COMBINED OPERATING 
& SERVICE MANUAL FOR 
BSS-02B MAGNETIC 
SUSCEPTIBILITY SONDE

Bartington Instruments Ltd. 
10 Thorney Leys Business Park 
Witney, Oxford. OX28 4GG 
Tel: +44 1993 706565 
Fax: +44 1993 774813

The copyright of this document is the property of Bartington Instruments Ltd. The document is 
supplied on the condition that it is to be treated commercially confidential and it may not therefore be 
disclosed to any third party without the written authorisation of Bartington Instruments.

Specifications may be subject to change without prior notice.

This product is not qualified for use in explosive atmospheres or life support systems. 
Consult Bartington Instruments for advice.

(89/336/EEC) 
EMC DIRECTIVE
LIST OF CONTENTS

1.0 INTRODUCTION

2.0 MAGNETIC SUSCEPTIBILITY MEASUREMENTS USING THE BSS-02B SYSTEM
   2.1 Measurements of interest
   2.2 Dimensional systems
   2.3 Calibration sample
   2.4 Digital and Pulse Rate interface
   2.5 Principles of operation

3.0 SERVICING THE BSS-02B SONDE
   3.1 Introduction
   3.2 Equipment required
   3.3 General description
   3.4 Principle of operation
   3.5 Removal and replacement of the diaphragm
   3.6 Silicone oil removal and replenishment
   3.7 Recommended spares

4.0 DATA SHEET & TECHNICAL SPECIFICATION

FIGURES

ALL DIMENSIONS ARE IN mm

Figure 1  BSS-02B borehole magnetic susceptibility sonde outline
Figure 2  BSS-02B borehole magnetic susceptibility sonde electronic interface
Figure 3  BSS-02B borehole magnetic susceptibility sonde mechanical interface
Figure 4  BSS-02B borehole magnetic susceptibility sonde section through coil & nose cone
Figure 5  Range of Magnetic Susceptibilities of Common Rocks
1.0 INTRODUCTION

The BSS-02B magnetic susceptibility sonde is intended to be used for prospection of magnetic minerals and stratigraphic correlation to depths of 6000m. The operating frequency is chosen to be sufficiently low to avoid interference from rock conductivities and the circuitry is temperature compensated to minimise thermally induced drift. The region of detection is situated 160mm from the tip of the pressure-equalised housing. The detector features a single focussed coil arrangement to achieve a single response to strata. The detection region has a full-width-half-maximum response of 25mm and measurements are digitised at a rate of approximately 20 per second giving a theoretical maximum logging rate of 0.5m per second. The tool is calibrated for operation in 50mm diameter unclad boreholes. Larger diameter holes can be logged where the angle of the borehole assures de-centralisation. Correction factors for this and for linearity error correction are given in the technical specification- Section 4.0.

A typical range of magnetic susceptibility together with rock types is given in Figure 5.

2.0 MAGNETIC SUSCEPTIBILITY MEASUREMENTS USING THE BSS-02B SYSTEM

2.1 Measurements of Interest

Measurements of interest are always positive and arise from either paramagnetic or mostly ferro or ferrimagnetic geological materials. Apparent (false-negative) paramagnetic values will arise only in strongly conductive media. For this reason the tool may not be used in the presence of ferrous or conductive cladding. The conductivity of normally encountered borehole fluids will not, however, be sufficiently high to produce this effect.

2.2 Dimensional Systems

The BSS-02B is calibrated in the cgs system. To convert to SI units multiply the cgs value by 4pi. For example:

\[ 1 \times 10^{-5} \text{ cgs} \equiv 1.26 \times 10^{-4} \text{ SI} \]

Note:- this refers to volume susceptibility which is dimensionless.

2.3 Calibration Sample

A cement and furnace ash composite block is supplied with each tool. Best practice is to check the calibration prior to and following a logging sequence. Thermal (ferrimagnetic) drift of the sample together with geometrical errors suggest that an error band of 10% should apply to the calibration check. The calibration of the tool with time and temperature is assumed to be superior to the calibration check sample.

2.4 Digital and Pulse Rate Interface

A six-wire interface is provided. The 15V 32mA max. power supply connects to a live and a common return line. Digital communication is via a three wire, 24-bit serial port and pulse rate is output via a single wire. See data sheet and Figure 2 for full details.
2.5 Principles of operation

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

\[ B = \mu_0 (H + M) \quad (1) \]

where:
- \( B \) is the flux density of the specimen in Tesla.
- \( \mu_0 \) is the permeability of free space. This is a constant (4\( \pi \times 10^{-7} \)).
- \( H \) is the applied field strength in AT/m.
- \( M \) is the magnetisation of the specimen in Tesla.

Dividing through by \( H \) we get:

\[ \frac{r \mu_0}{\mu_0 \kappa \mu_0} = \kappa \mu_0 \quad (2) \]

where:
- \( r \mu_0 \) is the relative permeability of the specimen (dimensionless)
- \( \kappa \) is the magnetic susceptibility of the specimen (dimensionless)

Rewriting, we get:

\[ \mu_0 \kappa = \mu_0 - \mu_0 \quad (3) \]

The BSS-02B instrument measures the magnetic susceptibility in the following way:

The sensor consists of a very high thermal stability oscillator for which a wound inductor is the principle frequency-determining component. When the inductor is surrounded only by air the value of \( \mu_0 \) determines the frequency of oscillation. When the inductor is placed within the influence of the specimen to be measured, the value of \( r \mu_0 \) determines the frequency of oscillation. Electronic circuitry digitises the \( \mu_0 \) and \( r \mu_0 \) dependant frequency values with a resolution of better than one part in a million and computes the value of magnetic susceptibility.

The value of \( \mu_0 \) is constant but the variable of interest, \( \kappa \), is, by comparison, small. For this reason any thermally induced electronics drift is compensated out during the calibration of the tool.

Any residual thermally induced baseline drift needs to be eliminated by obtaining a new "air" or \( \mu_0 \) value prior to logging. A residual value of circa one thousand units corresponding to air value accommodates drift and accommodates negative excursions.

Calibration is traceable to water (\( \kappa = -0.72 \times 10^{-6} \) CGS) via standards held by Bartington Instruments and measured using an MS2 meter and MS2B sensor.

Immunity to errors arising due to resistivity \( \rho \) can be demonstrated by reference to ‘skin depth’ \( S \), which is the depth of penetration of alternating magnetic flux for which the flux is attenuated to \( 1/e = (0.37) \) where:

\[ S = \sqrt{2 \rho \omega \mu} \quad \text{where} \ \omega \ \text{is the operating frequency in radians/second} \]

OM1741 Issue 4
Page 4 of 13
For example, if we choose the extreme case of pure, solid graphite as the conducting medium \( (\kappa \approx 0, \mu_r \approx 1.0) \), and a very low resistivity of \( \rho = 1.4 \times 10^{-5} \Omega \text{m} \), we get:

\[
S = \sqrt{2} \times 1.4 \times 10^{-5} / 2\pi \times 1.36 \times 10^3 \times 4\pi \times 10^{-7} \times 1 = 0.05 \text{m}
\]

This would depress any (artificial) value for \( \kappa \) but the next, much higher \( \rho \) value, would be for sulfides where measurements of \( \kappa \) should be virtually uninfluenced by \( \rho \).

### 3.0 SERVICING THE BSS-02-B SONDE

#### 3.1 INTRODUCTION

This section of the manual describes the functioning and servicing of the BSS-02-B.

**WARNING**

Servicing of this instrumentation must only be carried out by qualified engineers. In some instances fault diagnosis can only be accomplished with the equipment LIVE. Bartington Instruments do not accept responsibility for injuries caused to personnel as a result of operating their products with the equipment panels removed.

#### 3.2 Equipment required

Tools:
- Chain spanner
- Vacuum pump

#### 3.3 General description

The BSS-02-B sonde is constructed in 2 parts. Part 1 is an aluminium alloy barrel containing the printed circuit board at normal air pressure. Part 2 is a non-magnetic polymer enclosure containing the detector coil in silicone oil. The oil, which is at local pressure, provides a non-magnetic, non-electrically conductive medium for pressure equalisation of the coil enclosure and eliminates the requirement for a pressure vessel.

The silicone oil is retained by a polyurethane (P.U.) diaphragm and silicone grease at the tip of the sonde preventing an ingress of drill chippings. In this way the coil is mechanically isolated from pressure and temperature induced stresses in the enclosure which would otherwise cause significant measurement errors.

The top and bottom sections are united by a mid-adaptor which includes electrical feed-throughs for electrical connection between the coil and the electronics. Pressure seals of the mid-adaptor and customer stainless steel parts are by BS216 Nitrile "O" rings in a piston seal. Low differential pressure sealing of the detector coil tube parts is by BS126 Nitrile "O" ring in a piston seal.

#### 3.4 Principles of operation

The detector coil together with a capacitor bank and oscillator circuit produce an alternating magnetic field in the vicinity of the coil.

Any magnetic material which is bought within the influence of this field will bring about a reduction in the natural resonant frequency of the oscillator circuit.
The measurement of magnetic susceptibility poses a significant problem in measurement techniques due to the high dependency of the measurement on the temperature characteristics of the components. These measurements are frequently associated with large and frequently non-linear temperature-induced baseline drift errors.

Bartington Instruments employs a unique method of drift compensation and for this reason we recommend that repairs to the sonde electronics should only be made by complete replacement with a fully compensated coil and printed circuit board. The sonde should be returned to Bartington Instruments for this repair.

3.5 **Removal or replacement of the diaphragm**

The diaphragm is retained between the PEEK nose cone and the PEEK nose cone adaptor.

Place sonde vertically with nose upwards.

i. Remove the nose cone by unscrewing from PEEK barrel.

ii. Remove as much silicone grease from the nose cone as possible.

iii. Remove diaphragm

3.6 **Silicone oil removal and replenishment**

With diaphragm removed pour out old silicone oil. To replenish the oil:

i. Fill the PEEK barrel to the level of the diaphragm flange with silicone oil.

ii. Attach vacuum pump to nose cone via a suitable disk adaptor and momentarily apply vacuum to remove air.

iii. Observe any change in oil level and repeat filling and pumping as necessary.

iv. Press diaphragm in place using finger tip ensuring that no air is trapped beneath it.

v. Fill diaphragm cavity with silicone grease.

vi. Replace the nose cone with a new 'O' ring seal fitted.

vii. Fill nose cone cavity with silicone grease

NOTE: Always apply silicone grease thinly to "O" ring seals prior to assembly.

3.7 **Recommended spares**

i. 4 off Nitrile "0" rings BS216

ii. 2 off Nitrile "0" ring BS126

iii. Silicone oil

iv. Tube of silicone grease

v. 1 off Diaphragm
This sonde is used in mineral prospection and for stratigraphic correlation to depths of 6000 metres. The unit has a diameter of 43mm and is designed and calibrated for a 50mm borehole.

The sonde comprises two sections: an aluminium alloy cylindrical enclosure containing electronic circuitry and a high strength non-magnetic enclosure in which the detector is located.

The sonde operates from an unregulated 15V nominal supply and provides an output in the form of a three-wire CMOS serial interface for integration into the client's data acquisition system, and / or a single wire pulse rate output for use with rate meters and counters.

**FEATURES:**

- Wide measuring range: $10^{-5}$ to $10^{-1}$ cgs
- Low operating frequency: 1.36kHz
- Good vertical resolution: 25mm with dual coil system
- Operates to pressures of 10000 psi maximum
- Operates to temperatures of 120°C: calibrated to 90°C
- Fast: logs at up to 21 readings per second
- High spatial resolution: will resolve strata down to 25mm
- Low temperature induced drift: $<20 \times 10^{-5}$ cgs over the calibrated temperature range ambient to 90°C
### TECHNICAL SPECIFICATION

**BSS-02B Sonde**

**Mechanical**

- Construction: P.E.E.K. enclosure
- Overall length of sonde: 720mm
- Weight in air: 815gms
- Pressure barrel may be supplied by user
- Seals: pressure barrel bottom to mid-Adaptor 2 Viton "O" rings BS 216 mid-adaptor to P.E.E.K. barrel 1 Viton "O" ring BS 126
- P.E.E.K. barrel to nose 1 Viton "O" ring BS 126
- Alternative mating threads: BSS-02B-2 1.375"[INCH]-12UNF-3A
  - BSS-02B-3 1.375"[INCH]-16UN

**Pressure compensation:** A single polyurethane diaphragm

- Volume of silicone oil: 155ml
- Note: the nose section is filled with silicone grease to prevent the ingress of contaminants. This should be cleared to a depth of 10mm and replaced as required.

**Performance**

- Maximum operating pressure: 10,000 psi
- Maximum stratigraphic (spatial) resolution: 25mm F.W.H.M.
- Temperature induced baseline drift: < 20 x 10^-5 cgs from 20°C to 90°C
- Temperature induced scaling drift: < 0.1% full scale
- Maximum operating temperature: +120°C
- Sensing coil type: focused dual coil
- Overall length: 97mm
- Separation: 27mm
- Diameter: 35mm
- Distance from nose to centre of detection: 160mm
- Principle of operation discrimination: ac induction by frequency
- Operating frequency: 1.36 kHz
- Power supply rejection ratio: not measurable

**Electrical**

- Power requirements: +14 to +18Vd.c.at 32mA
- Input connection: 300mm of 6-core PTFE coated leads
- Connector type: none
- Interface: three-wire 5V CMOS serial Interface and single wire pulse Rate output all ESD protected

A pulse of approximately 50µS width is output at a rate which is proportional to the current measurement. Refresh time is 47.5mS but will extend by 0.2mS for every 1000 units of measurement. Maximum output is 16000cps.

**Digital Data Output**

The /Ready signal goes low for a period of 10mS when the conversion has been completed and bit 24 (MSB) is present on the SDO Line. The minimum repetition period of /Ready is 47.5mS in air but will extend by 0.2mS for every 1000 units of measurement. Each low to high transition of Clock In will cause the next bit to be placed on the SDO line. Data can be conveniently clocked into the external interface on high to low transitions of Clock In. Minimum clock pulse width is 0.5µS.

Data are presented as 24 bits with the MSB first.

**Calibration**

The system is scaled to a change of one least significant bit = 1x10^-5 cgs units. (One measurement unit).

A residual value of circa 1000 accommodates negative values and ageing effects.

To calculate true value of K

\[ K \times 10^{-5} \text{ cgs} = (R + R^2 / 10^5) \times 10^{-5} \text{ cgs} \] where R is the measured value.

**BSS-02B Accessories**

**Calibration Block**

- Dimensions of cylinder: OD 153mm
- Bore: L 153mm
- Weight: 50mm
- Calibration value: ≈100 x 10^-5 cgs (as marked)
- Temperature coefficient: +0.05% / °C

Note: To simulate groundwater effects the calibrator should be grounded via hand contact. This will depress the measured value by approximately -15 x 10^-5 cgs.

**Combined Operation manual & Service manual**

Specifications of the products described in this brochure are subject to change without prior notice.

Bartington Instruments Ltd
10 Thornley Leys Business Park
Witney
Oxford OX28 4GG UK
Tel: +44 1993 706565
Fax: +44 1993 774813
Email: sales@bartington.com
Web site: www.bartington.com
Figure 1 - BSS-02B BOREHOLE MAGNETIC SUSCEPTIBILITY SONDE OUTLINE DRAWING
GENERAL:
1. THE SYSTEM IS SCALED TO $1_{\text{LSB}} = 1 \times 10^{-5}$ CGS
2. A RESIDUAL VALUE OF CIRCA 1000 IS PRESENT FOR AIR TO ACCOMMODATE AGEING EFFECTS
3. INPUT * OUTPUT LOGIC IS 5V CMOS COMPATIBLE
4. THE ‘AIR’ OPERATING FREQUENCY OF THE SENSOR IS 1.36kHz
5. THE FULL DYNAMIC RANGE IS FROM $1 \times 10^{-5}$ TO $1 \times 10^{-1}$ CGS

Figure 2 - BSS-02B BOREHOLE MAGNETIC SUSCEPTIBILITY SONDE ELECTRONIC INTERFACE
Figure 3 - BSS-02B BOREHOLE MAGNETIC SUSCEPTIBILITY SONDE

MECHANICAL INTERFACE

AN INTERFACE ADAPTOR (TO PREVENT CONTACT BETWEEN PCB TUBE AND SONDE OUTER TUBE) CAN BE FITTED, IF REQUESTED.

PART SECTIONS THRO' CENTRELINE

OUTER TUBE SUPPLIED BY CUSTOMER

ALUMINIUM ALLOY PCB TUBE

BSS-02B

3 X φ3.5 HOLES CSK TO φ6 AVAILABLE AROUND PERIPHERY AS SHOWN

PCB

FLYING LEADS 300mm LONG

MID-BULKHEAD

PCB TUBE

5
Figure 4 - BSS-02B BOREHOLE MAGNETIC SUSCEPTIBILITY SONDE SECTION THRO’ COIL & NOSE CONE
Figure 5 - Magnetic Susceptibility of Common Rocks

- Magnetite
- Ilmenites
- Serpentines
- Basalts
- Gabbros
- Granites
- Metamorphics
- Sediments
- Iron Carbonates
- Limonites
- Hematites