

Model 6400 Series

Helmholtz Coil

User Manual



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An ESCO Technologies Company

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A	Initial Release	December, 2001
B	Updated title to reflect series. Revise to current style standards. Removed filter addendum, add filter information as a numbered section	June, 2009
C	Update table format in Section 3, Specifications. Update measurement in Section 5, Operation from 2.45 cm to 2.54 cm	April, 2011

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Notes, Cautions, and Warnings

	Note: Denotes helpful information intended to provide tips for better use of the product.
	Caution: Denotes a hazard. Failure to follow instructions could result in minor personal injury and/or property damage. Included text gives proper procedures.
	Warning: Denotes a hazard. Failure to follow instructions could result in SEVERE personal injury and/or property damage. Included text gives proper procedures.

 See the ETS-Lindgren *Product Information Bulletin* for safety, regulatory, and other product marking information.

1.0 Introduction

ETS-Lindgren Model 6400 Helmholtz Coils create an extremely uniform low frequency magnetic field between and in the center of the coils. The generated field can be applied as a magnetic field immunity test system or a low frequency calibrator. The strength of the magnetic field generated is directly proportional to the number of turns in the coils and the current applied to them. The coils are wound in series so that the magnetic field produced by current flowing in one coil aids the field in the other coil. The windings on all standard Helmholtz coils are wound of insulated magnet wires. The wire gauge varies depending upon the model of the coil system and details are found in the Specification section of this manual. The maximum current of a custom Helmholtz coil is determined by the wire gauge.

Several of the Helmholtz coils are equipped with a rotatable, adjustable-height pedestal capable of supporting equipment under test (EUT) in the center of the assembly base. Equipment which is exposed to the homogenous magnetic field should be placed on the equipment test table with the height adjusted so that the center of the equipment is closely aligned with the axis of the coils.

Ferromagnetic objects within the cylindrical volume of the coil tend to distort the magnetic fields in areas near the object. The coil system has been constructed with minimal metallic components limited to the copper conductors, the electrical connectors and the caster frames. The casters, however, are outside of the coil cylinder and cause practically no field disturbance.

Precision in the manufacture of the coils and their support assembly are well within a design tolerance of 0.5 cm (0.2 in) in both radius and axial separation. The limit of this tolerance would produce a maximum error of 0.55% in the accuracy of the magnetic field constant under the worst conditions. For this reason the Helmholtz coil is considered a standard and produces a magnetic field whose accuracy is governed by the accuracy of the current monitoring equipment.

Model 6406S or Split Base Helmholtz Coils

A standard ETS-Lindgren Helmholtz coil consists of two identical circular coils placed in parallel and spaced one radius apart. The coils are both mounted to a single base with an adjustable pedestal placed in the center to position the EUT. Some EUT's, however, do not fit conveniently on the pedestal. In these instances a split base option may be ordered. Each coil is mounted on a separate wheeled base for positioning on either side of the EUT, such as an automobile.

The Model 6406S Helmholtz Coil consists of two coils secured on separate base mounts in the Helmholtz configuration which can be used as a low frequency calibrator. The coil provides a magnetic field which is essentially homogenous throughout the volume of a 0.60 meter (2 foot) cylinder in its center. The coil forms are rigidly supported by a nonmetallic, nonmagnetic framework. The supplied cable assembly and proper orientation of the coils insures that the Helmholtz coil system is arranged in the series-aiding configuration.

ETS-Lindgren Product Information Bulletin

See the ETS-Lindgren *Product Information Bulletin* included with your shipment for the following:

- Warranty information
- Safety, regulatory, and other product marking information
- Steps to receive your shipment
- Steps to return a component for service
- ETS-Lindgren calibration service
- ETS-Lindgren contact information

2.0 Maintenance

CAUTION

Before performing any maintenance, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.



Maintenance of the Helmholtz coil is limited to external components such as cables or connectors.

Clean the exterior of the coil using a damp cloth and mild cleaner. Always unplug the unit before cleaning.

If you have any questions concerning maintenance, contact ETS-Lindgren Customer Service.

Maintenance Recommendations

Maintenance is limited to periodically cleaning the coil with a clean, damp cloth.

Annual Calibration

See the *Product Information Bulletin* included with your shipment for information on ETS-Lindgren calibration services.

Service Procedures

For the steps to return a system or system component to ETS-Lindgren for service, see the *Product Information Bulletin* included with your shipment.

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3.0 Specifications



Currents higher than the "Maximum Current Input" listed may be used if the appropriate duty cycles are applied



See table in Appendix B for conversion to Gauss/Ampere

	Model 6402	Model 6402M
Type	Mono-axial	Mono-axial
Coil Radius	30.5cm (12.0 in)	30.5cm (12.0 in)
Turns Per Coil	36	5
Gauge (AWG)	10	20
Coil Factor (Amperes/Meter/Ampere)	84.3	11.14
Coil Factor (Gauss/Amperes)	1.06	0.14
R (Ohms DC)	0.5	0.7
L (mH)	3.5	70
Max Continuous Field (Gauss)	21.2	1.5
Max. Current Input (Amperes Continuous)	20	10
Self Resonance (kHz)	32	500
Homogeneity	±10% within a 19.8cm cylinder	±10% within a 25.4cm cylinder
Mating Connector	MS3106, A-20- 09S	BNC

	Model 6403	Model 6404
Type	Mono-axial	Mono-axial
Coil Radius	45.7cm (17.9 in)	60.9cm (23.9 in)
Turns Per Coil	25	56
Gauge (AWG)	10	10
Coil Factor (Amperes/Meter/Ampere)	39.79	65.25
Coil Factor (Gauss/Amperes)	0.50	0.83
R (Ohms DC)	2.5	1.5
L (mH)	40	19
Max Continuous Field (Gauss)	10	16.5
Max. Current Input (Amperes Continuous)	20	20
Self Resonance (kHz)	40	40
Homogeneity	±10% within a 23cm cylinder	±10% within a 40cm cylinder
Mating Connector	MS3106, A-20- 23S	MS3106, A-20- 09S

	Model 6406	Model 6406S	Model 6408
Type	Mono-axial	Mono-axial	Mono-axial
Coil Radius	91.4cm	91.4cm	115.0cm
Turns Per Coil	64	110	64
Gauge (AWG)	10	6	10
Coil Factor (Amperes/Meter/Ampere)	50.06	86.04	39.79
Coil Factor (Gauss/Amperes)	0.63	1.08	0.50
R (Ohms DC)	2.5	1.7	3.0
L (mH)	45	100	64
Max Continuous Field (Gauss)	12.6	43.2	10
Max. Current Input (Amperes Continuous)	20	40	20
Self Resonance (kHz)	43	4	>10
Homogeneity	±10% within a 0.6m cylinder	±10% within a 0.6m cylinder	±10% within a 0.7m cylinder
Mating Connector	MS3106, A-24- 09S	MS3106, A-24- 09S	MS3106, A-24-09S

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4.0 Theory of Operation

CAUTION

Before operating any components, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.

The basic premise of a Helmholtz coil is that it produces a homogeneous magnetic field in its center which is directly proportional to the number of turns in the coils and the current applied to them. A Helmholtz coil is a parallel pair of identical circular coils spaced one radius apart and wound so that the current flows through both coils in the same direction. The winding results in a very uniform magnetic field between the coils with the primary component parallel to the axes of the two coils. The uniform field is the result of the addition of the two field components parallel to the axes of the two coils and the difference between the components perpendicular to the axes. The primary purpose of this device is to provide a uniform, low frequency magnetic field for susceptibility testing of electronic equipment.

The magnetic field strength (H) produced by a given AC or DC current through the coil pair is given approximately by the formula

$$H \approx 0.899 \frac{NI}{R}$$

- H is the magnetic field in oersteds
- N is the number of turns per coil
- I is the coil current in amperes
- R is the coil radius in centimeters

In SI Units, this becomes the formula where

$$H \approx 0.715 \frac{NI}{R}$$

- H is the magnetic field in amperes per meter
- N is the number of turns per coil
- I is the coil current in amperes
- R is the coil radius in meters

If instead of magnetic field intensity (H) the magnetic flux density (B) is the parameter of interest the equation, when expressed in CGS units, becomes

$$B = \mu H \approx 0.899 \mu \frac{NI}{R}$$

- B is the magnetic flux density in gauss
- μ is the relative permeability
- N is the number of turns per coil
- I is the coil current in amperes
- R is the coil radius in centimeters

In SI units, the relationship is given by

$$B = \mu\mu_0 H \approx 8.99 \times 10^{-7} \mu \frac{NI}{R}$$

- B is the magnetic flux density in teslas
- μ is the relative permeability
- μ_0 is the permeability constant
- N is the number of turns per coil
- I is the coil current in amperes
- R is the coil radius in meters

For the unloaded coil, the relative permeability, μ , is one, so that $B = H$ in CGS units, and $B = \mu_0 H$ in SI units.

Refer to Appendix B: Conversion Table for Magnetic Units for more unit conversions.

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5.0 Operation

CAUTION


Before operating any components, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.

CAUTION

If high driving current is required at a high frequency, take precautions to avoid shock or burn from the high voltages developed across the reactive elements.

Helmholtz Coil Placement


Place the Helmholtz coil in a space relatively free of metal objects and structures. This will insure a minimum of distortion and the best possible homogeneity of magnetic fields within the test volume.




Push the coil assemblies into position by holding the coil section of each assembly. Do not push the coil assemblies using the thermoplastic support rods.

Helmholtz Coil EUT Table

For units equipped with an adjustable table, the table should be set at the desired height before placing the test item on it. To adjust the table height, first loosen the clamp screw(s) and then move the table height up or down to the desired level. Hand-tighten the clamp screw(s). The table can be lifted off of the platform to accommodate larger EUTs. Simply remove the plastic support screws on the floor of the coil platform that attach the table and gently lift and remove the table.



The marks on the support column are spaced 2.54 cm (1 inch) apart for reference. A mechanical stop limits the table travel within its lowest and highest position.



The top of the table is within 2.54 cm (1 inch) of the coil system axis when the lowermost inch mark is at the top of the base column.

Limit the weight of the equipment placed on the table to the coil specifications in the chart that follows. Center the EUTs mass over the center of the base. Do not lubricate the support column, but keep the column clean by periodically cleaning with a clean, damp cloth.

Model	Weight Limit
6402	18 kg (40lb)
6402M	4.5 kg (10lb)
6403	18 kg (40 lb)
6404	34 kg (75 lb)
6406	34 kg (75 lb)
6406S	Split base, no table
6408	34 kg (75 lb)

With the exception of the wire, connectors and casters (if equipped) the entire coil structure is made of non-conductive, non-magnetic materials. Handle the structure carefully at all times, taking precautions to avoid subjecting it to thermal or mechanical shock.

Adding Power to the Helmholtz Coil


When connecting the AC or DC current source for driving the Helmholtz coil magnetic field generator coil, be sure the connecting leads are of sufficiently heavy gauge to handle the required current. For example, AWG 10 wire is required for 20 amperes, based on a rule of thumb of 500 circular mills per ampere. Also be certain that there is good mechanical bonding between connecting leads to both the current source and the Helmholtz coil input connector.

The coils are wound with #10 AWG copper wire so that they may be driven with 20 amperes continuously for generating magnetic fields up to 10 gauss. Lower intensity fields may be generated by using a calibrated current supply or by monitoring the voltage across a series resistor. The Models 6402M, 6406S and certain custom coils are not wound with #10 AWG, therefore power should be applied to correlate with the wire gauge.

Magnetic fields greater than one gauss may be generated at frequencies from DC to 200 Hz. However, if higher frequencies are required, the coil impedance will require fairly high driving voltages to drive enough current through the coil in order to reach the desired field intensity. In certain cases, it may be necessary to series resonate the coil if high driving current is required at a high frequency. If this is the case, take precautions to avoid shock or burn from the high voltages developed across the reactive elements.

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Appendix A: Warranty

 See the *Product Information Bulletin* included with your shipment for the complete ETS-Lindgren warranty for your Helmholtz Coil System.

DURATION OF WARRANTIES FOR A HELMHOLTZ COIL SYSTEM

All product warranties, except the warranty of title, and all remedies for warranty failures are limited to two years.

Product Warranted	Duration of Warranty Period
Helmholtz Coil System	2 Years

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Appendix B: Conversion Table for Magnetic Units

	To Convert From				
	Unit System:	SI (MKS)		CGS	
	Magnetic Quantity:	<i>B</i>	<i>H</i>	<i>B</i>	<i>H</i>
	Units	tesla	amp-turn/m	gauss	oersted
					gamma
To	tesla	1	$4\pi \times 10^{-7}^\dagger$	10^{-4}	10^{-4}^\ddagger
	amp-turn/m	7.96×10^{54}	1	79.57747^\dagger	79.57747
	gauss	10^4	$4\pi \times 10^{-3}^\ddagger$	1	1^\ddagger
	oersted	10^{44}	$4\pi \times 10^{-3}$	1^\ddagger	1
	gamma	10^9	$4\pi \times 10^{21}$	10^5	10^{57}
Multiply by above value					

[†] Assumes $\mu = 1$; if $\mu \neq 1$, multiply by value of μ to convert from *H* to *B*.

[‡] Assumes $\mu = 1$; if $\mu \neq 1$, divide by value of μ to convert from *B* to *H*.

1 tesla \equiv 1 weber/m².

For example,

1 tesla = 10^4 gauss.

1 gauss = 79.6 ampere-turns/m in an unloaded coil ($\mu = 1$).

If $\mu = 2.50$, 1 tesla = $7.96 \times 10^5 / 2.50 = 3.18 \times 10^5$ amp-turns/m.

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