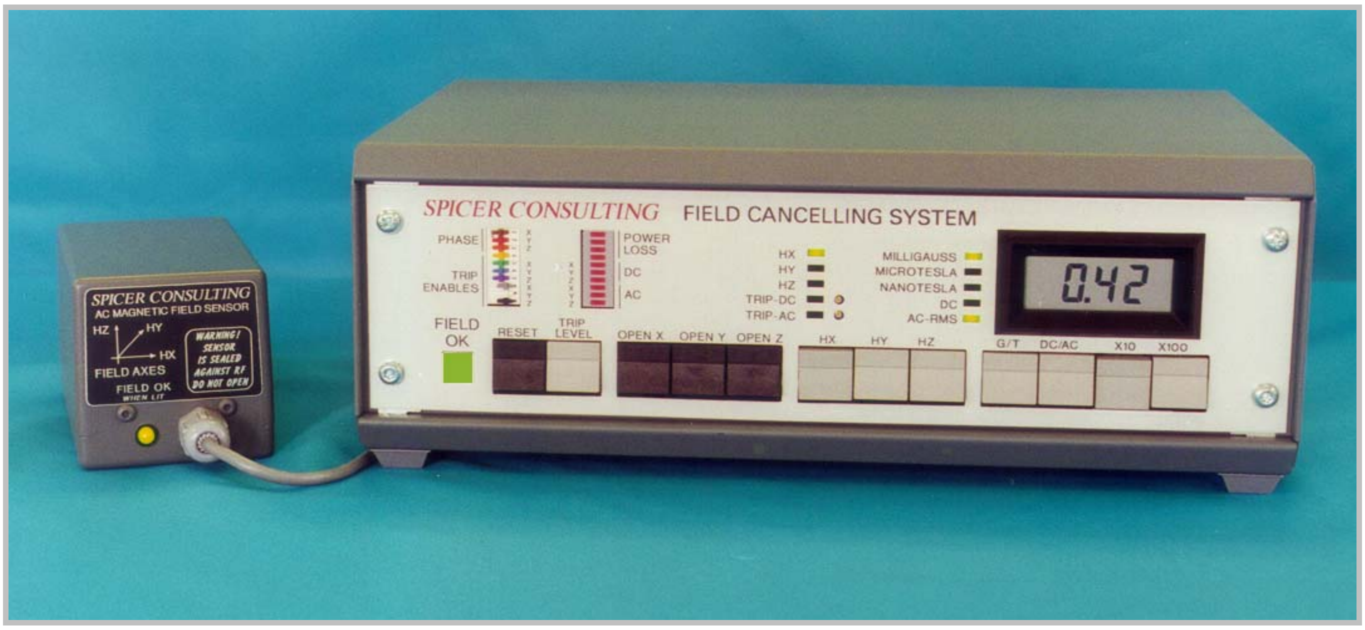
**SPICER CONSULTING** **SYSTEM SC12**

# SC12 Magnetic Field Cancelling System




- **Protects your investment in electron beam technology by stabilising the magnetic field environment**
- **Measures and cancels magnetic fields**
- **Simple "set and forget" operation**
- **Dynamic, real time, system which automatically adapts to changes in the ambient magnetic field in 100 μs**
- **AC field cancelling from 0.5 Hz to 5 kHz**
- **DC field cancelling from DC to 2.5 kHz with optional SC20/DC sensor**
- **Full 3 axis (X, Y, Z) system**
- **50 x field improvement (typical)**
- **Up to 50 mG (5.0 μT) pk-pk cancelling range**
- **Multiple sensor option for TEMs and CD metrology tools**

**Overview**

Today's high performance electron beam tools are very sensitive to changing ambient magnetic fields. The fields move the beam causing loss of resolution and measurement accuracy. The SC12 system stabilises the ambient field and restores the resolution and accuracy.

The SC12/AC system can reduce the amplitude of AC fields by typically 50 x at 60 Hz. The SC12/DC system can also reduce the amplitude of low frequency and DC fields by 100 x at DC.

The SC12 system comprises a Magnetic Field Control Unit, a Magnetic field Sensor and three (X, Y, Z) multicore cables which are installed in the room where the field is to be cancelled. The Control Unit drives currents through the cables to create a field of the correct amplitude, phase and direction to null out the ambient field. The magnetic field sensor measures the field and the control loop uses real time negative feedback to create the correct drive currents for the cables.

***SPICER CONSULTING,*** Eden Laboratory, Broadmead Road, Stewartby, Bedfordshire, England MK43 9ND
Tel: +44 1234 765773 Fax: +44 1234 765778 E-mail: enq@spicerconsulting.com Web: www.spicerconsulting.com

## Product Description

The SC12 is a second generation Magnetic Field Cancelling System, designed to improve the performance of electronic instruments that are sensitive to magnetic fields, such as electron microscopes and electron beam metrology tools.

The SC12 system comprises a Magnetic Field Control Unit, a Magnetic field Sensor and three (X, Y, Z) multicore cables which are installed in the room where the field is to be cancelled. A typical installation on an SEM is shown in Fig. 1 below. The Control Unit is not shown.

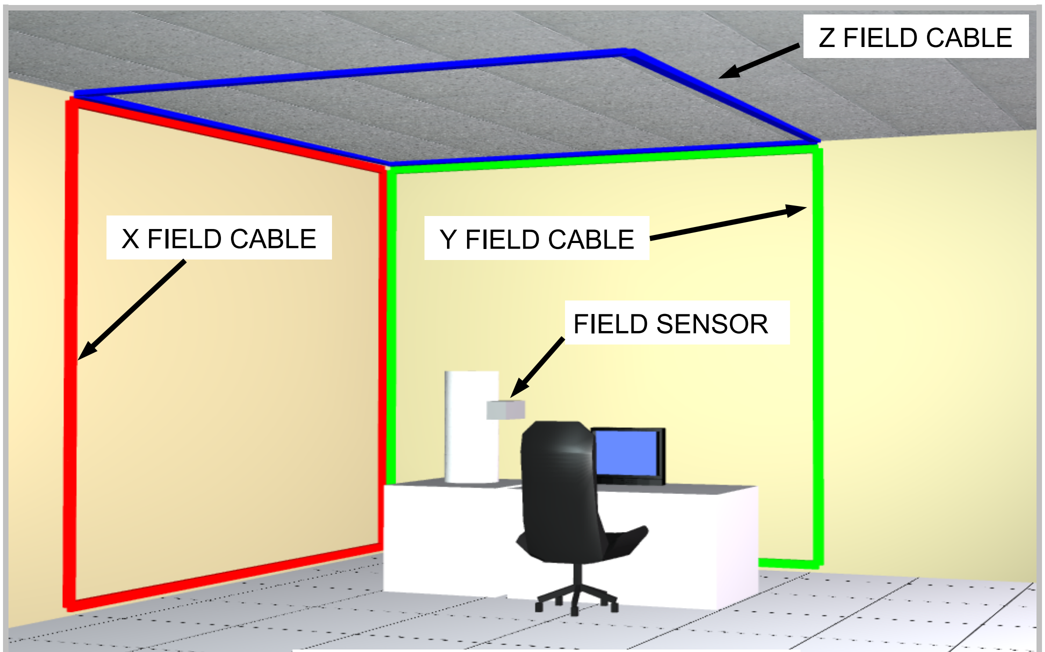


Fig. 1 Typical SEM Room Installation

The cables make one turn and are shown in red, green and blue in Fig. 1 for clarity. The actual cables are grey and usually installed in white plastic conduits. Where the room has a false ceiling, the Z cable is usually installed above it.

The magnetic field sensor is usually located close to the bottom of the electron beam column. It is provided with a mount to enable it to be strapped to the column if required.

The magnetic field control unit contains three power amplifiers which drive currents through the multicore cables to generate the cancelling field. The magnetic field sensor measures the field on X, Y, Z orthogonal axes in real time, then the measured signals are amplified and fed back in anti-phase to the power amplifiers. Hence the system is closed loop and the negative feedback nulls the field at the sensor location. The amount by which the field is reduced is determined by the loop gain of the system, which depends on the details of the installation, but is typically 50 times.

The system does not cancel the earth's magnetic field, nor does it cancel the field everywhere in the room. It creates a region around the magnetic field sensor where the field is much reduced. The volume of this region depends mostly on the gradient of the ambient field, so is bigger when the source of the interfering ambient field is further from the sensor. For applications with nearby sources having large gradients please consult our support staff.

The magnetic field measured by the sensor is continuously monitored and compared with user definable "trip levels" to provide "GO/NOGO" indication of the field quality. A large green LED on the control unit and a smaller LED on the sensor indicate that the field is "OK".

The control unit has a 3.5 digit panel meter to display the measured magnetic field. The real time measured fields are also available as analog voltage levels for oscilloscope or chart recorder display. The SYSTEM SC12/AC can measure and display the true RMS amplitude of AC fields. The SYSTEM SC12/DC can also measure and display the value of incremental changes in the DC field. The panel meter can be switched to display any of the axes.

## The SC12 Control Unit

The functions of the SC12 control unit are shown in detail in Fig. 2 below.

The front panel switches are coloured grey or black. The grey switches control the panel meter and have no effect on cancelling so can be pressed at any time. The black switches will interrupt cancelling so must be used with care.

Most of the grey switches latch mechanically so their state is not lost if the power fails.

The system will start cancelling automatically after power loss. There is a one minute start up delay to allow the magnetic field sensors to settle. Power loss is indicated on the red LED display.

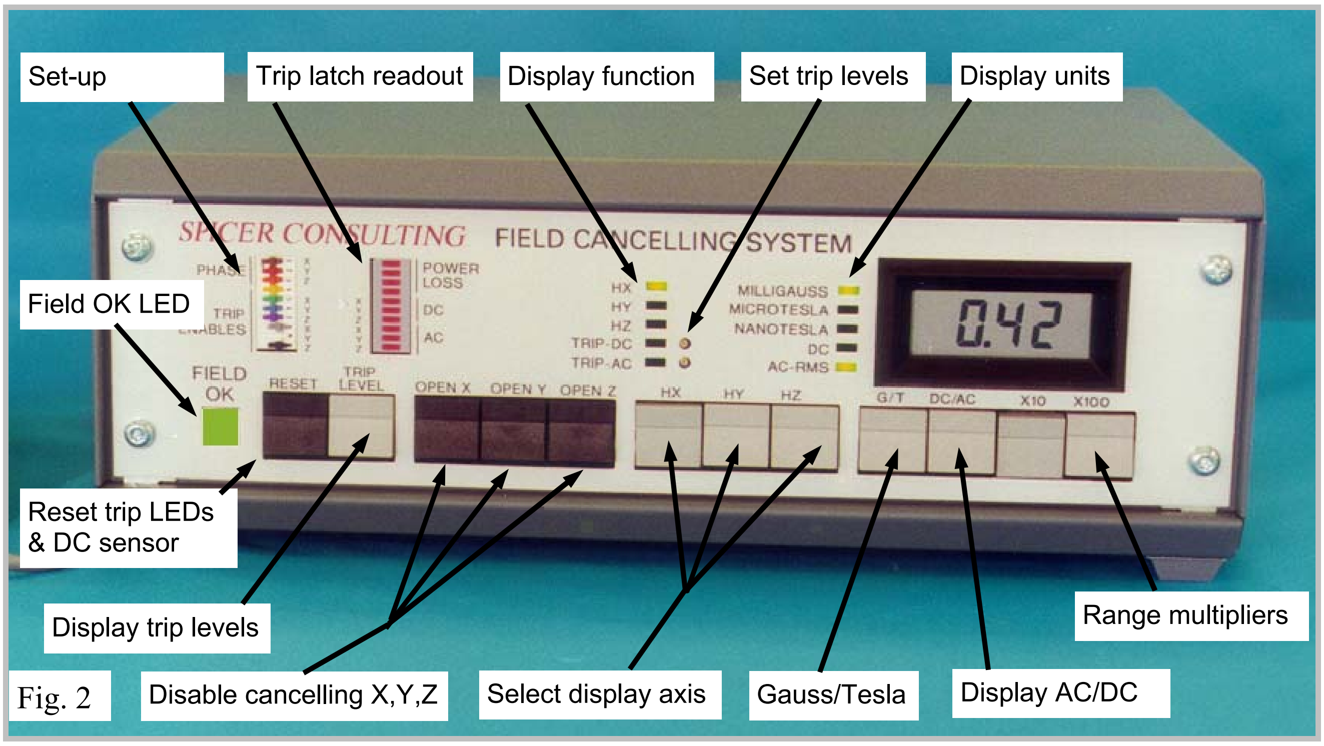


Fig. 2

## Installation options

The SC12 field cancelling cables are made with a loop and a tail. The loop creates the field and the tail (which makes no field) connects the loop to the control unit. The loop part is shown in Fig. 1 in red. green and blue. SC12 “ROOM” cables have X and Y loops 16 metres long and a Z loop 20 metres long. Longer cables are available to special order. The cables must not be shortened.

The installation shown in Fig. 1 is suitable for most SEM applications where the electron beam column is typically 1.5 metres from the room walls. The maximum field which can be cancelled (the dynamic range) depends on the size and position of the cable loops relative to the electron beam column. In Fig. 1. with 5m x 3m X and Y loops and the column 1.5m from the walls the dynamic range is about 25 mG (2.5 µT) pk-pk.

In order to specify the SC12 performance more rigorously, it is necessary to use a reference cable installation geometry.  This is shown in Fig. 3.

The electron beam column is centred in the 3m x 5m X and Y loops (which cross over above and below the column) and the 5m x 5m Z loop. The SC12 specifications on page 6 apply to this reference room installation.

For OEM customers who wish to build the SC12 system into their electron beam tool, cables for Helmholtz coil installation are available. OEM customers should consult Spicer Consulting staff for applications support. Helmholtz cables are not recommended for general applications because the Helmholtz coil configuration requires a custom frame to be built around the electron beam tool, which severely limits access to the tool. The cancelling performance is generally inferior to room cables.

For large TEM’s the cancelled volume is more important and customers are advised to consult our support staff for design of the field cables.

When the room is large and the walls are too far from the electron beam column, or in clean rooms

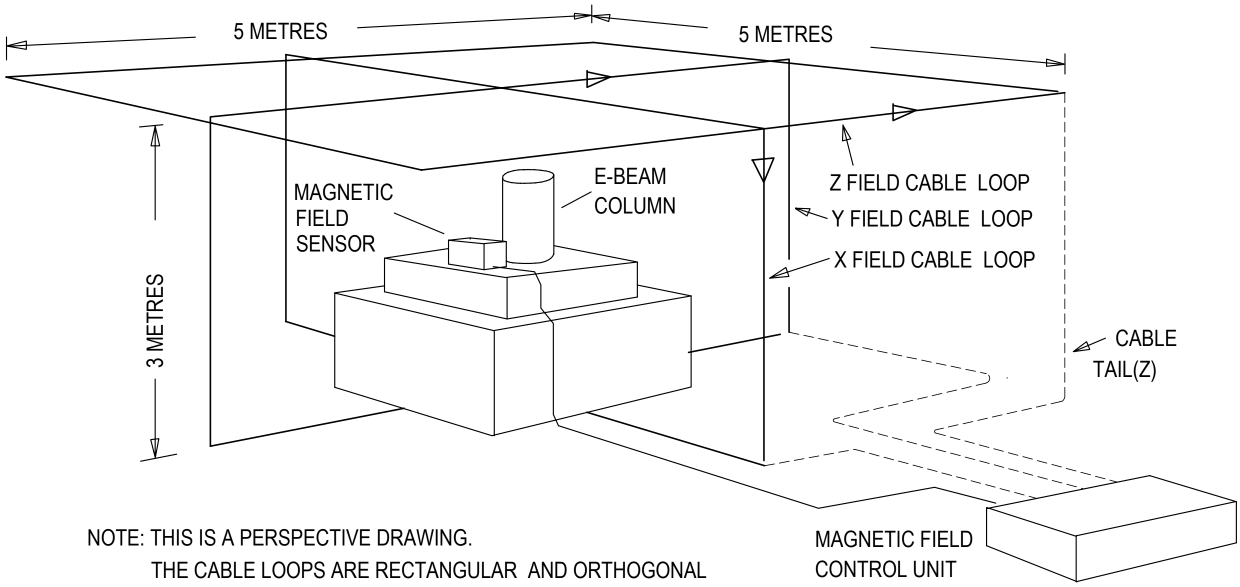



Fig. 3. Reference room installation

where there are no local walls, alternative cable installations are possible. One option which we have used in semiconductor wafer fabs on CD metrology SEMs is to install the field cables under the cleanroom raised floor. The X and Y cables use a flat quadrupole configuration and they are custom designed for the particular installation. The dynamic range is less than the reference installation but the cables are effectively invisible to the customer. A similar cable configuration can be installed above a false ceiling if it is not too high. For these options, please consult our support staff.


Fig. 4 SC20 DC Sensor

**Sensor options**

The magnetic field sensors used in the SC12 are designed and manufactured by Spicer Consulting specifically for field cancelling. A photograph of the SC12 AC sensor is on the front page of this data sheet, the SC20 Wideband DC sensor is shown in Fig. 4. This is a new design for the planned next generation SC20 field cancelling system but it can also be used with the SC12 system.

The most commonly used configuration has one AC sensor as shown in Fig. 1. Multiple sensor configurations are also available. An example is in Fig. 5 which shows two AC sensors installed on a JEOL 200 kV TEM. The sensors are on custom mounts at goniometer height on either side of the column. The magnetic field outputs from the sensors are combined in the mixer unit shown

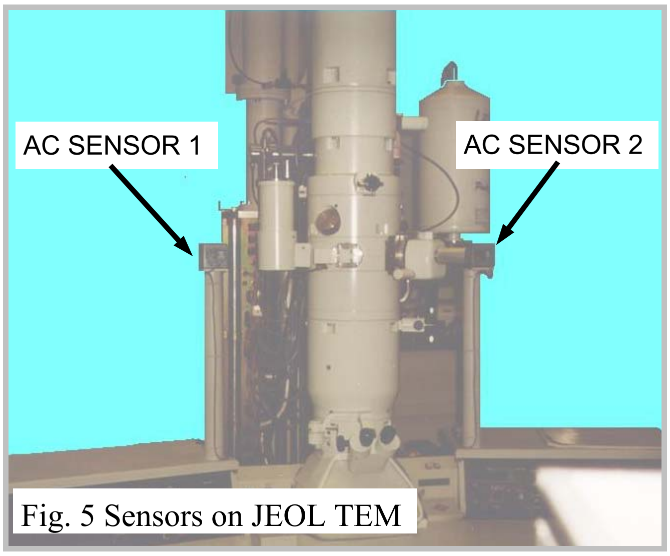



Fig. 5 Sensors on JEOL TEM

in Fig. 6 before sending to the SC12 control unit. This has the effect of creating a “virtual sensor” which can appear to be located inside the column.

Fig. 6. Mixer for 2 sensors


Fig. 7. Hitachi S9360 CDSEM

The mixer controls enable the apparent position of the sensor to be adjusted separately for the X, Y, and Z axes to tune the cancelling system for optimum improvement in the TEM imaging. The same configuration can be used with two SC20 Wideband DC sensors.

Fig. 7 shows a Hitachi S9360 CDSEM. Like most CDSEMs the electron beam column is enclosed in its cabinet along with numerous ion pumps, actuators and the wafer handling robot. The most common problem affecting CDSEMs is low frequency interference from adjacent equipment in the wafer fab, especially plasma etch machines which use a rotating magnet array to stir the plasma and from optical lithography scanners with magnetic drive. The use of two DC sensors with a mixer overcomes the problems of congestion in the cabinet (which makes it impossible to locate the sensors anywhere near the column) and gradients in the interfering field. The mixer is used to tune the image movement caused by the interfering field to a minimum. Installation on CDSEMs requires considerable skill in applying the SC12. For this application please consult our support staff.

**Application examples**

Examples of sensor locations on JEOL and LEO SEMs are shown in Figs. 8 and 9.

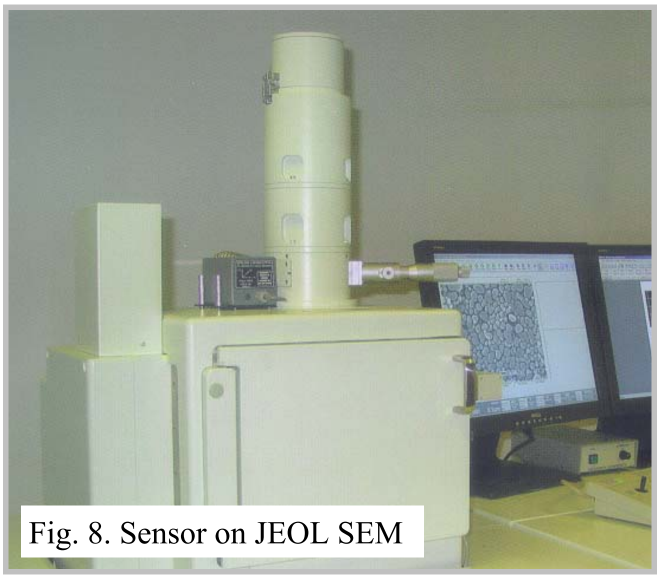


Fig. 8. Sensor on JEOL SEM

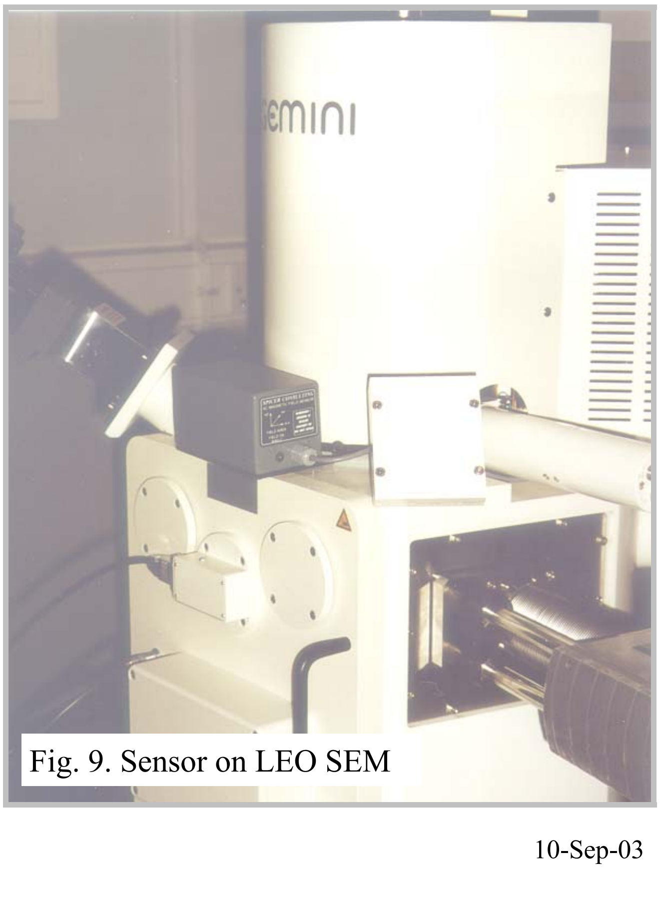


Fig. 9. Sensor on LEO SEM

**Disclaimer**

Mechanical vibration, acoustic noise and ground loops in the electron beam tool installation can produce imaging defects similar to magnetic fields. The SC12 system cannot improve images which are affected by these other interfering sources because they are not magnetic fields.

## Specifications

| | |
|---|---|
| **CO-ORDINATE SYSTEM** | X, Y, Z rectangular Cartesian |
| **UNITS** | Gauss, Tesla (switchable) |
| **FIELD CANCELLING** | |
| ***1. Basic SC12AC system*** | |
| Components cancelled | X, Y, Z field components |
| Dynamic range | 50 mG (5 µT) pk-pk per axis (with ref. installation Fig. 3) |
| Field reduction ratio | 50 X (typical) at 50/60 Hz |
| Bandwidth | 0.5 Hz - 5000 Hz |
| Detector noise limit | 2 µG (0.2 nT) pk-pk |
| ***2. With SC20 Wideband DC sensor*** | |
| Ambient DC field | ± 2 G (± 200 µT) max |
| Dynamic range | ± 25 mG (± 2.5 µT) incremental, per axis (with ref. installation Fig. 3) |
| Field reduction ratio | 50 X (typical) at 50/60 Hz<br>100 X (typical) at DC (incremental) |
| Bandwidth | DC - 2500 Hz |
| Noise and drift | DC drift/24 hours < 100 µG (10 nT) after 2 hour warm-up<br>DC noise (0.0001- 0.01 Hz) 30 µG (3 nT) pk-pk (typical)<br>Spot noise (at 50 Hz) 1 µG /√Hz (0.1 nT/√Hz) |
| **FIELD MEASUREMENT** | |
| Types | Real time field<br>AC - true RMS amplitude<br>Incremental DC (with DC sensor) |
| Display | |
| RMS & DC | 3.5 digit LCD panel meter |
| Sensor dynamic range | 40 mG pk-pk |
| Meter ranges | X 1 range 0 - 1.999 mG (199.9 nT) RMS<br>± 1.999 mG (199.9 nT) DC<br>X 10 range 0 - 19.99 mG (1.999 µT) RMS<br>± 19.99 mG (1.999 µT) DC<br>X 100 range 0 - 199.9 mG (19.99 µT) RMS<br>± 199.9 mG (19.99 µT) DC |
| Accuracy | |
| RMS | ± 1.0 % of reading ± 3µG (0.3 nT) |
| Incremental DC | ± 5.0 % of reading |
| Real time field monitor | |
| | Signals X, Y, Z, real time field<br>Scaling 500 mV/mG<br>Range ± 10 Volts<br>Source resistance 10 kΩ<br>Connectors 3 x BNC<br>Bandwidth 5 Hz - 20 kHz (AC sensor )<br>DC - 5 kHz (DC sensor) |
| Trip Range Adjustments | |
| | AC-RMS 0 - 2.0 mG (200 nT)<br>DC 0 - 5.0 mG (500 nT) |
| **POWER** | 120/240 V 50/60 Hz, 50 VA |