Helmholtz Coil

MANUAL

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INTRODUCTION

EMC Test Systems 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 ETS Helmholtz coils are made of AWG-10 wire providing a maximum current no greater than 20 Amperes with the exception of the Model 6402M, which is designed specifically for Metrology applications and the 6406S split base unit (see the "Specifications" section for coil details). On custom Helmholtz coils, wire gauge determines the maximum current.

Several of the Helmholtz coils are equipped with a rotatable, adjustable-height pedestal capable of supporting EUT's 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. These 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 0.635 centimeter (0.250 inch) 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.

This manual covers Models 6402, 6403, 6404, 6406, 6406S and 6408. The Model 6406S and 6408 have additional, model specific, assembly and operation instructions included in a special section.

THEORY OF OPERATION

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. This winding results in a very uniform magnetic field between the coils with the primary component parallel to the axes of the two coils. This 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:

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

where: *H* is the magnetic field in oersteds,
N is the number of turns per coil,
I is the coil current in amperes,
and
R is the coil radius in centimeters.

In SI units, this becomes:

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

where: *H* is the magnetic field in amperes per meter,
N is the number of turns per coil,

I is the coil current in amperes,

and

R is the coil radius in meters.

In terms of magnetic flux density, B, also sometimes called magnetic induction, these formulas become:

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

in CGS units, where:

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,

and

R is the coil radius in centimeters.

In SI units, the relationship is given by:

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

where: 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,

and

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 the "Conversion Table for Magnetic Units" at the back of this manual for more unit conversions.

OPERATING INSTRUCTIONS

The following practices should be adhered to in using and maintaining Helmholtz coils:

1. 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.

2. 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), 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 equipment under test. Simply remove the plastic support screws that attach the table, on the floor of the coil platform, and gently lift and remove the table.

   NOTE: *The marks on the support column are spaced 2.45 centimeters (1 inch) apart for reference. A mechanical stop limits the table travel within its lowest and highest position.*

   NOTE: *The top of the table is within 2.45 centimeters (1 inch) of the coil system axis when the lowermost inch mark is at the top of the base column.*

3. Limit the weight of the equipment placed on the table to the coil specifications (see chart). Center its mass over the center of the base. Do not lubricate the support column, but keep it clean.

Model	Weight Limit
6402	22.6 kg (50 lb)
6402M	4.5 kg (10 lb)
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)

4. Except for the wire, connectors and casters (if equipped) the entire coil structure is made of non-conductive, non-magnetic materials including wood, linen phenolic, nylon and Formica. Handle the structure carefully at all times, taking precautions to avoid subjecting it to thermal or mechanical shock.

5. 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 mils 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.

6. 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.

7. 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.

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.

MODEL 6406S

A standard ETS 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 can 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.

NOTE: *Push the coil assemblies into position by holding the coil section of each assembly. Do not push the coil assemblies using the delrin support rods.*

PARTS LIST

Item	QTY	Description
1	2 ea	Coil Assembly
2	2 ea	Base Assembly
3	4 ea	Brace Rod (white Delrin)
4	8 ea	Rod End (white Delrin)
5	8 ea	Bracket-Rod End (linen phenolic)
6	4 ea	Bolt (Delrin) 1 ¼-12 thd x 6 3/8"
7	8 ea	Bolt (Delrin) ¾-16 thd x 2 1/16"
8	16 ea	Bolt (Delrin) 5/8-11 thd x 1 ¾"
9	1 ea	Cable-Power Input (MS3106-A24-9S w/ MS3057-16A-W/B)
10	1 ea	Cable (15 ft) (MS3106-A24-9S w/ MS3057-16A-W/B)

ASSEMBLY INSTRUCTIONS

1. Unpack crate containing Base Assemblies and other parts.
2. Place Base Assembly (2) right side up on its casters and move to a location to provide space for mounting the six foot diameter coils.
3. Unpack parts and place them on the Base Assembly for convenience when needed.
4. Open the crate containing the two Coil Assemblies (1) observing the "OPEN HERE" marked on one side of the crate.
5. Remove four Brace Rod Assemblies (3), one Coil Assembly (1) and unwrap. Position the Coil Assembly (1) in front of the Base Assembly (2) with the two screw holes at the bottom and the connector box toward the inside of the Base Assembly. Align holes and install two Delrin Screws (6) finger tight. Support the coil in the vertical position until the brace rods are installed.
6. Remove the two Delrin Screws (7) from the two Rod End Brackets mounted on the Coil Assembly.
7. Insert the end of the Brace Rod Assembly (4) into each Coil Assembly Bracket and install Delrin Screws (7) finger tight.
8. Position Brace Rod Assembly Bracket over holes in Base Assembly and install four Delrin Screws (5) finger tight.

9. Check the Coil Assembly is positioned vertically and perpendicular to Base Assembly. Tighten all screws.
10. Should the Coil Assembly not be vertical to the Base Assembly, adjust the length of the Brace Rods (3) as follows:
    a. Remove the two Delrin Screws (7) from the Bracket Assembly mounted on the Coil Assembly.
    b. Screw Rod Ends (4) into or out of the Brace Rod (3) as required.
    c. Reinstall Brace Rod Assembly.
11. Repeat steps 2 through 10 for the other half of the Helmholtz Coil System.
12. A power input cable (9) with connector is supplied for connecting to coil assembly. (No connector is supplied at opposite end of cable for customer power source.) Connect the power source to the connector on the junction block (mounted on one coil base assembly only) and attach the short cable from the junction block to the connector on the coil assembly.
13. A cable (10) with connector is supplied for interconnecting the coil assemblies. Attach the long interconnecting cable from the junction block to the connector on the other coil assembly.

MODEL 6408

ASSEMBLY INSTRUCTIONS

The Helmholtz coil has been dismantled for shipment and is crated in two wooden crates. The largest crate contains the two coils. This crate should be unpacked by laying on either large side and removing the two plywood cover sheets. Before removing the coils, unpack the base assembly as follows:

1. The second crate should be opened from the top side as marked. Carefully remove the six coil braces, the equipment stand, the large carton containing the test stand platform, the small carton containing plastic bolts and check valve, and the cable assembly. Remove the dark brown coil platform and set it on the floor with casters down. Remove the four large bolts from the base that are located near the cradle areas of the base.
2. Next, remove one coil from the first crate and place it in a cradle on one side of the base in such a manner that the face of the coil with the Cannon connector faces toward the opposite cradle area.
3. The coil connector should position toward the end of the platform which has two holes drilled for mounting the cable assembly block. Align the two large holes on the face of the coil with the holes in the platform cradle side. Run the bolts through the coil and into the base assembly. Then snug the bolts moderately tight.

CAUTION: *Until the coil is assembled and braced, be careful with instabilities which could cause the coil to sway or tip.*

4. Remove the second coil from the crate and mount it in the same manner as the first coil, with the connector facing inward and just opposite the connector on the first coil. The two drilled holes in the base should be approximately midway between the two connectors.
5. Remove the wrapping from the four shorter braces and place them in position between the coils. Do not tighten bolts until all braces are in place.

6. The tabs on the compression connectors should be down on the upper bars and up on the lower bars. All bolt heads in the compression connectors should face outward from the coil assembly. In this manner, the compression connectors will be located toward alternate ends of the horizontal braces as they go around the coils. Remove the delrin bolts from the compression connectors and insert the long braces in a vertical slanted configuration. Replace the bolts and tighten.
7. Unwrap the cable assembly, remove the mounting bolts from the bottom of the connector block and position the block over the two holes in the platform located between the Cannon connectors on the coil faces. The connector on the connector block should face away from the center of the coil platform. Reach beneath the platform and insert the mounting screws through the coil base and into the tapped holes in the connector block. The ends of the cable may now be connected to the coil connectors on each coil.
8. Place the small check valve over the center hole in the test platform mounting area so that the cross cuts in the valve face upward. The smooth side should be down and cover the center hole. Carefully position the base of the test platform over the check valve so that the bottom of the test platform is flush with the coil base. Align the six holes in the base of the test platform with those in the coil base and insert the six bolts and tighten moderately.
9. Next position the test platform table top with the support flange downward, and screw the table top to the shaft until snug. It may be necessary to tighten the upper knurled set screw in order to keep the shaft rigid while tightening the platform table.
10. When everything has been installed properly, loosen the two lower knurled set screws and lift the table top. Upon releasing the table, it should settle slowly against the leaking air in the center column. Lifting should be faster since the check valve allows air to enter the center column rapidly. The grooves in the support column are 2.54 centimeters (1 inch) apart for adjusting the height of the table. Be certain that the lower set screws are positioned into a notched area before placing a load on the test platform.

The coil is now ready for use.

SPECIFICATIONS

ELECTRICAL

Model	6402	6402M	6403	6404	6406	6406S	6408
Type	Monaxial	Monaxial	Monaxial	Monaxial	Monaxial	Monaxial	Monaxial
Mean Coil Radius	30.5 cm (12.0 in)	30.5 cm (12.0 in)	45.7 cm (17.9 in)	60.9 cm (23.9 in)	91.4 cm (35.9 in)	91.4 cm (35.9 in)	115.0 cm (45.3 in)
Number of Turns (per coil)	36	5	25	56	64	110	64
Gauge (AWG)	10	20	10	10	10	6	10
Total Resistance (Ohms DC)	0.5	0.7	2.5	1.5	2.5	1.7	3.0
Total Inductance (mH)	3.5	70	40	19	45	100	64
Amperes/Meter/Ampere	84.30	11.14	39.79	65.25	50.06	86.04	39.79
Coil Factor (gauss/ampere)	1.06	0.14	0.50	0.83	0.63	1.08	0.50
Homogeneity	+/- 10% within a 19.8 cm (7.8 in) cylinder	+/- 10% within a 25.4 cm (10.0 in) cylinder	+/- 10% within a 23.0 cm (9.0 in) cylinder	+/- 10% within a 40.0 cm (1.3 ft) cylinder	+/- 10% within a 0.6 m (2.1 ft) cylinder	+/- 10% within a 0.6 m (2.1 ft) cylinder	+/- 10% within a 0.7 m (2.5 ft) cylinder
Self Resonance (kHz)	32	500	40	40	43	4	>10
Maximum Current Input (Amperes continuous) *	20	10	20	20	20	40	20
Maximum Continuous Field (Gauss)	21.2	1.5	10.0	16.5	12.6	43.2	10.0
Mating Connector	MS3106 A-20-09S	BNC	MS3106 A-20-23S	MS3106 A-24-09S	MS3106 A-24-09S	MS3106 A-24-09S	MS3106 A-24-09S

*Higher currents may be used if the appropriate duty cycles are applied.

PHYSICAL

Model	6402	6402M	6403	6404	6406	6406S	6408
Coil Diameter	0.6 m (2.0 ft)	0.6 m (2.0 ft)	0.9 m (3.0 ft)	1.2 m (4.0 ft)	1.8 m (6.0 ft)	1.8 m (6.0 ft)	2.4 m (8.0 ft)
Width	31.8 cm (12.5 in)	31.8 cm (12.5 in)	53.3 cm (21.0 in)	86.4 cm (34.0 in)	101.6 cm (40.0 in)	88.9 cm (35.0 in)	127.0 cm (50.0 in)
Depth	62.2 cm (24.5 in)	62.2 cm (24.5 in)	93.9 cm (37.0 in)	127.0 cm (50.0 in)	187.9 cm (74.0 in)	187.9 cm (74.0 in)	236.0 cm (93.0 in)
Height	62.2 cm (24.5 in)	62.2 cm (24.5 in)	99.0 cm (39.0 in)	137.0 cm (54.0 in)	193.0 cm (76.0 in)	187.9 cm (74.0 in)	241.3 cm (95.0 in)
Weight	30 kg (67 lbs)	30 kg (67 lbs)	32.7 kg (72.0 lbs)	57.6 kg (127 lbs)	225 kg (475 lbs)	225 kg (475 lbs) approx. each coil and base	158.7 kg (350.0 lbs)

CONVERSION TABLE FOR MAGNETIC UNITS

		To Convert From:				
	Unit System:	SI (MKS)		CGS		
	Magnetic Qty.:	*B*	*H*	*B*	*H*	*B*
	Units	tesla	amp-turn/m	gauss	oersted	gamma
To:	tesla	1	$4\pi \times 10^{-7\dagger}$	10^{-4}	$10^{-4\dagger}$	10^{-9}
	amp-turn/m	$7.96 \times 10^{5\ddagger}$	1	$79.57747^{\ddagger}$	79.57747	$7.96 \times 10^{-4\ddagger}$
	gauss	10^{4}	$4\pi \times 10^{-3\dagger}$	1	$1^{\dagger}$	10^{-5}
	oersted	$10^{4\ddagger}$	$4\pi \times 10^{-3}$	$1^{\ddagger}$	1	$10^{-5\ddagger}$
	gamma	10^{9}	$4\pi \times 10^{2\dagger}$	10^{5}	$10^{5\dagger}$	1
		Multiply by above value.				

† Assumes $m = 1$; if $m \neq 1$, multiply by value of m to convert from H to B.

‡ Assumes $m = 1$; if $m \neq 1$, divide by value of m to convert from B to H.

1 tesla ≡ 1 weber/m^2.

For example,

1 tesla = 10^4 gauss.

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

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

WARRANTY STATEMENT

EMC Test Systems, L.P., hereinafter referred to as the Seller, warrants that standard EMCO products are free from defect in materials and workmanship for a period of two (2) years from date of shipment. Standard EMCO Products include the following:

- Antennas, Loops, Horns
- GTEM cells, TEM cells, Helmholtz Coils
- LISNs, PLISNs, Rejection cavities & Networks
- Towers, Turntables, Tripods & Controllers
- Field Probes, Current Probes, Injection Probes

If the Buyer notifies the Seller of a defect within the warranty period, the Seller will, at the Seller's option, either repair and/or replace those products that prove to be defective.

There will be no charge for warranty services performed at the location the Seller designates. The Buyer must, however, prepay inbound shipping costs and any duties or taxes. The Seller will pay outbound shipping cost for a carrier of the Seller's choice, exclusive of any duties or taxes. If the Seller determines that warranty service can only be performed at the Buyer's location, the Buyer will not be charged for the Seller's travel related costs.

This warranty does not apply to:

- Normal wear and tear of materials
- Consumable items such as fuses, batteries, etc.
- Products that have been improperly installed, maintained or used
- Products which have been operated outside the specifications
- Products which have been modified without authorization
- Calibration of products, unless necessitated by defects

THIS WARRANTY IS EXCLUSIVE. NO OTHER WARRANTY, WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED, INCLUDING BUT NOT LMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE REMEDIES PROVIDED BY THIS WARRANTY ARE THE BUYER'S SOLE AND EXCLUSIVE REMEDIES. IN NO EVENT IS THE SELLER LIABLE FOR ANY DAMAGES WHATSOEVER, INCLUDING BUT NOT LIMITED TO, DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

Note: Please contact the Seller's sales department for a Return Materials Authorization (RMA) number before shipping equipment to us.