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Operating Instructions

MS 300 - 3 Axis THREE-AXIS HELMHOLTZ COIL SYSTEM

Preserve for future application!

BA - No.: 1580030102

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General description

The *MS 300 – 3 Axis Helmholtz coil-set* is a Coil designed for laboratory use. Its specifications are on Page 11.

Figure 1: A view from the *MS 300 – 3 Axis* coil-set.

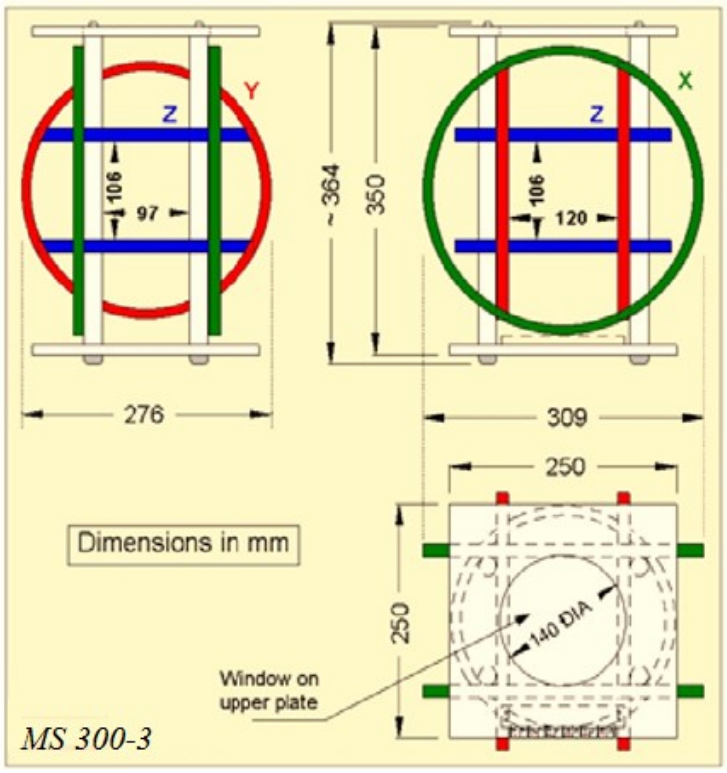

Figure 2: Main dimensions of the MS 300 – 3 Axis coil-set (in mm)

• Assembly

It is not required. The coil-set is supplied ready to be used.

Coil-set installation

Normally, a basic aspect to be considered when installing a device of this type is that this must be sited far enough from ferromagnetic masses, since these could alter in excess the field at the coils centre. The acceptable distances depend on the sensibility of the experiments and measurements to be performed, as well as on the volume and shape of the said ferromagnetic masses.
Due to the previously mentioned it is also convenient to use a table totally constructed from non-ferromagnetic materials, such as wood or aluminium, in order to install the coil-set on its top.
The table might be strong and rigid enough to safely withstand the coils and to prevent these from oscillating, since oscillations could affect some sensitive magnetic measurements.

The coil-set has four fixed anti-slip feet, fastened with the same screws that are fixing the lower plate.

To pick-up the coil-set it must not be grasped by the coils as these, or their brackets, could get damaged.

Both hands must be used to catch it by its lower or upper plate, or both.

• Circuit description

Each coil from a pair is identified with the "***a***" letter or with the "***b***" letter. In this way, for example, the ***X*** pair is formed by the ***X-a*** and ***X-b*** coils.
By other hand, the aluminium form of each coil makes a loop itself and also it is used as if it were a one-turn coil, with its respective independent connections on the terminal block *(CON1)*. These coils are called with the "***s***" suffix, so the ***X*** pair is associated to the ***Xs*** pair, for example.
We call this way of electrical use for the coil forms as "In Circuit Coil Forms", by which the versatility of the coil assembly is increased.
The following drawing illustrates the previous. This is just a simplified diagram only for the *X* pair, but it is equally valid for the *Y* and *Z* pairs. A complete diagram can be found on page 10.

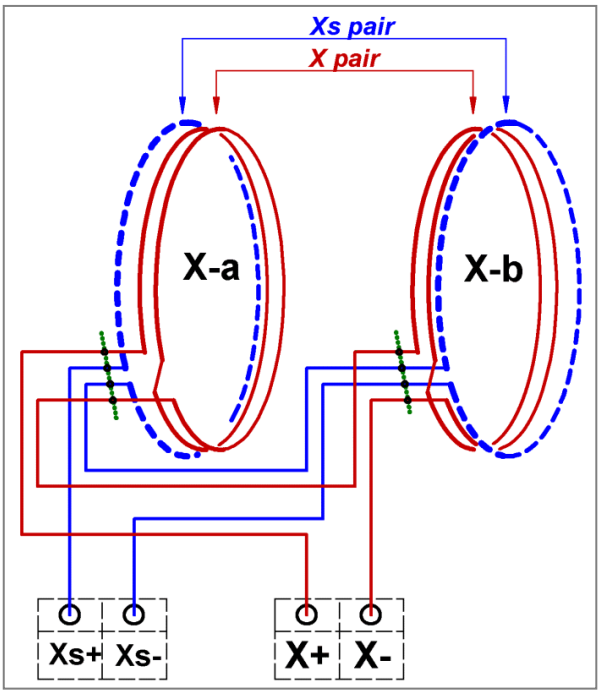

Figure 3: Simplified wiring diagram.

The indicated polarities are a convention adopted for the field direction. When the power supply is connected according to these polarities the direction of the generated fields is as it is shown in the following Figure 4.

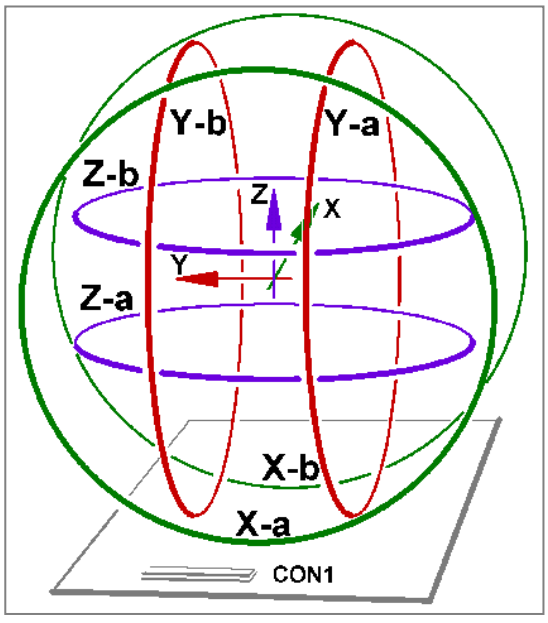

Figure 4: Direction of the fields generated with the polarity indicated on the terminal block.

If a compass is located at the coils centre and fields are generated with the polarity as indicated on the terminal block, the compass will point North in the arrows direction.

• Basic coil-set use

The *CON1* terminal block located at the assembly base is used for the current supply of each pair of coils (see Fig. 5).

Each coil pair will generate in air a field of 500 µT (microTesla) for each Ampere of input current at its centre. It is equivalent to a Magnetising Field of 398 A/m per Ampere.

For a current of 1 A to pass by a coil pair it is necessary to apply a voltage of 2.7 to 4.2 V, approximately. Each coil pair has a resistance slightly different (see "Specifications"), which furthermore varies with temperature. It must be taken into account that the copper wire resistance increases substantially when coil temperature raises, for what constant current power supplies are more suitable than constant voltage power supplies, generally.

It is normal that the coils get hot with the current. This heating is noticeable from about 3 Amperes per pair. Above of about 4 A the coils can produce pain when touched.

With the higher admissible currents the coils can burn the skin if touched!

The coils do not have any protecting device against excessive currents. The currents as indicated on the specifications must not be exceeded.

• The forms as secondary coils:

As it was explained on "Circuit description", each one of the aluminium forms is used as a one-turn coil. The coil-set is supplied with the forms connected between them making extra Helmholtz pairs (or secondary pairs), whose connections are found at the *CON1* terminal block (see Fig. 5). The forms from the ***X*** pair make the ***Xs*** pair, the ***Y*** pair has the ***Ys*** associated pair and the ***Z*** has the ***Zs***.

The pairs constituted by the forms can be powered independently from the main pairs. In this way they can be used, for example, to modulate the field generated by the main pairs.

*Maximum admissible current for every secondary pair circuit is of **10 A,** in a sustained way.*

The field generation ratio for each forms pair can be seen in "Specifications", on page 11.

The aluminium forms also work as screens (shields) for electrical fields. This function could be especially useful for noise suppression when the coils are used as a detector for magnetic flux variations. This is the case, for example, when the magnetic moment of a magnet is measured, a quite usual application for Helmholtz coils.

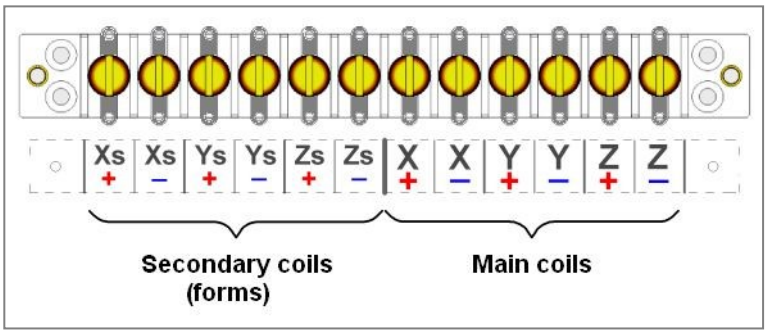

Figure 5: Distribution of terminals at *CON1* terminal block for *MS 300 – 3 Axis coil-set*

- Its use with alternate current

The coils can be supplied with alternate current until some kHz, taking always into account the reactance due to its inductance. At 50 Hz (or 60 Hz, in according to the geographical area) these could be powered by simple transformers (plus an in serial current limiting resistance, if necessary). Some signal generators and suitable amplifiers for almost pure inductive loads would be necessary for other frequencies.
For the higher frequencies it is sometimes suitable to make a resonant circuitry by connecting capacitors, in parallel or in series, to a coil pair.
Alternating voltages to 500 V *peak-to-peak*, equivalent to 178 V *rms* in case of a sinusoidal voltage, can be applied to *MS 300 – 3 Axis coil-set* pairs, provided that the maximum current *rms* as specified (the same as for direct current) is not exceeded. The voltage to be applied for a certain current would depend on the voltage frequency.
In case to be supplied with current pulses, the maximum voltage amplitude of the pulses must be of 250 V *peak*, positive or negative.
When the coils are used with alternate current, it is very important not to have the coil pairs constituted by the aluminium forms short-circuited at its *Xs*, *Ys* and *Zs* terminals (for example: *Xs+* connected to *Xs-*). If they were short-circuited, or with a very low impedance among their terminals, a current circulation will be induced in those pairs, what could alter substantially the fields generated by the main pairs (*X*, *Y* or *Z*).

Warning:
Beware when alternate or pulsing magnetic fields are generated at higher intensities.

- Some alternative uses
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- **As a gradient generator:**

It is possible to generate lineal magnetic gradients at the coils centre. For this it is necessary to invert the connections for one of the coils of the proper pair. This configuration of the coils is often called “anti-Helmholtz”.
For example: for the *X* pair the *X*+ and *X*- connections on *CON-Xa* might be inverted. Alternatively the inversion could be done on *CON-Xb*.
An equivalent operation can be performed for the other axes.

With small superimposed gradients:

It is possible to generate small gradients superimposed to the main homogeneous fields, on every axis, by using the pairs made up by the aluminium forms (working as one-turn coils).
For this, the wires from one coil must be inverted on its connection plate (*CON-Xa*, for example) for to get the anti-Helmholtz configuration, by what a gradient will be generated when current is passing by this pair. This wire inversion is shown in the following Figure 6, which can be compared with the standard configuration in Figure 3 (Page 5).

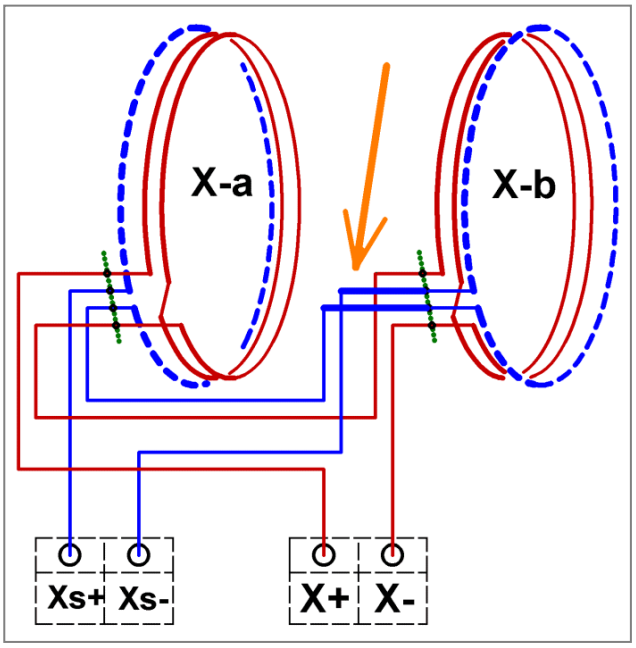

Figure 6: “Anti-Helmholtz” wiring for the ***Xs*** pair. The arrow indicates the modified connections (thicker blue line) in respective to the standard circuit in Figure 3.

Even though the gradient so generated will be small with moderate currents, because these are one-turn coils, it could be enough in some cases.
An example could be when the terrestrial magnetic field cancellation in a very high degree is attempted on a volume. Sometimes this is impossible with Helmholtz coils due to the presence of small gradients created by field distortions caused by building ferromagnetic structures, nearby machinery, etc. In such a case the generation of small gradients, with the right magnitudes, superposed to the Helmholtz coil field can help to improve the final homogeneity at the coil-set centre.

That anti-Helmholtz connection, or any other wiring modification of the set, will make the warranty void.

- **As sensing coils:**

It is frequent the use of Helmholtz coils as sensors for the measurement of magnetic flux variations. A typical example is in the measurement of the Magnetic Moment of a magnet (or some magnetised piece).
When the *MS 300 – 3 Axis coil-set* is used in this way, the produced signal for each axis will be available on *CON1* terminal.
Sensitivity is very similar on the three axes.
It must be noted that the *MS 300 – 3 Axis coil-set* is not optimised for this use, due to what it would produce a signal lower than those from a coil-set designed for that purpose, which would have a much larger number of turn of a much thinner wire.

Centring aids

There *is* a M6 (6 mm) threaded hole centred in the lower board, which can be used to fix a stand. See Fig. 7.
At the centre of the pillars there is a groove around its perimeter to help in localising the central plane of the set. The line of sight in between two grooves on opposite pillars is on the said central plane. See Fig. 7.

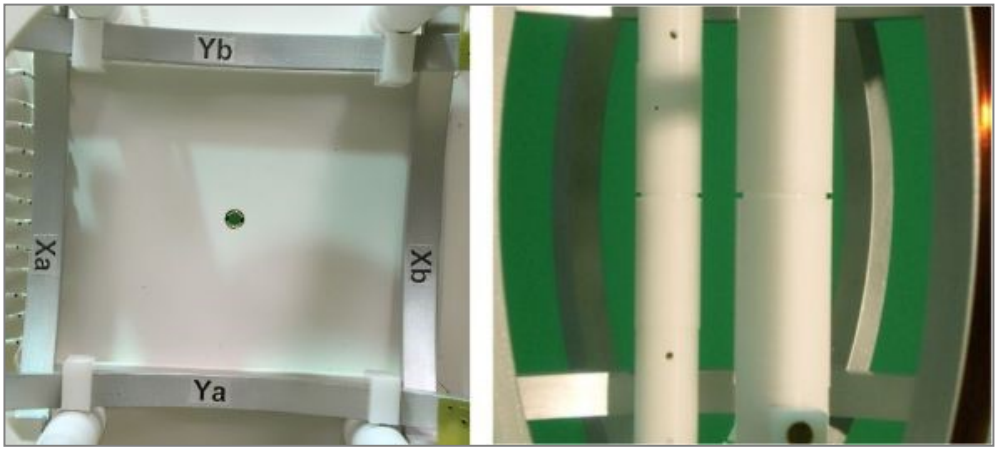

Figure 7: Centring aids.

Wiring diagram

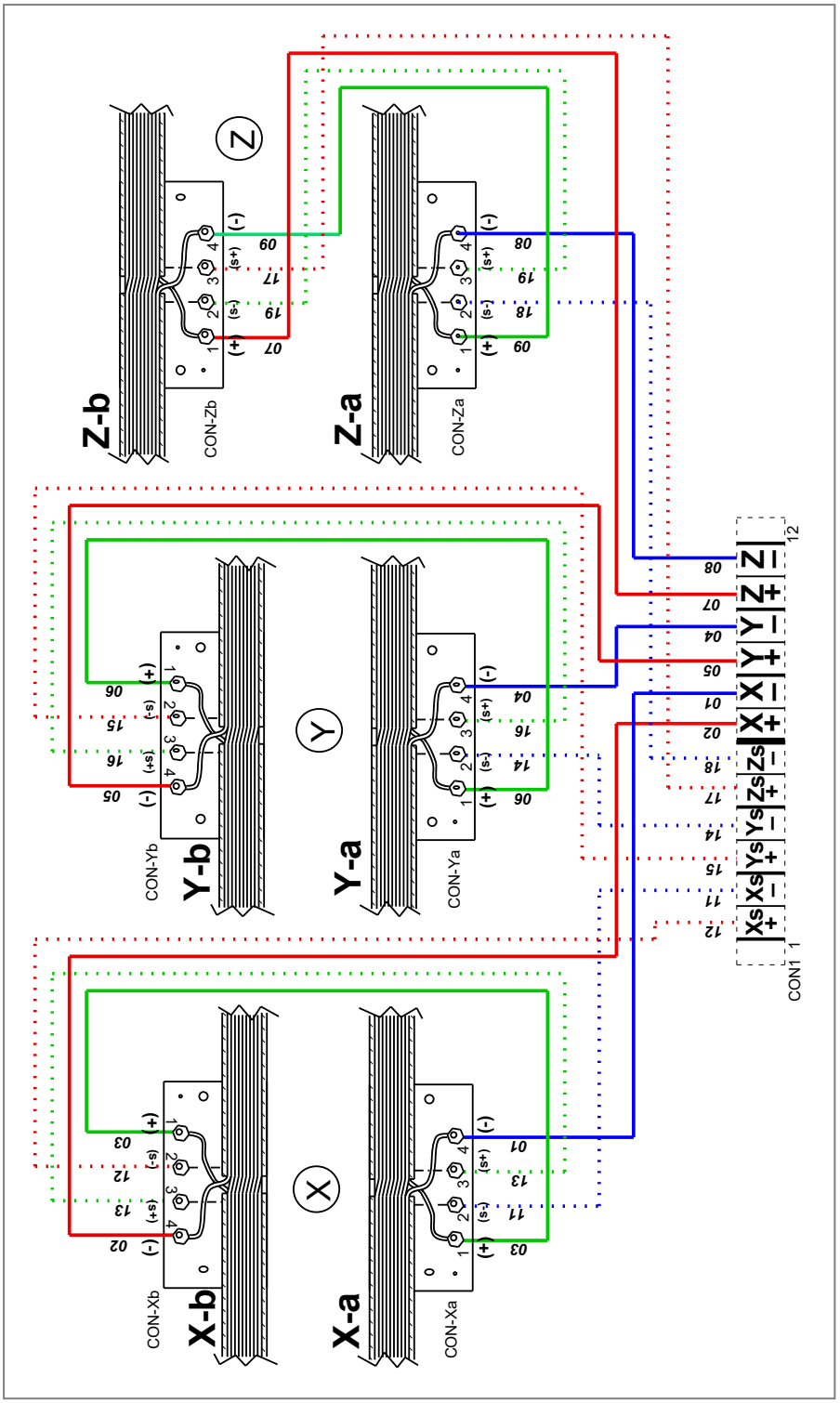

Figure 8: General wiring diagram for the *MS 300 – 3 Axis coil-set*

- Specifications

Coil-set specifications

• **Field/Current ratio**	Approx. 500 µT/A (5.00 Gauss/A; 398 Am/A), for each X, Y or Z pair. Error: ±1 %, maximum.
Maximum field	2.0 mT (20 Gauss) in a permanent manner for each pair. Around 3.0 mT (30 Gauss) during 2 minutes.
Maximum admissible current	4.0 A in a permanent manner for each pair. Around 6 A for 2 minutes.
Isolation voltage	250 V DC minimum, in between windings and forms and in between coil pairs. Tested: at 500 V DC ($R_{isolation}$ >2 GΩ).
Field homogeneity	Differences smaller than ±1 %, in respective to the centre, in a spherical volume of 70 mm in diameter, coils centred. Differences smaller than ±5 % in a spherical volume of 100 mm in diameter. These volumes to 1% and 5% are larger on some directions.
Orthogonality error	< ± 0.2º.
Connections	Terminal block with 4 mm (M4) screws.
Max. working temperature	80 ºC for the coil-set. 100 ºC for the windings.
Coils section	Windings: 8.5 x 10 mm, maximum. Total (forms): 10 x 13 mm.
Materials	Windings in enamelled copper wire and epoxy resin filled. Coil forms in aluminium alloy. Coil terminals plates in epoxy resin/glass fibre (FR4) with covers in PVC. Lower and upper support plates in foamed PVC. Supporting pillars and brackets in Acetyl. Screws in brass and Nylon.
Maximum dimensions	Height 364 mm x Width 309 mm x Depth 276 mm.
Weight	5 kg
Accessoires	Measuring Report

Specifications for each coil pair

	X Pair (larger)	**Y Pair (medium)**	**Z Pair (smaller**
Effective diameter	300 ±1 mm	266 ±1 mm	237 ±1 mm
Number of turns (per coil)	83	74	66
DC resistance, at 20 ºC **(1)**	4.21 Ω ±3 %	3.35 Ω ±3 %	2.66 Ω ±3 %
• **Self-inductance**	10.4 mH ±5 %	7.1 mH ±5 %	4.9 mH ±5 %
Self-resonance frequency - with external 50 pF in parallel (with one of the form terminals wired to one of the coil terminals. Example: *Xs-* to *X-*) **(2)**	~ 25 kHz	~ 34 kHz	~ 42 kHz
Field as generated only by the forms when used as coils (Xs, Ys, Zs) **(3)**	6.0 µT/A ±3 %	7.1 µT/A ±3 %	7.7 µT/A ±3 %

(1) – Resistance values as measured at *CON1* terminal block.
(2) – This frequency in higher without any wiring in between coil and form, or "floating" windings.
(3) – We call this concept "*In Circuit Coil Forms*". See "Circuit Description" on page 2.

- These specifications are subject to future changes without prior notice -