected on the 10-turn dial.

In both cases, analogue temperature information from the MS2WF is compared to an internally generated reference (proportional), and the resulting error information (integral) is used to maintain the correct temperature.

Temperature rate of change (differential) information is measured to minimise over- and undershoot which could occur when selecting a new temperature. Maximum current is limited to 4A (cold furnace) by a safe operating area monitor. The platinum furnace's high positive temperature coefficient of resistance will limit this current to 3A maximum at elevated temperatures.

19.3. RS-232 Buffer

With a computer, MS2 meter and MS2WF connected to the appropriate connectors, the RS-232 serial data between the computer, the MS2 meter and the MS2WF digital panel meter are routed through the MS2WFP.

The computer transmits characters 'Z' and 'M' which are recognised by the MS2 meter, causing a zero and measure operation respectively. The measurement value is transmitted back to the computer at the end of the measurement period. The computer also transmits data strings which are recognised by the temperature meter and cause it to set the appropriate thermocouple linearization, or take a reading, as required. The meter responds by transmitting an ASCII character string.

The temperature meter has an RS485 interface and a 232/485 converter is used at the temperature meter terminals. The signals from the MS2 meter and temperature meter are output through the same RS-232 connector to the computer.

19.4. Data Format

The temperature and magnetic susceptibility values are transmitted as ASCII character strings which are evaluated by the software.

20. Operating Instructions for Susceptibility/Temperature System

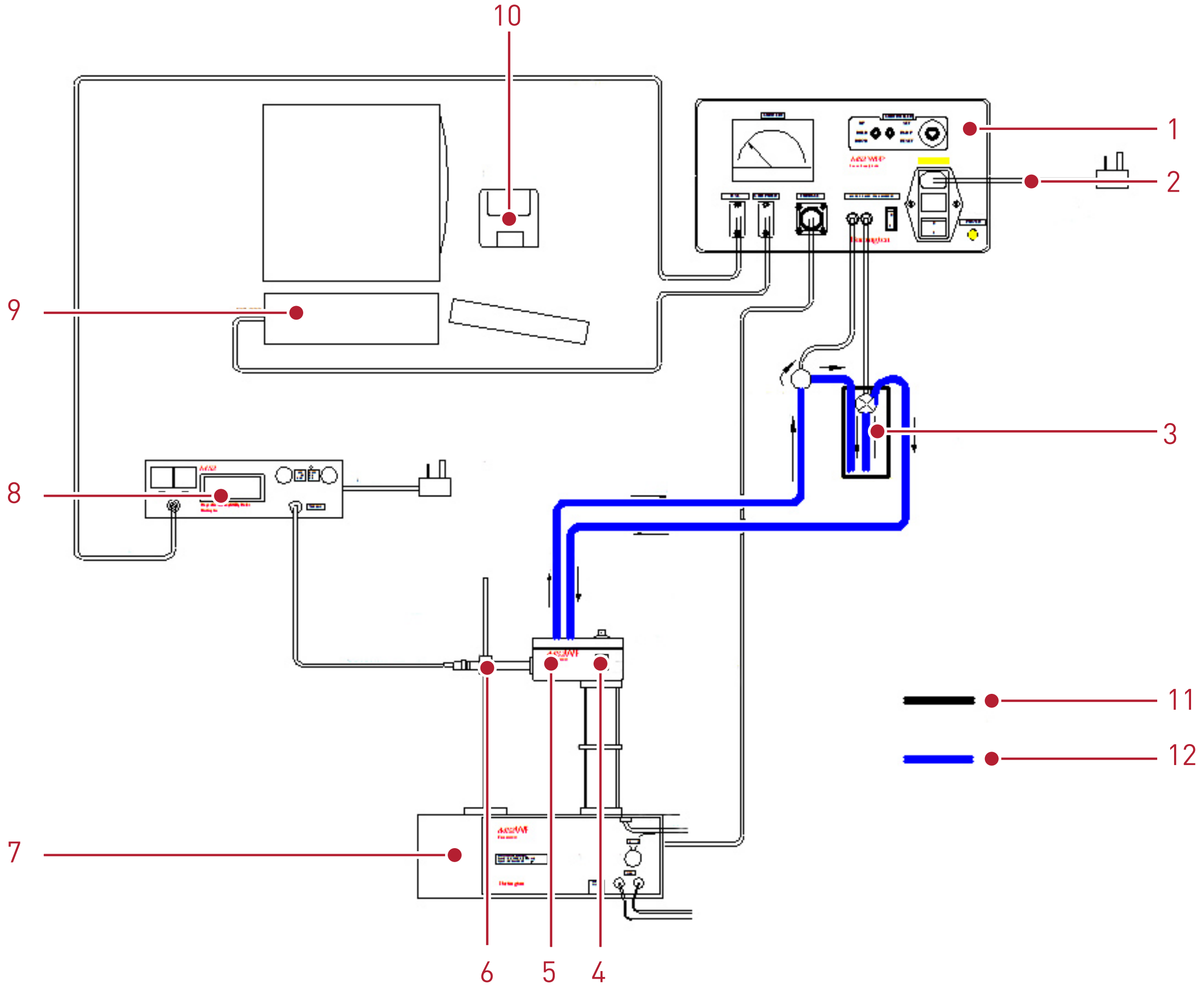

Figure 22. Susceptibility/temperature system.

Key to Figure 22

1. MS2WFP
2. AC line 240/110V
3. Water pump
4. Sample
5. MS2W
6. Clamp
7. MS2WF furnace
8. MS2 meter
9. Computer
10. GeoLab software
11. Cables
12. Water pipe

Note: This section is to be read in conjunction with the operation manual for GeoLab.

Caution: The furnace tube is protected by a transit tube which is retained by a hose clip. Remove this before use carefully to avoid damage to the furnace insulation.

20.1. Setting Up the Equipment

Place the equipment on a suitable non-magnetic bench with access to a mains electricity supply but away from potential sources of electrical noise, e.g. large electric motors. Figure 23 shows the equipment layed out in close formation, from the left: MS2/3 Meter, MS2WF Furnace, MS2W sensor, MS2WFP Power Supply. .

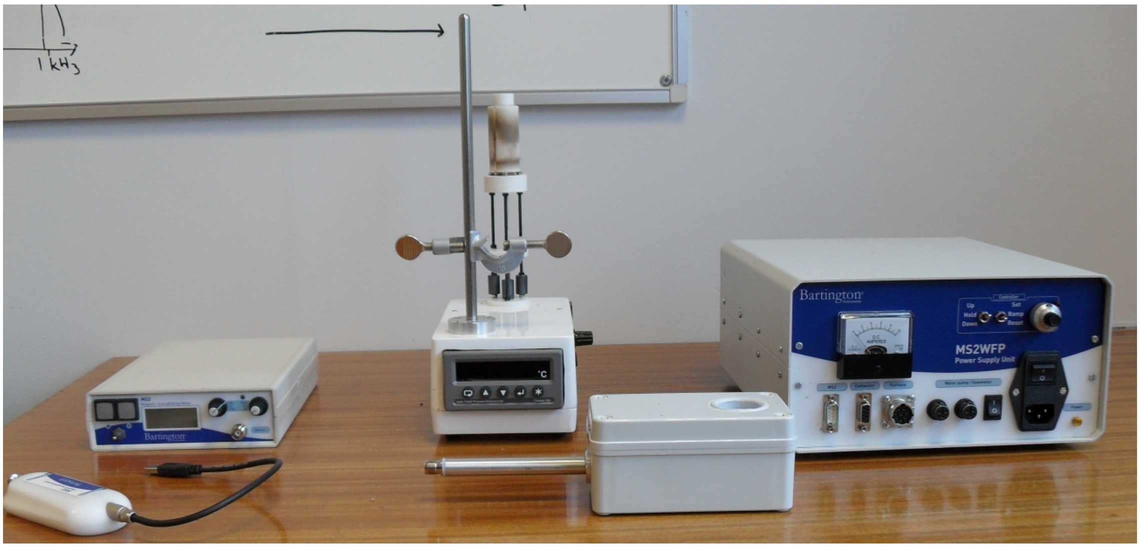

Figure 23. X/T Equipment .

Plug in the mains supply. Connect the silver shielded cable to the MS2WF, the RS232 connections to the computer and MS2/3, and the power connections to the water pump and flow meter. The connections on the MS2WFP are shown in Figure 24 below.

Figure 24. MS2WFP Connections

20.1.1. Mains Voltage Selection

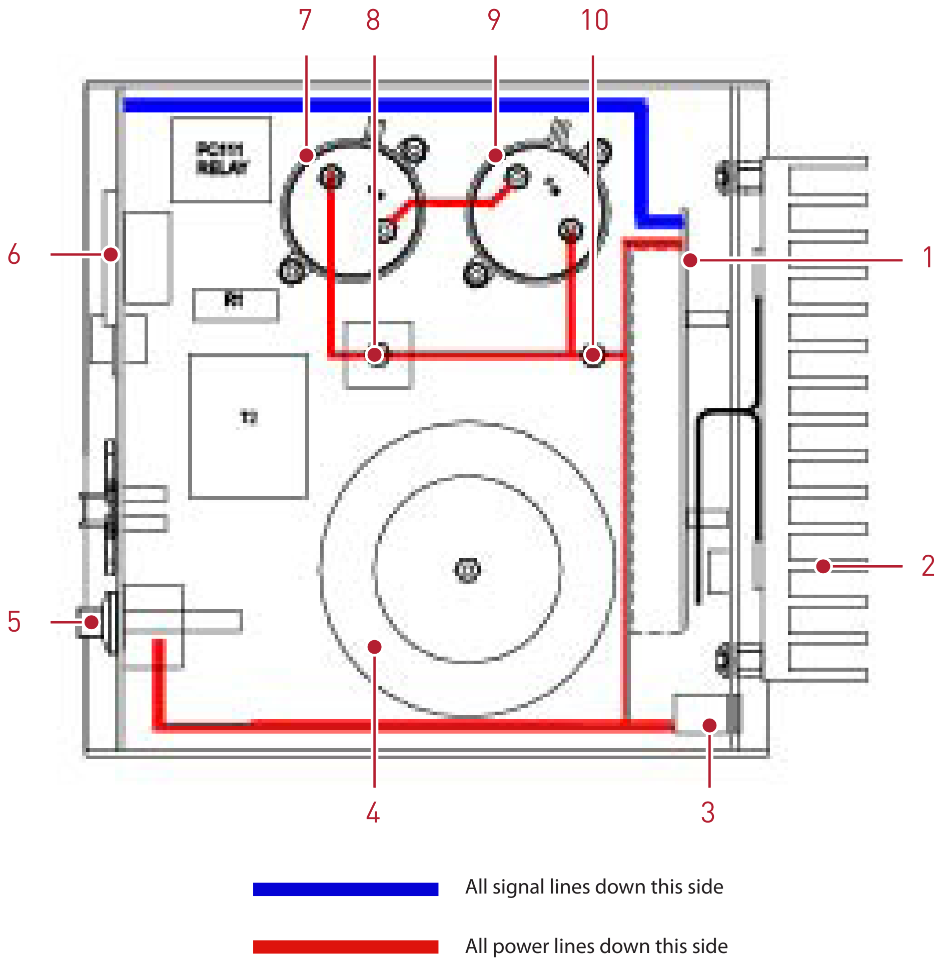

Figure 25. MS2WFP outline drawing and mains voltage selection.

Key to Figure 25

1. PC11
2. Heatsink
3. Voltage selector (110V or 240v)
4. Transformer
5. Controller & power supply
6. Ammeter
7. Capacitor C2
8. Rectifier
9. Capacitor C1
10. Main earth point

Before connecting to a mains electricity supply, check that the MS2WFP power supply is set to the required AC supply voltage. The voltage selection is performed using the voltage selector switch, which is mounted on the bottom left hand side of the rear panel of the power supply unit. This is shown in Figure 26. The selected voltage should be displayed on a label positioned by the power inlet socket. To alter the supply voltage, proceed as described in the figure, always remembering to record the new voltage on the label.

Figure 26. MS2WFP Mains voltage selector Switch.

20.1.2. Water Supply Connection

The closed water cooling system supplied with a reservoir and pump should normally be used. However, in an emergency, the water supply can be derived from the relatively cool sub-surface mains supply. Connect the inlet flow from the water pump to the lower 6mm nipple on the probe type MS2W. Connect the outlet, which should be unrestricted and as short as possible, to the upper nipple.

Figure 27. Water Supply Connections

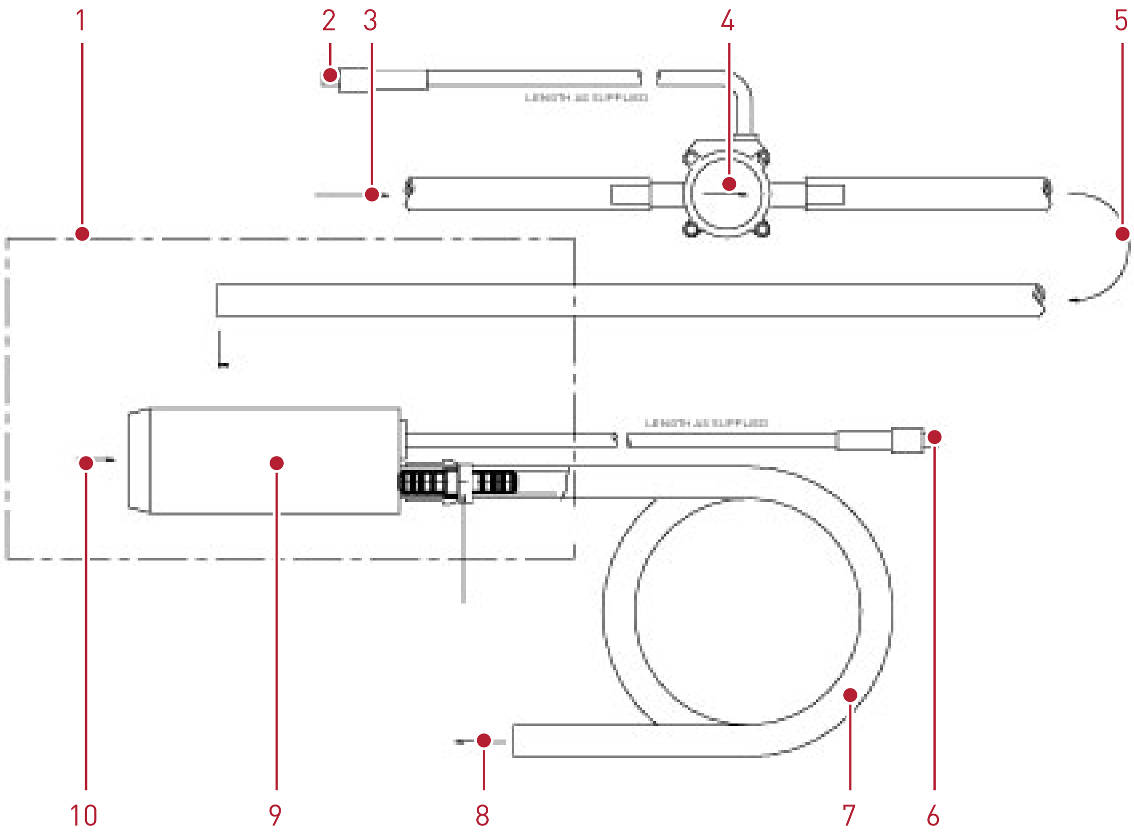

Figure 28. Water cooling system for susceptibility/temperature system

Key to Figure 28

1. Reservoir
2. Power supply to liquid flow sensor
3. Direction of flow from upper nipple on MS2W30
4. Liquid flow sensor
5. To reservoir
6. Power supply to water pump
7. PVC tubing
8. Direction of flow to lower nipple on MS2W30
9. Water pump
10. Water in

Note: The flow sensor must be connected to the pipe coming from the MS2W30 outlet pipe.

Note: The water pump may need to be primed when the system is initially set up. Before connecting to the MS2W lower 6mm nipple, immerse the pump in the reservoir, and suck water from the reservoir and through the pump into the inlet flow pipe.

Caution: It is the user's responsibility to ensure continuity of water supply during operation of the furnace. Failure in the water supply at elevated furnace temperatures will result in damage to the MS2W probe.

WARNING: Do not switch on the mains electricity supply until:

1. All connections are made.

2. Power supply controls are set to RESET and HOLD and the 10-turn dial is set to zero.

20.2. Connection to a Computer (GeoLab for Windows Software)

Note: The software will run on Windows 98, Windows 2000, Windows XP, Windows 7 and Windows 8. If there is no RS-232 serial port available then a USB-Serial adaptor can be used. The GeoLab program is supplied with an operating manual.

Note: For successful data transmission between a host computer and the rest of the system it is important that correct protocols are used, i.e. 1200 baud, 8 data bits, no parity, and 2 stop bits. This is achieved by setting the three-way switch on the rear panel of the MS2 meter to position B. The temperature meter is pre-set to this protocol. For further information see the GeoLab operation manual.

When power is applied, the temperature meter runs through a self-test routine and the temperature is displayed after about 10 seconds. The temperature will only be correct if the thermocouple type selected by the switch is the same as the thermocouple selected during the last GeoLab run. The thermocouple range selection is done when the user information is entered at the start of each run.

20.2.1. Connecting an MS3 Meter

When using an MS3 meter, this will also need setting to Mode B. If the meter was ordered with the X/T system then this step will have been performed during production.

Setting an MS3 to Mode B:

This can be accomplished by downloading and installing 'Bartsoft' from Bartington Instruments. After installing the software plug in the MS3 via the USB port and install the relevant drivers. Open Bartsoft and click Meters->Multi Susceptibility Meter->RS232 Setting. See Figure 29. Set this to B and click 'Update'. The MS3 is now ready to use with the X/T equipment via the RS232.

Note: For further information please see the manuals OM2647 Bartsoft and OM3227 MS3.

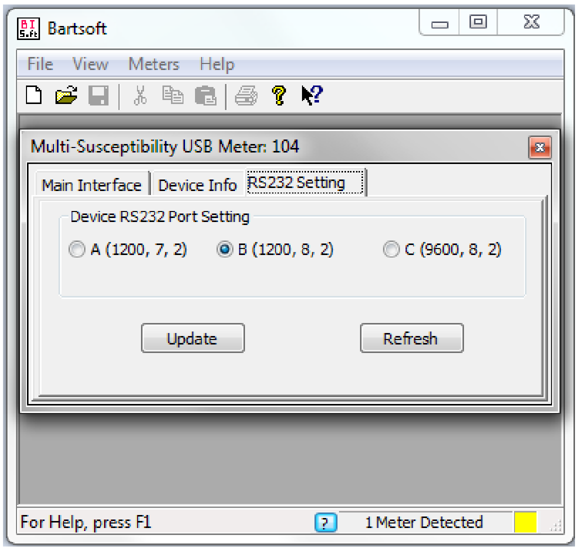

Figure 29. Setting MS3 to Mode B in Bartsoft

20.3. Sensor Orientation

Figures 22 and 30 show the sensor in a vertical orientation around the furnace for high temperature measurements. The MS2W should be clamped onto the MS2WF so that the sample cavity encapsulates the furnace. The MS2W sensor should not be in contact with the MS2WF furnace.

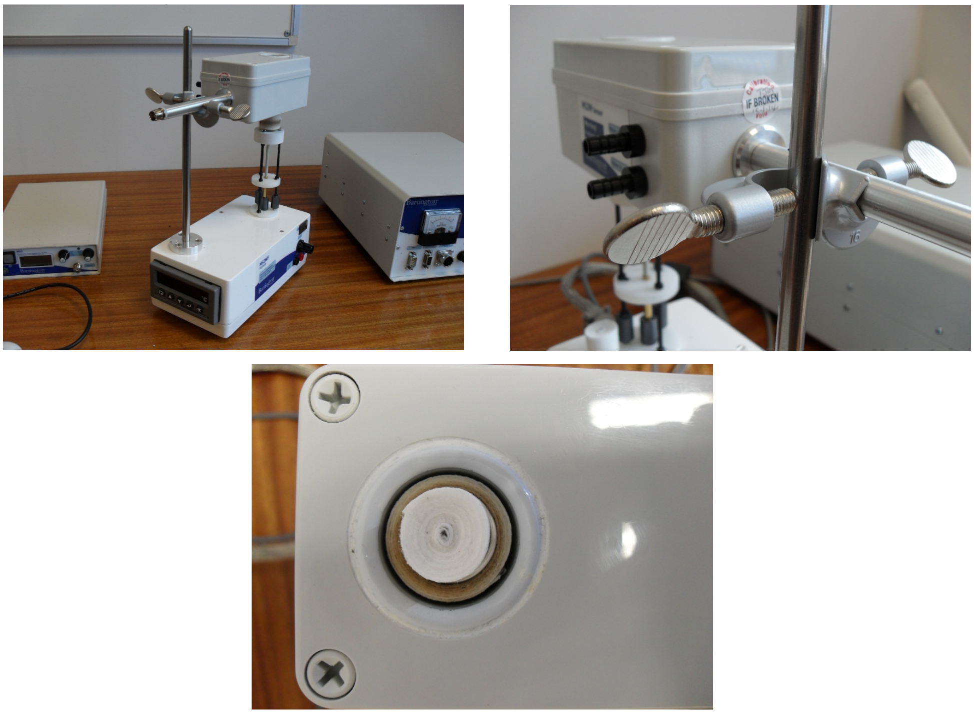

Figure 30. Mounting the MS2W on the MS2WF

If low temperature measurements only are to be performed (no furnace) then it may be advantageous to mount the sensor horizontally.

> **Note:** The sensor will detect the presence of the metal base. This is not a problem as the instrument is zeroed before commencing readings, but the sensor clamp should be checked to ensure that no movement of the sensor can occur. Similarly the probe connecting cable should not be disturbed when measurements are being taken.

When the furnace is not in use, i.e. for low temperature measurements, the type 'T' thermocouple will be connected and selected, and coolant supplied to the system.

When the furnace is to be used, position the sensor as shown in figures 22/30 so that its most sensitive detection region is located in the middle of the sample and at the thermal centre of the furnace.

> **Note:** Allow the system to stabilise for 30 minutes with the MS2 meter running and water flowing through the sensor for optimum low drift performance.

> **Note:** At switch on, the water pump will run at an elevated flow rate for a short time in order to prime the system.

20.4 Sample Insertion

For sample preparation see Preparation of Samples.

The tweezers supplied with the equipment should be used to pick up and move the crucible containing the sample to be measured. It can then be carefully placed it into the furnace, as shown in Figure 31.

Figure 31. Using tweezers to insert crucible into MS2W

Once the crucible has been placed, the thermal plug should then be inserted on top prior to heating. Figure 32 shows a photograph of what how it should look prior to heating.

Figure 32. Plug inserted above crucible

20.5. High Temperature Measurements

Before taking measurements the manual selection switch on the MS2WF should be set to S or T. The S thermocouple is the standard thermocouple, used in high temperature measurements. The switch is shown in Figure 33.

The power supplied to the furnace is controlled using the two toggle switches and the 10-turn dial on the MS2WFP controller. See Figure 34.

Note: Always begin with the dial set to Z, the SET/RAMP/RESET switch set to RESET, and the UP/HOLD/DOWN switch set to HOLD.

Figure 33. MS2WF Thermocouple Selection Switch

Figure 34. MS2WFP Control Panel

Switch on the MS2WFP power supply and the water pump, and check for leaks and water flow. The flow switch in the water system is activated when the pump is turned on. If the water flow is not established due to lack of water or a restriction in the pipework, then the current to the furnace will be interrupted and no heating will occur. A warning beep will sound if the water pump is switched on but no flow is detected. The water pump should be switched off when the sample reaches room temperature after a measurement run.

To set the furnace to a pre-determined temperature, select the temperature on the dial and switch to SET.

To use the ramp facility, set the desired ramp rate on the dial where rate of temperature increase is approximately 5°C/minute per turn.

Select RAMP and UP, and commence taking readings until the maximum desired temperature is reached.

Note: After resetting, the ramp begins from a temperature of 0°C. There will be a considerable delay before the ramp reaches the temperature of the sample and current starts to flow in the windings of the furnace to keep the furnace temperature at the level of the ramp. The RESET switch sets the ramp back to 0°C.

Select DOWN to reduce the temperature at the same (or some new) rate. At any time the current temperature can be HELD but, if this facility is to be used, a low ramp rate should be selected to minimise the effects of sample thermal time lag.

There are no restrictions on the way in which the controller is used, other than to avoid pre-setting a cold furnace to a high temperature, and thereby subjecting it to high in-rush current and thermal shock. If rapid heating is required, observe the ammeter and keep the current below 4A.

Note: Fluctuations in line supply voltage can cause loss of temperature regulation at high temperatures and a conditioning transformer may be required.

20.6. Thermal Gradients

Under equilibration conditions, thermal gradients for a sample correctly positioned within the sample cavity will be circa 2-3°C anywhere within the sample. However, when subjected to varying temperature, the centre of the sample will thermally lag behind the surface of the sample. This thermal gradient can be calculated from the empirical formula:

$G = R/1.6$

where G = thermal gradient in °C/7mm

R = ramp rate in °C/minute

20.7. Low Temperature Measurements

These will usually be performed using the larger sample size and without the furnace. The T thermocouple can be connected just above the toggle switch on the MS2WF furnace, shown in Figure 35, and is used for low temperature measurements.

The sample can be attached to the tip of the type 'T' thermocouple using plasticine. When taking low temperature measurements the furnace heater is not used, so the MS2WFP controls can be set to RESET, HOLD and dial=0.

Connect the T thermocouple, and select this type on the furnace switch. The sample should then be cooled, using liquid nitrogen or similar, to the lowest temperature required. Following cooling the sample should be placed in the MS2W sensor. The sample will then warm up naturally to room temperature, and readings can be taken in increments as the temperature increases. During this operation the sensor aperture can be horizontal or vertical, whichever is more convenient.

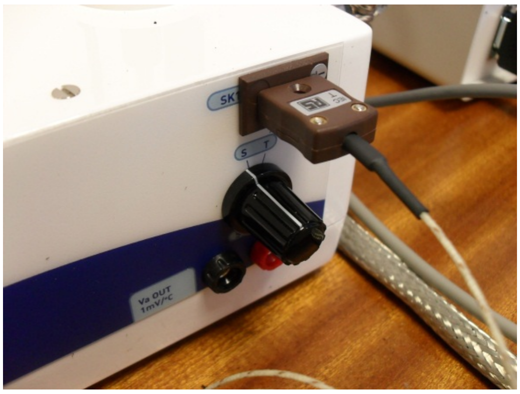

Figure 35. Connection for T type Thermocouple

Note: The sensor should be orientated horizontally for these measurements.

WARNING: The glass tube of the MS2W sensor may be damaged if a tightly fitting sample is inserted. Use only the recommended sample size. If other components/objects are to be placed within the cavity, ensure that they will not expand on recovery to room temperature and damage the glass. Smaller samples can be used for low temperature measurements within the furnace. The type 'T' thermocouple will be used and the furnace controller switched from RESET to RAMP or SET as the temperature passes through zero.

20.8. GeoLab

The GeoLab program supplied prompts the operator to select the correct thermocouple, and to set the power supply to a rising or falling ramp, and collects the magnetic susceptibility measurements as a function of temperature. See the Geolabsoft manual, OM0004, for further information.

21. Troubleshooting

21.1. No Push-Button Operation

If the meter continues to recycle, check the M-Z toggle switch is in the centre position. Otherwise, suspect a cable or sensor fault: try alternative cables or sensor.

21.2. Large Variations in Measured Values

The main causes of a wide spread in the measured values are:

Cause	Solution
External interference from RF sources such as fluorescent lighting, welding equipment, radio transmitters, mobile phones, transformers in nearby equipment, etc.	Try new location or shield the sensor.
The sensor is too close to a conducting metal object or surface such as a metal bench top or components.	Move away.
Low battery voltage.	Completely discharge the battery and recharge for 48 hours whilst switched off. Run with mains adaptor connected. Replace battery.

21.3. Serial Communications Problems

If problems are experienced with serial RS-232 communications between the MS2 meter and a PC running Multisus2 or GeoLab, check the following:

1. **Power save.** If the PC is a laptop, turn off all power-saving features as they may cause the interface to close while waiting for a reading from the MS2 meter. There may be power save features in the PC and in Windows.

2. **RS-232-USB converters.** If an RS-232 to USB converter is used, check that the USB connection is recognised by the PC, and check the number of the com port allocated to the converter by Windows. This may vary each time the PC is used depending on the number of other devices connected. Details can be found in the Device Manager of your computer's Windows Control Panel. Ensure latest drivers are installed.

3. **Receive and Transmit Buffers.** The MS2 meter uses single characters to trigger the measurements. Any buffers in the PC communications port may inhibit this operation.

Buffers should therefore be minimised. Using the Device Manager of your computer's Windows Control Panel, select the port to be used and select: Port Settings\Advanced\. Set the Receive Buffer and Transmit Buffer to Low (1).

4. **MS2 Meter Settings.** Check the rotary switch on the rear panel of the MS2 meter. This switch controls the serial baud rate and format of the data. Using a screwdriver, the switch should be set as follows:

    - for operation with Multisus2 or Bartsoft, set to position A
    - for an X/T system running under GeoLab, set to position B
    - for operation with a Geotek conveyor system, set to position C.

5. **Multisus2.** Use the menu item Serial Port\Set Baud Rate and Port to select the port to which the MS2 meter is connected. Select 1200 baud as the rate. Select Serial Port\Test Communications to check the zero setting and receipt of the meter measurements by the PC. The meter should normally be switched on when prompted by the program to ensure that any invalid characters transmitted by the meter at switch-on are cleared from the PC input ports.

6. **Cables.** Newer meters will have been supplied with a single cable from the MS2 meter to a 9-pin D-type RS-232 connector for direct connection to a computer or RS-232-to-USB adaptor. Earlier meters will have a cable with a 25-pin connector, a 25-pin to 9-pin adaptor, and 9-pin to 9-pin cable. It is necessary to use all three components for correct operation. Similarly, the X/T system is supplied with labelled cables for connection and these special cables must be used.

7. **Battery.** If the MS2 meter internal battery is discharged, the first effect will be to produce random noise in the readings. If the battery becomes further discharged then it may cause the serial communication to fail. To maintain the battery in good condition it should be completely discharged, at six-monthly intervals, by leaving the meter running with a sensor connected, and then recharged for 48 hours with the meter switched off. Eventually the battery will require replacement: see Replacing the MS2 Meter Battery.

    Note: When running the meter with the serial output connected, leave the mains adaptor switched on and charging the battery whenever possible.

22. Storage and Transport

The MS2 system is a precision electronic instrument and should be treated as such.

Bartington Instruments supplies its products in appropriate packaging for transporting. This packaging should be used for any future transport.

Refer to the product brochure for this product's maximum environmental, electrical and mechanical ratings.

Caution: Exceeding the maximum environmental ratings may cause irreparable damage to the equipment.

23. Disposal

This product should not be disposed of in domestic or municipal waste. For information about disposing of this product safely, check local regulations for disposal of electrical / electronic products.

23.1. Waste Electrical and Electronic Equipment (WEEE) Regulations

This product complies fully with Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and WEEE Regulations current at the time of printing.

Appendix 1. Magnetic Susceptibility of Common Rocks

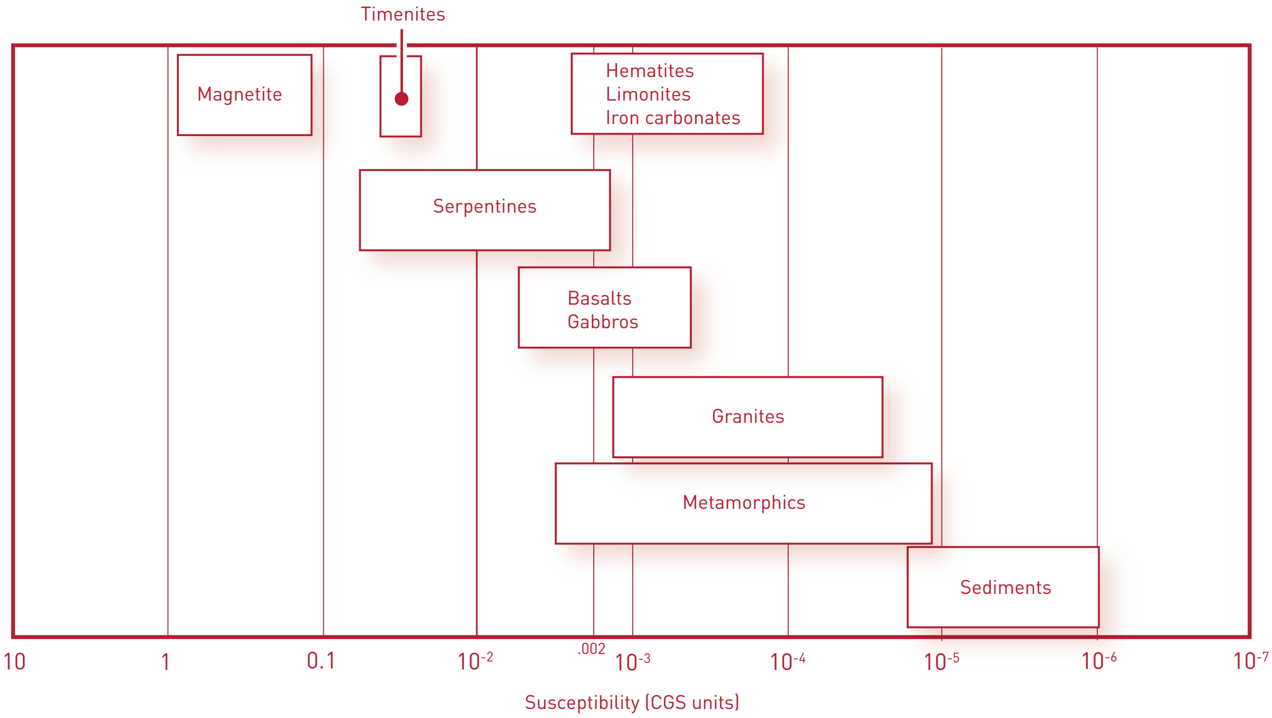

Figure A1.1. Magnetic susceptibility of common rocks

Appendix 2. Calibration Graphs for MS2C Sensor

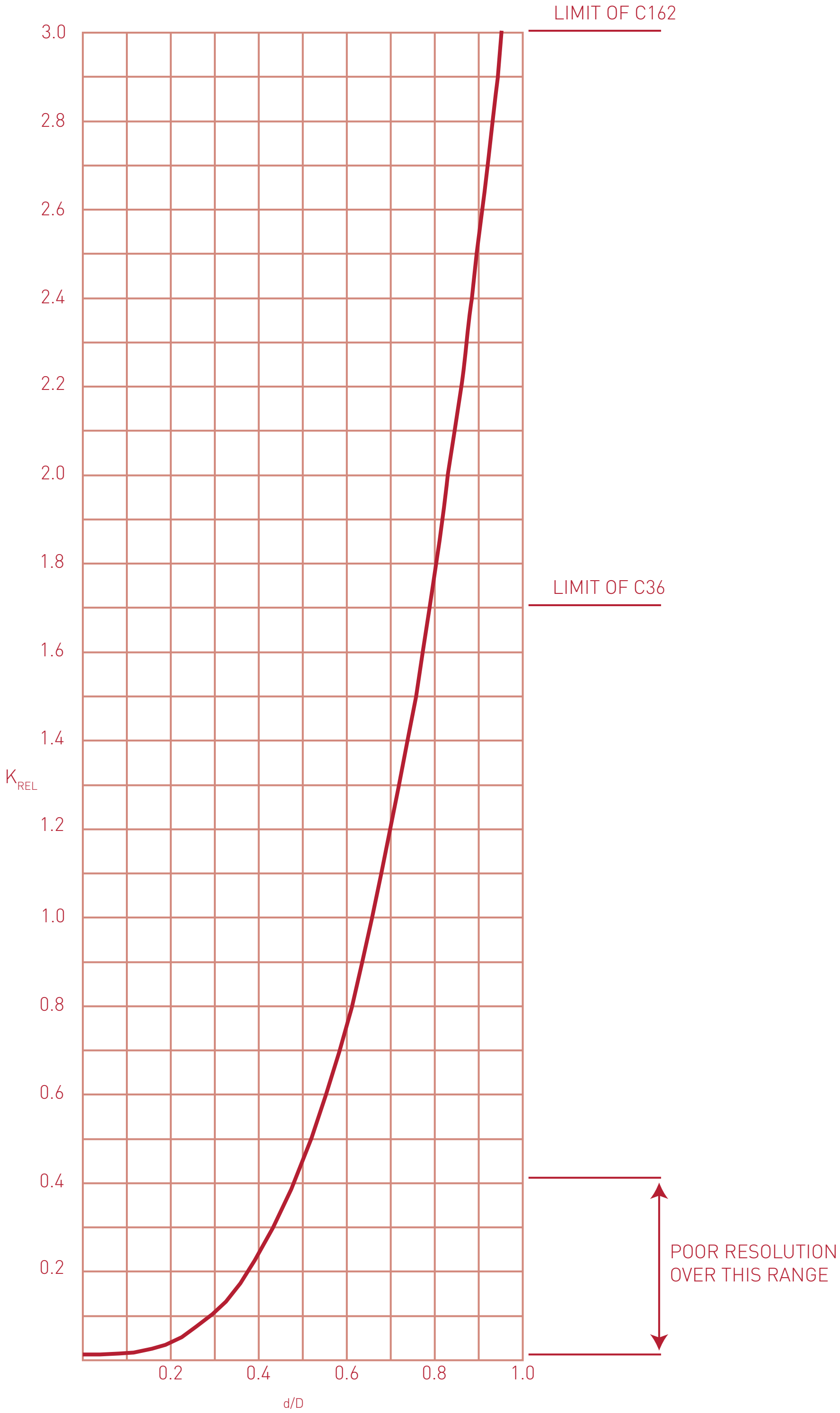

Figure A2.1. Relative response to varying core diameter within MS2C sensor.

In Figure A2.1, d = core diameter and D = MS2C aperture + 8mm. The figure shows the variation in the calibration value of χ_{vol} for varying core diameter d for a long core (length l greater than 2D). The measured value will be equal to χ_{vol} when d/D = 0.66. For other ratios of d/D the relative response will approximate to $\chi_{REL} = 3.45 * (d/D)^3$.

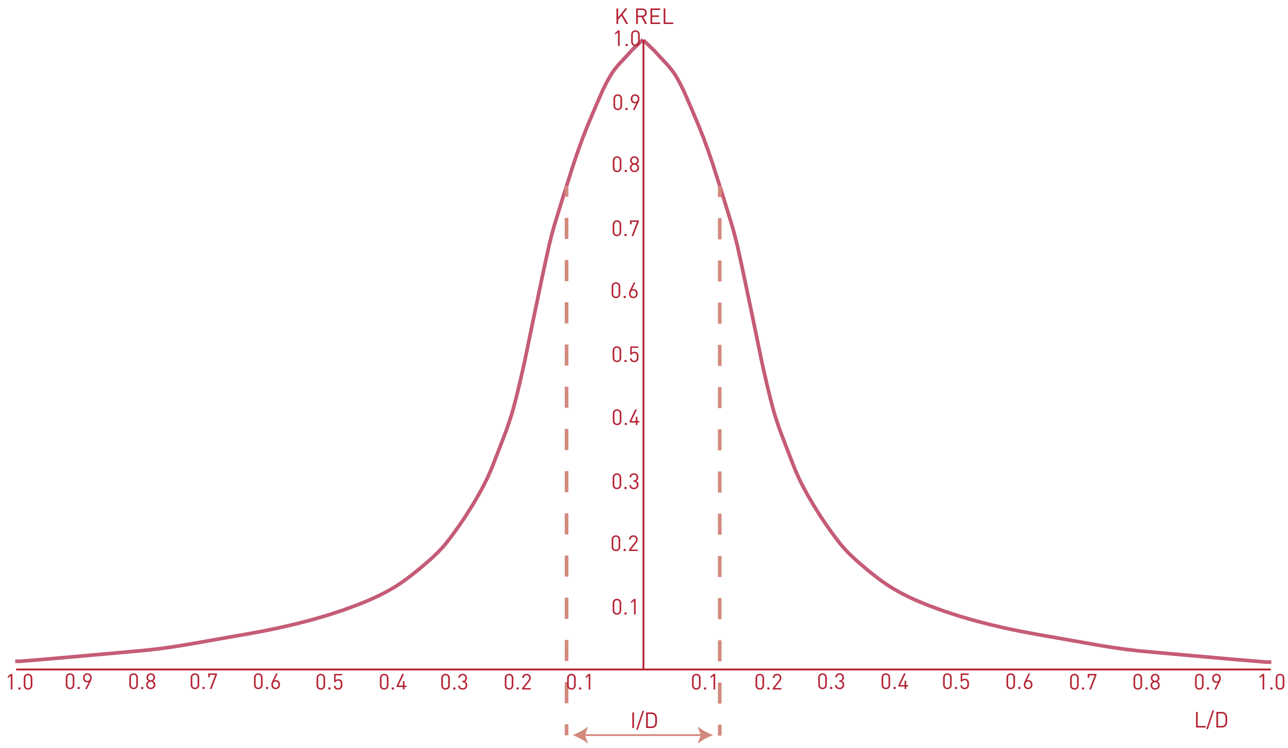

Figure A2.2. Thin section response of MS2C sensor.

Figure A2.2 shows the relative (arbitrary units) response in the measured value to the horizontal displacement L of a thin discoidal section of stratum diameter d = 0.85D.

Both graphs present the variable of interest in relation to coil diameter D (8mm greater than the nominal diameter of the aperture).

For a period of core length l = 0.25D the enclosed volume will produce a value of approximately χ_{vol} x 2, but only for the diameter d stated above.

Appendix 3. Anisotropy of Magnetic Susceptibility Measurements (AMS)

For accurate measurements of AMS it is necessary to use the MS2B sensor in conjunction with the AMS adapter and AMSWIN-BAR software. These are not supplied as standard with the MS2B, but can be purchased separately.

A3.1. Installation of the AMS Adapter

To use the AMS adapter, the tall sample platen must be removed from the MS2B and replaced with the short one supplied with the AMSWIN-BAR kit. The MS2B platen height must then be adjusted to centralise the sample. The procedure is described below.

A3.1.1. Changing the Platen

The stages for changing the planet are shown in Figure A3.1a-i.

Figure A3.1a-b. Changing the MS2B platen.

1. The tall sample platen is removed by unscrewing its retaining screw in the bottom of the sample aperture.

Figure A3.1c-d. Changing the MS2B platen.

2. Replace the tall sample platen with the short one, and secure it in position by replacing and tightening the retaining screw.

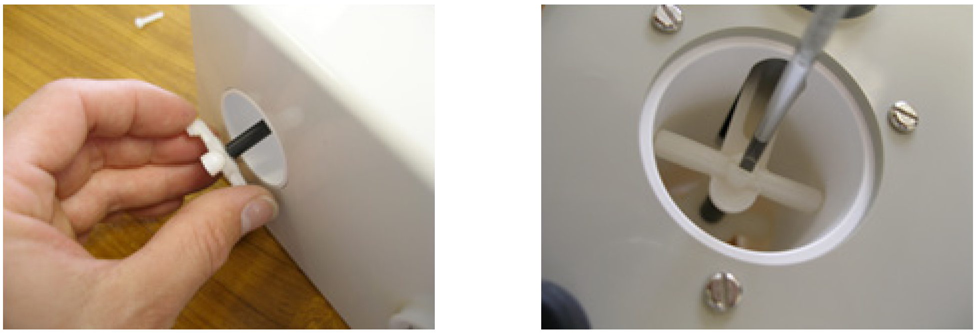

Figure A3.1e-f. Changing the MS2B platen.

3. Refer to Appendix 4 to re-adjust the Platen height in order to centre the sample within the aperture.

Sample adaptors are supplied with the AMSWIN-BAR package. Instructions for measurement procedures are given in the AMSWIN-BAR CD-ROM © Morris Magnetics Inc.

Appendix 4. Adjusting MS2B the platen height.

The platen height must be adjusted to centralise the sample within the sensor.

1. Remove the cap covering the adjustment screw and the miniature screwdriver.

2. Connect the MS2 meter to the MS2B, switch ON and perform a zero.

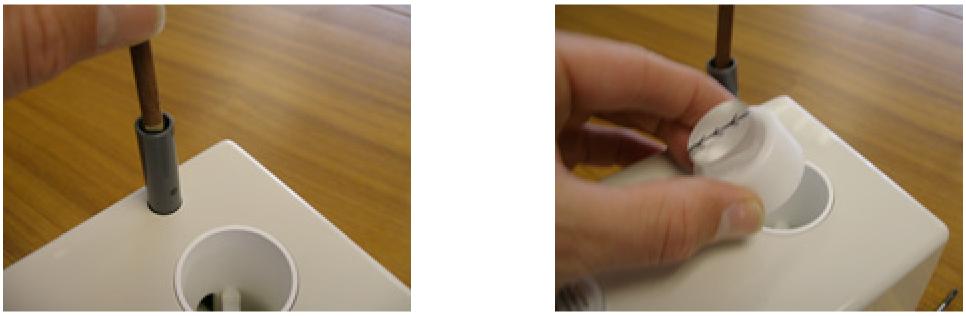

Figure A3.1g-h. Changing the MS2B platen.

3. Insert the screwdriver into the adjustment screw. Position the sample on the platen and place it into the sample aperture.

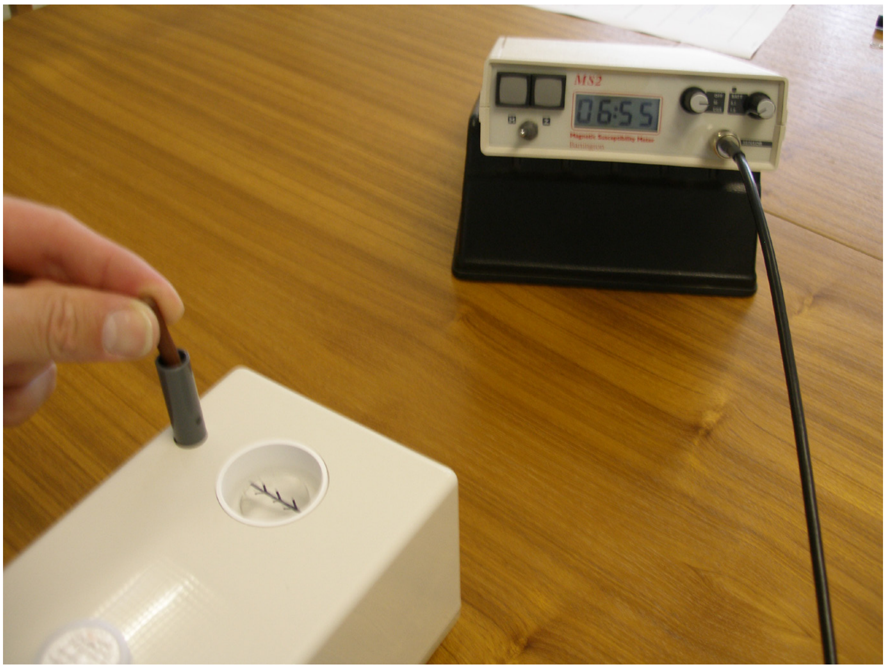

Figure A3.1i. Changing the MS2B platen.

4. Adjust the screw to obtain a maximum reading on the meter.

5. Replace the adjustment screw cap and replace the miniature screwdriver.

Appendix 5. Calculating Magnetic Susceptibility

The magnetic state of a specimen is generally described by the following equation:

$B=\mu_0 (H+M)$ ... (1)

where:

B is the flux density of the specimen in T (Tesla). ($B = \mu H$)

μ_0 is the permeability of free space in N A^{-2}. This is a constant ($4\pi x10^{-7}$)

H is the applied field strength in Am^{-1}.

M is the magnetisation of the specimen in Am^{-1}. ($M = \chi_{vol}H$)

Dividing through by H we get:

$\mu= \mu_0 + \mu_0\chi_{vol}$ ... (2)

where:

μ is the permeability of the specimen (in N A^{-2})

κ is the volume magnetic susceptibility of the specimen (dimensionless)

Rewriting, we get:

$\mu_0\chi_{vol} = \mu - \mu_0$ ... (2)

The MS2/3 magnetic susceptibility system relies on the principle that any changes in the permeability of a core will cause a change to the inductance of a wound inductor.

The sensors operate on the principle of AC induction. Power is supplied to the oscillator circuit within the sensor, generating a low intensity alternating magnetic field.

The frequency of oscillation is determined by the inductance of the system. When the inductor contains only air, the permeabilty μ_0 determines the inductance. When a sample is introduced inside the inductor, the change in permeability also leads to a change in inductance.

The meter reads the frequency values for μ_0 and μ, and uses them to calculate the change in inductance, and thus the magnetic permeability. The magnetic susceptibility is then calculated using equation (2).

The value of μ_0 is constant but the variable of interest is relatively small. Therefore any thermally induced sensor drift needs to be eliminated by occasionally obtaining a new 'air' value, to re-establish the μ_0 reference.

Notes

Distributed By:
GMW Associates
955 Industrial Road, San Carlos, CA, 94070 USA
PHONE: +1 650-802-8292 FAX: +1 650-802-8298
EMAIL: sales@gmw.com WEB: www.gmw.com

Bartington® Instruments

T: +44 (0)1993 706565
F: +44 (0)1993 774813
E: sales@bartington.com

Bartington Instruments Limited
5 Thorney Leys Business Park,
Witney, Oxford, OX28 4GE, England.

www.bartington.com

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