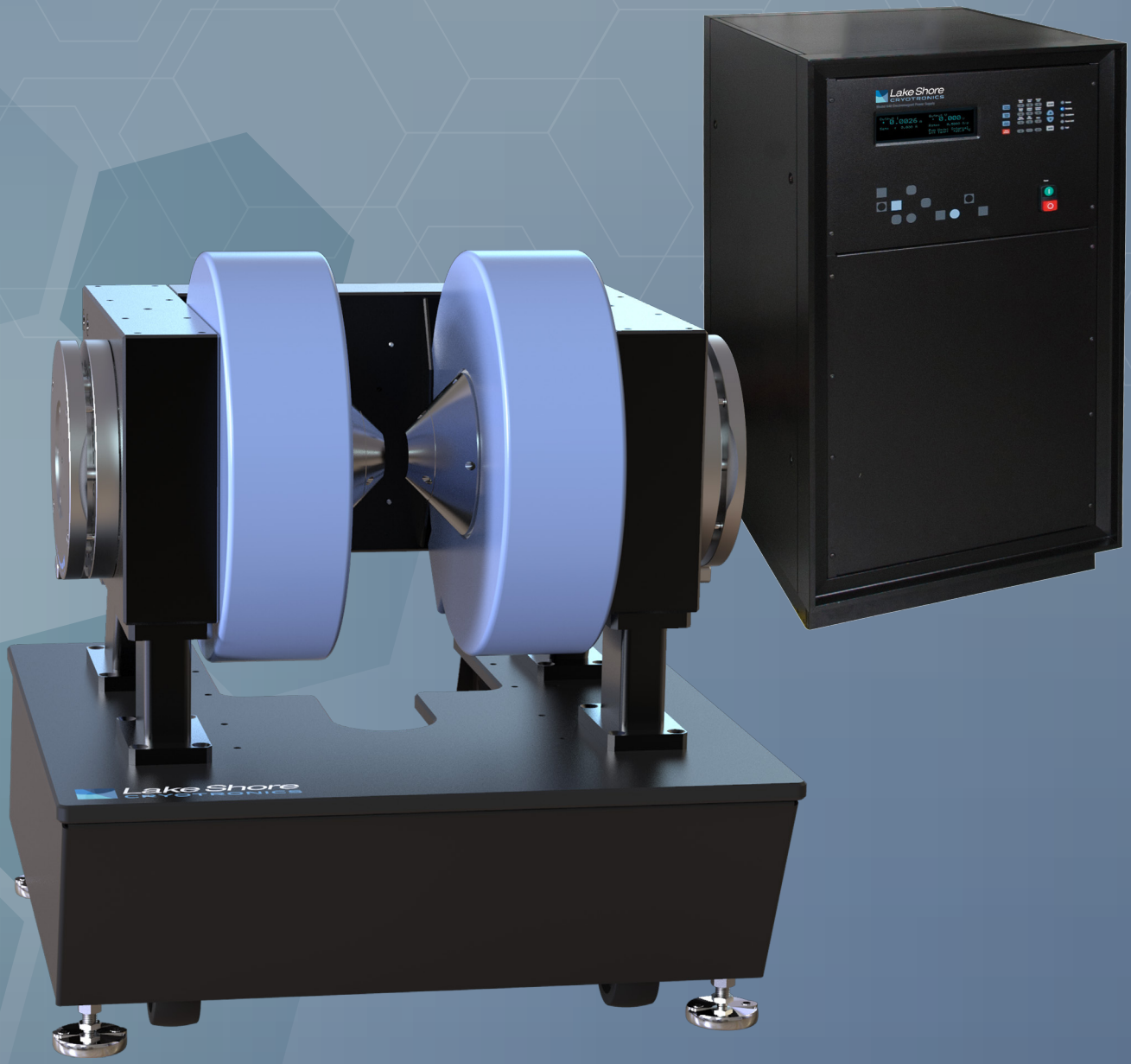
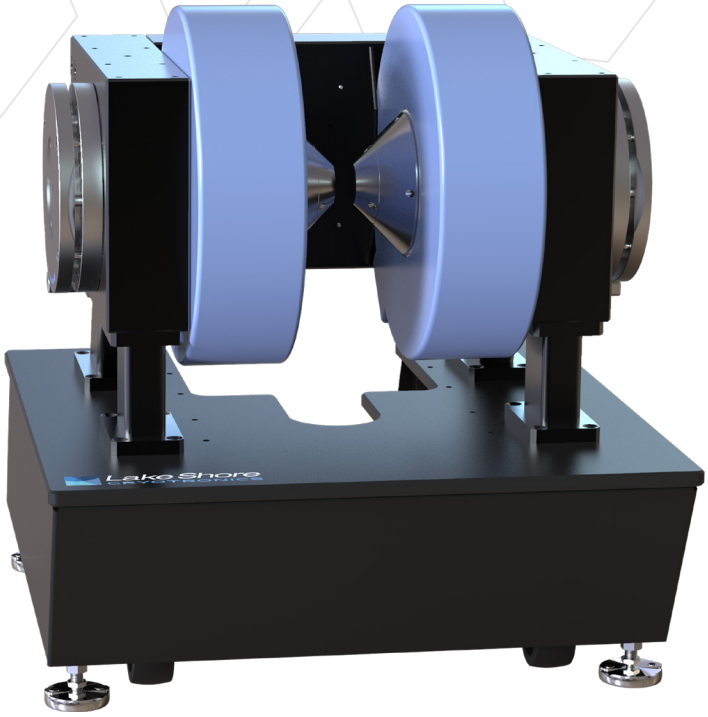
EM-V Series Electromagnets and Electromagnet Power Supplies



Lake Shore
CRYOTRONICS
a **DwyerOmega** brand



EM-4V, EM-7V features

- Indexed pole gap settings (ExactGAP™) allow repeatable air gap changes without having to re-calibrate between changes
- Exceptional field intensities achieved with cylindrical or tapered pole caps
- Water-cooled coils provide excellent field stability and uniformity
- Removable pole caps facilitate variable pole face configurations and easy pole cap exchange
- Accurate pole alignment by precise construction of the air gap adjustment mechanism
- The EM-4V/EM-7V yoke designed for optimum air gap accessibility for both top and bottom of the magnet
- Compact size of the EM-4V permits convenient bench-top mounting
- Optional optical access pole caps available
- Optional shim kit is available

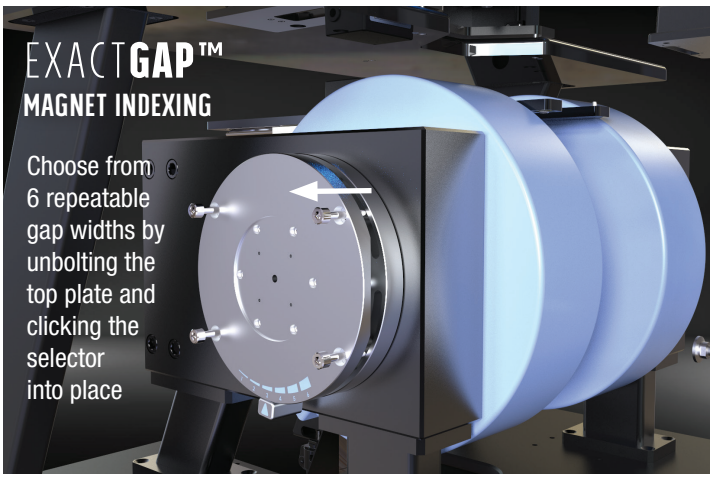
Introduction

The Lake Shore EM-4V and EM-7V electromagnets (EM-V Series) produce magnetic fields with a variety of indexed air gap and pole cap configurations. The EM-V Series are ideally suited for integration into customer-designed magnetic test platforms for applications including magneto-optical studies, magnetic hysteresis studies, in-line annealing, Hall effect studies, susceptibility measurements, spin magnetic resonance demonstrations, and biological studies.

The EM-V Series magnet coupled with a Lake Shore magnet power supply (MPS) and teslameter form a versatile laboratory electromagnet capable of producing magnetic fields up to 3.22 T and supporting very fast ramp rates of up to 1 T/s. This system, with true bipolar MPS power output, provides rapid uniform magnetic field ramping and field reversal to avoid discontinuities that occur during zero crossover when using unipolar power supplies.

ExactGAP™ indexed gap settings

The EM-V Series electromagnets feature ExactGAP™ indexed pole settings. The ExactGAP™ pole gap indexing makes it fast and easy to reconfigure the magnet gap for the required sample or option size without having to re-calibrate the magnet after changing the gap. Choose from 6 repeatable gap widths by unbolting the top plate and clicking the selector into place. The EM-V Series incorporate water-cooled coils and precision yokes made of magnetically soft, ultra-pure steel, assuring precise pole cap alignment as well as excellent field homogeneity and stability.



Transform your electromagnet into a modular characterization system

The EM-V Series can be upgraded to a modular characterization system (MeasureReady™ MCS-EMP). This transforms the electromagnet into a complete measurement solution using options to enable sample inserts (for both magnet and electrical experiments), sample temperature control options, preconfigured measurement module options, and MeasureLINK™-MCS software to control data collection and analysis.

MCS-EMP modular characterization system

Shown with optional sample holder in GlideLOCK™ mount



Electromagnet (power supply not shown)



Electromagnet system controller (ESC)

MCS-EMP modules and options

Electronic measurement modules
FastHall™ Hall effect
(Others to come)



Temperature options
GlideLOCK™ oven
CCR/CCR-O



Temperature control



Sample options
High performance sample holder/insert & cards
Room temperature top-side optical access
Manual rotation



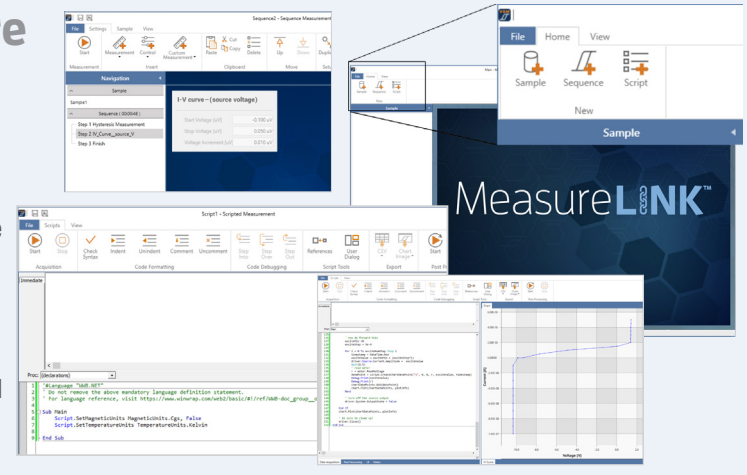
Compatible measurement instruments
I55 precision current/voltage source
372/3708 AC resistance bridge
Add your own third-party instruments



MeasureLINK™-MCS software

MeasureLINK™-MCS software is the key component of each MeasureReady™ MCS system. It facilitates field control, temperature control, measurement sequencing, and integration functions.

This flexible software allows the user to monitor the real-time performance of the MCS-EMP and to construct measurement sequences from a set of predefined controls. The menu-driven graphical user interface (GUI) provides the ability to control field and temperature to a specific setpoint or to loop these parameters through a range of settings with a specified step value. The sequences can be saved and recalled for use in repeated measurements.



Please see the MCS-EMP catalog for more details

EM-V Series electromagnet specifications

The EM-V Series electromagnets produce variable magnetic fields with a variety of air gap and pole cap configurations. They are ideal for applications including magneto-optical studies, magnetic hysteresis studies, in-line annealing, Hall effect studies, susceptibility measurements, spin magnetic resonance demonstrations, and biological studies.

Applied field strength with optional high-field 2 in pole face—EMP-HF (±1%)

ExactGAP™ setting	Air gap	EM-4V maximum field	EM-7V maximum field
Index 1	7.5 mm (0.30 in)	27.6 kOe (2.76 T)	32.2 kOe (3.22 T)
Index 2	12 mm (0.47 in)	25.2 kOe (2.52 T)	29.8 kOe (2.98 T)
Index 3	20 mm (0.79 in)	20.3 kOe (2.03 T)	26.0 kOe (2.60 T)
Index 4	25 mm (0.98 in)	17.2 kOe (1.72 T)	23.8 kOe (2.38 T)
Index 5	28 mm (1.10 in)	15.5 kOe (1.55 T)	22.7 kOe (2.27 T)
Index 6	50 mm (1.97 in)	9.1 kOe (0.91 T)	16.0 kOe (1.60 T)

Applied field strength with standard 2 in pole face (±1%)

ExactGAP™ setting	Air gap	EM-4V maximum field	EM-7V maximum field
Index 1	7.5 mm (0.30 in)	26.1 kOe (2.61 T)	30.5 kOe (3.05 T)
Index 2	12 mm (0.47 in)	23.7 kOe (2.37 T)	28.3 kOe (2.83 T)
Index 3	20 mm (0.79 in)	19.6 kOe (1.96 T)	24.7 kOe (2.47 T)
Index 4	25 mm (0.98 in)	16.9 kOe (1.69 T)	22.8 kOe (2.28 T)
Index 5	28 mm (1.10 in)	15.4 kOe (1.54 T)	21.7 kOe (2.17 T)
Index 6	50 mm (1.97 in)	9.1 kOe (0.91 T)	15.4 kOe (1.54 T)

Applied field strength with standard 4 in pole face[1] (±1%)

ExactGAP™ setting	Air gap	EM-4V maximum field	EM-7V maximum field
Index 1	57.5 mm (2.26 in)	7.9 kOe (0.79 T)	13.5 kOe (1.35 T)
Index 2	62 mm (2.44 in)	7.3 kOe (0.73 T)	12.8 kOe (1.28 T)
Index 3	70 mm (2.76 in)	6.5 kOe (0.65 T)	11.7 kOe (1.17 T)
Index 4	75 mm (2.95 in)	6.1 kOe (0.61 T)	11.0 kOe (1.10 T)
Index 5	78 mm (3.07 in)	5.9 kOe (0.59 T)	10.7 kOe (1.07 T)
Index 6	100 mm (3.94 in)	4.6 kOe (0.46 T)	8.6 kOe (0.86 T)

Applied field strength with standard 7 in pole face[2] (±1%)

ExactGAP™ setting	Air gap	EM-7V maximum field
Index 1	146.5 mm (5.77 in)	6.0 kOe (0.60 T)
Index 2	151 mm (5.94 in)	5.9 kOe (0.59 T)
Index 3	159 mm (6.26 in)	5.6 kOe (0.56 T)
Index 4	164 mm (6.46 in)	5.4 kOe (0.54 T)
Index 5	Not recommended for this pole cap configuration	
Index 6	Not recommended for this pole cap configuration	

[1]Achieved by removing high or standard 4 in to 2 in pole caps
[2]Achieved by removing standard 7 in to 4 in pole caps; only valid for EM-7V magnet

EM-4V typical field uniformity

Magnet configuration		Uniformity over 1 cm^3	1% cylindrical volume	
Pole cap mm (in)	Air gap mm (in)		Diameter mm (in)	Length mm (in)
51 (2.0)	13 (0.5)	±0.16%	36 (1.4)	13 (0.5)
51 (2.0)	25 (1.0)	±0.35%	18 (0.7)	25 (1.0)
102 (4.0)	25 (1.0)	±0.05%	64 (2.5)	25 (1.0)
102 (4.0)	51 (2.0)	±0.15%	18 (0.7)	51 (2.0)

EM-7V typical field uniformity

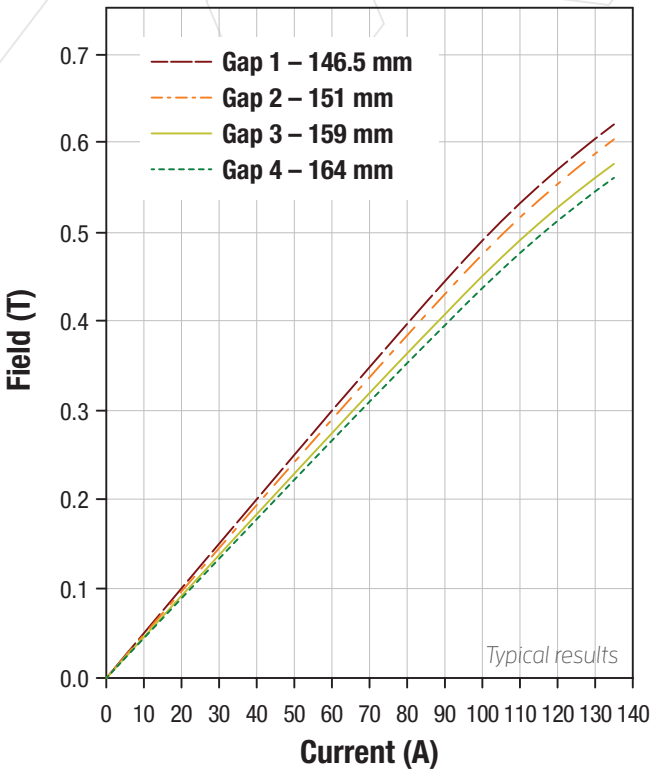
Magnet configuration		Uniformity over 1 cm^3	1% cylindrical volume	
Pole cap mm (in)	Air gap mm (in)		Diameter mm (in)	Length mm (in)
51 (2.0)	13 (0.5)	±0.11%	36 (1.4)	13 (0.5)
51 (2.0)	25 (1.0)	±0.33%	10 (0.4)	25 (1.0)
102 (4.0)	25 (1.0)	±0.03%	66 (2.6)	25 (1.0)
102 (4.0)	51 (2.0)	±0.08%	23 (0.9)	51 (2.0)

NOTE: The third column gives uniformity over one cubic centimeter volume centered in the magnet gap. The last two columns give the cylindrical volume within which the magnetic field deviates by less than 1% from the central field. The cylindrical volume is coaxial with the magnet poles and centered in the gap.

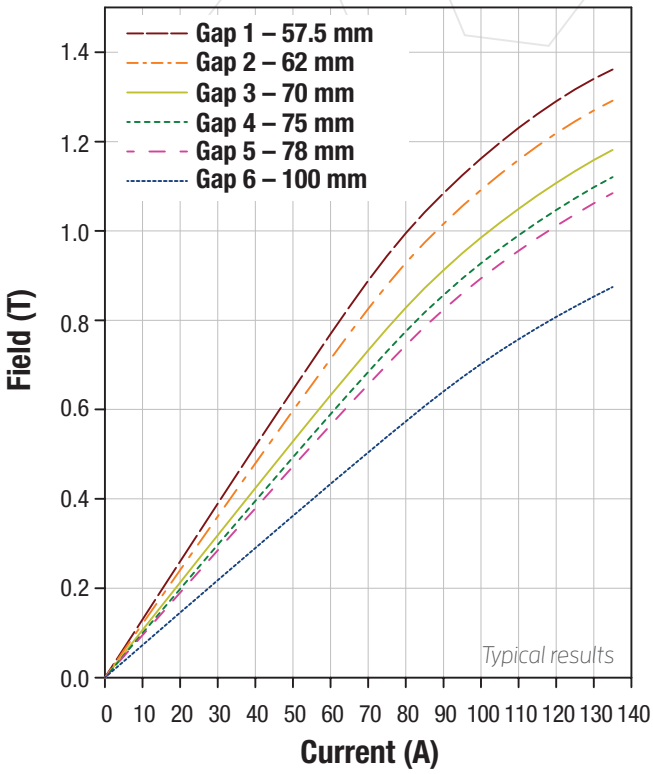
	EM-4V	EM-7V
Air gaps With no pole caps	57.5, 62, 70, 75, 78, and 100 mm	
With 2 in pole caps	7.5, 12, 20, 25, 28, and 50 mm	
Coil resistance, nominal	0.25 Ω per coil (0.5 Ω total wired in series)	1.00 Ω per coil (0.5 Ω total wired in parallel)
Coil resistance, cold	0.23 Ω per coil (0.46 Ω total wired in series)	0.92 Ω per coil (0.46 Ω total wired in parallel)
Coil resistance, maximum	0.27 Ω per coil (0.54 Ω total wired in series)	1.08 Ω per coil (0.54 Ω total wired in parallel)
Integrated pole diameter	100 mm (4 in)	178 mm (7 in)
Available pole cap diameters	50 mm (2 in)	100 mm (4 in) and 50 mm (2 in)
Cooling water	Tap water or closed cooling system	
Water flow rate	7.6 L/min (2 gal/min)	11.4 L/min (3 gal/min)
Pressure drop	200 kPa (30 psi)	220 kPa (32 psi)
Water chiller cooling capacity	2.5 kW (8,530 BTU/h)	5.0 kW (17,060 BTU/h)
Water inlet temperature	15 °C to 25 °C (59 °F to 77 °F)	
Coil over temperature limit	45 °C (113 °F)	
Coil spacing, nominal	121 mm (4.75 in)	178 mm (7 in)
Coil size-width, nominal	121 mm (4.75 in)	132 mm (5.2 in)
Coil size-diameter, nominal	311 mm (12.25 in)	445 mm (17.5 in)
Current (maximum continuous operating)	±70 A	±135 A
Voltage, nominal	±35 V (approximately 38 V at maximum coil temperature)	±70 V (approximately 38 V at maximum coil temperature)
Continuous input power, nominal	2.5 kVA (2.65 kVA at max temperature)	9.45 kVA (10.125 kVA at max temperature)
Suggested power supply	Lake Shore Model 643	Lake Shore Model 648
Size		
Height	77 cm (30.3 in)	52.7 cm (20.8 in)
Width	78.7 cm (31 in)	78.7 cm (31 in)
Depth	88.9 cm (35 in)	88.9 cm (35 in)
Weight	201.9 kg (445 lb)	635 kg (1400 lb)
Shipping weight	215.5 kg (475 lb)	660 kg (1500 lb)
Shipping dimensions	0.97 m × 0.58 m × 0.56 m (38 in × 23 in × 22 in)	0.86 m × 1.22 m × 1.19 m (34 in × 48 in × 47 in)

EM-V Series field plots (nominal)

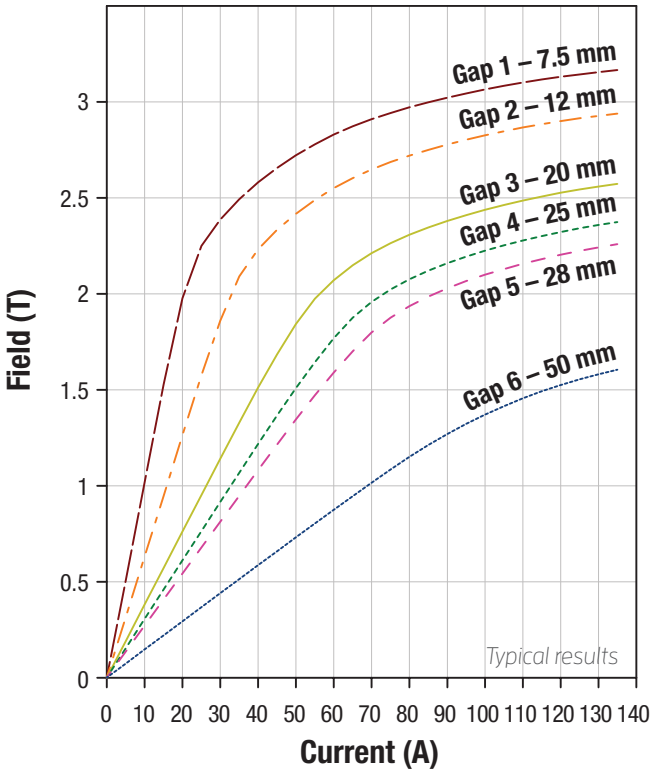
EM-7V no pole caps field plot



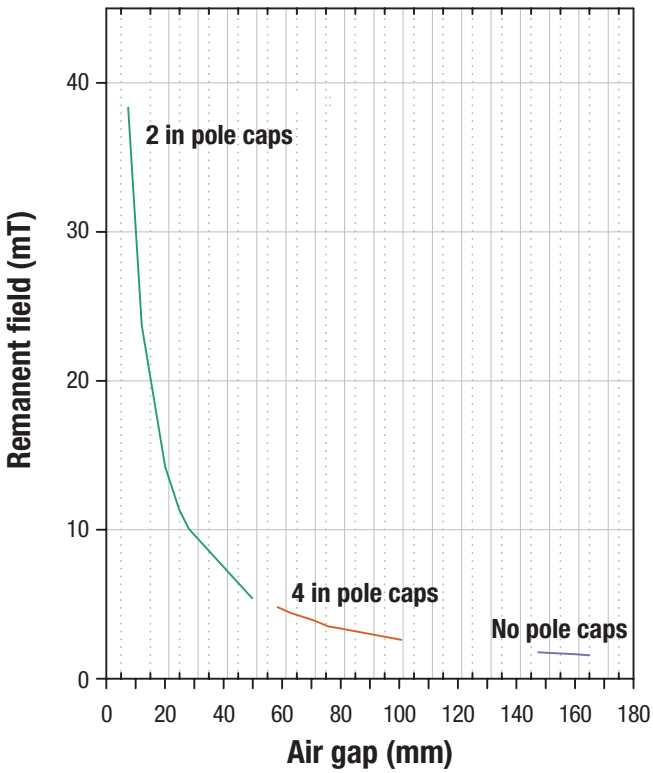
EM-7V 100 mm (4 in) pole caps field plot



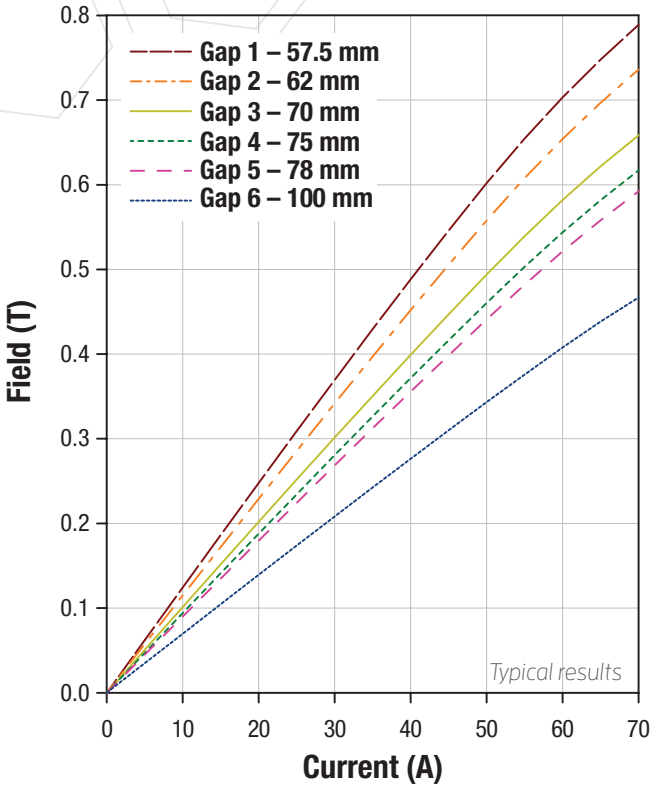
EM-7V 50 mm (2 in) pole caps field plot



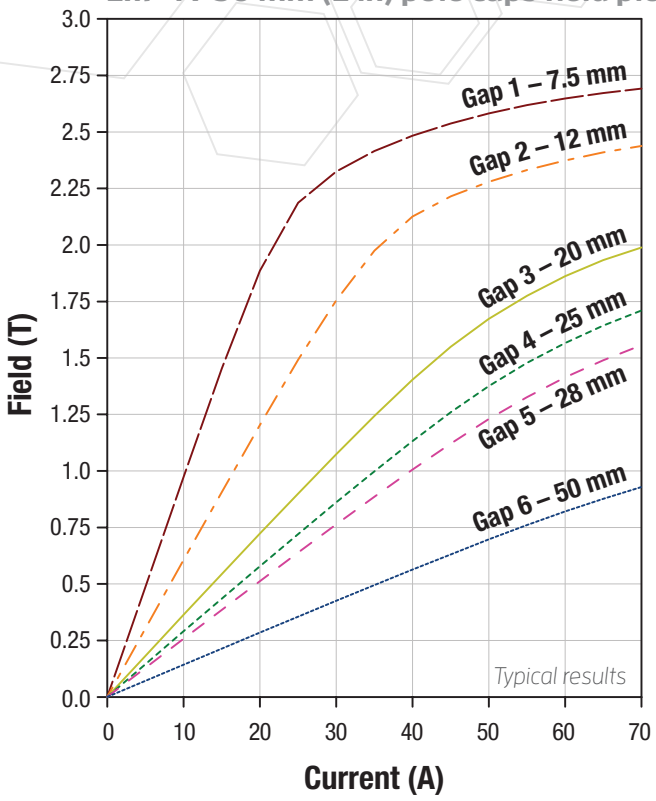
EM-7V remanent field



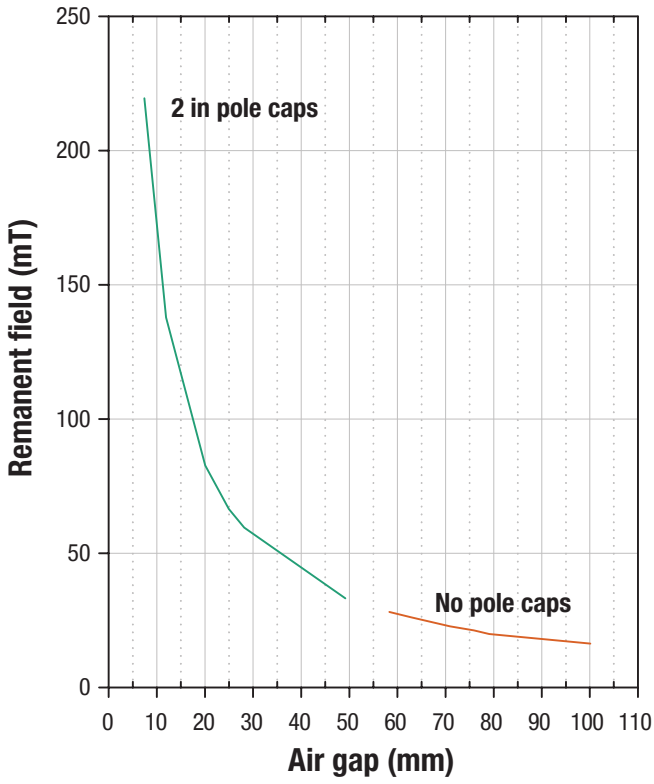
EM-4V no pole caps field plot

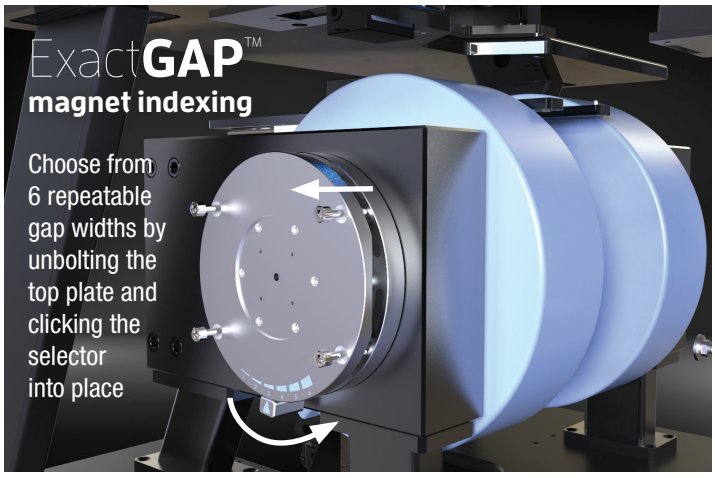


EM-4V 50 mm (2 in) pole caps field plot



EM-4V remanent field







Electromagnet Power Supplies

Model 643 electromagnet power supply



Model 643 features

- Low noise
- Compact design
- CE mark certification
- ±70 A/±35 V, 2450 W
- Built-in fault protection
- Analog programming and IEEE-488 and USB interfaces
- Bipolar, linear, true 4-quadrant output
- 0.1 mA of programmed current resolution
- Can be modulated to frequencies up to 0.17 Hz at ±70 A

Introduction

The Model 643 electromagnet power supply is a linear, bipolar current source providing true 4-quadrant output, eliminating the need for external switching or operator intervention to reverse current polarity. The Model 643 is capable of supplying ±70 A/±35 V to a nominal 0.5 Ω, 0.5 H load, and the output can be modulated from an external source to frequencies up to 0.17 Hz at ±70 A. Internally programmed output provides 20-bit resolution, while externally programmed output provides unlimited resolution.

The compact, low noise design of the Model 643 makes it the ideal supply for use in laboratory settings. When combined with a Lake Shore EM-4V electromagnet and Model 475 DSP gaussmeter, the 643 provides a versatile field control system ideal for a wide range of applications. These include magneto-optical, magnetic hysteresis and susceptibility, Hall effect measurements, and in-line annealing.

Output architecture

The 643 output architecture relies on low noise linear input and output stages. Its linear circuitry permits operation with less electrical noise than switch-mode electromagnet power supplies. The clean field background allows greater resolution and finer detail in results drawn from data taken during high sensitivity experiments. One key benefit of this architecture is CE compliance to the electromagnetic compatibility (EMC) directive, including the radiated emissions requirement.

The true 4-quadrant output capability of the 643 is ideal for sweeping through both positive and negative fields. Tightly integrated analog control of the 4-quadrant output provides smooth current change with very low overshoot. This eliminates the need for external switching or operator intervention to reverse the polarity, significantly simplifying system design. The transition through zero current is smooth and continuous, allowing the user to readily control the magnetic field as polarity changes. This is achieved without reversal contactors or relays, which would produce unintended field spikes and other discontinuities. As a result, field hysteresis and other biases are avoided in the experimental data.

Output programming

The 643 output current is programmed internally via the keypad or the computer interface, externally by analog programming input, or by the sum of the external and internal settings. For internal programming, the 643 incorporates a proprietary 20-bit digital-to-analog converter (DAC) that is monotonic over the entire output range and provides resolution of 0.1 mA. External programming provides unlimited resolution.

The 643 generates extremely smooth and continuous ramps with virtually no overshoot. The digitally generated constant current ramp rate is variable between 0.1 and 50 A/s. To ensure smooth ramp rate, the 643 updates the high-resolution DAC 23.7 times/s. A low-pass filter on the output DAC smooths the transitions at step changes during ramping.

Output reading

The Model 643 provides high-resolution output readings. The output current reading reflects the actual current in the magnet, and has a resolution of 0.1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 0.1 mV. All output readings can be prominently displayed on the front panel and read over the computer interface.

Protection

The Model 643 provides built-in protection against short circuit, open circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and abrupt change of the external programming input. In the event of water flow failure, flow sensors provide feedback to the Model 643 and output current is set to 0 A. Internal heat sink, cold plate, and transformer temperatures are also monitored. Warnings are displayed before temperature limits are exceeded and current is set to 0 A. If temperatures continue to increase over safety limits, the Model 643 turns off.

A proprietary circuit limits the power dissipated in the water-cooled cold plate should low resistance and high line conditions exist. The Model 643 protects itself if operated into resistances outside of nominal limits. By limiting current output, the power supply will safely operate into a shorted load, and it operates safely into high resistance loads by limiting voltage output. The Model 643 is also protected against power loss under full operation and nominal magnet load. Both low and high power line conditions are reported on the front panel display.

Interfaces

The Model 643 includes both parallel IEEE-488 and USB computer interfaces that provide access to operating data, stored parameters, and remote control of all front panel operating functions. The USB interface emulates an RS-232C serial port at a fixed 57,600 baud rate, but with the physical connections of a USB. This allows you to download firmware upgrades, ensuring your power supply is using the most current firmware version with no need for any physical changes. The Model 643 also provides two analog monitors for output current and voltage. Each monitor is a buffered, differential, analog voltage representation of the signal being monitored. The current monitor has a sensitivity of 7 V/70 A output, while the voltage monitor has a sensitivity of 3.5 V/35 V output.

Display and keypad

The Model 643 incorporates a large 8-line by 40-character vacuum fluorescent display. Output current and output voltage readings are displayed simultaneously. Five front panel LEDs provide quick verification of instrument status, including ramping, compliance, fault, power limit, and computer interface mode. Error conditions are indicated on the main display along with an audible beeper. Extended error descriptions are available under the status key.

The keypad is arranged logically to separate the different functions of the power supply. The most common functions of the power supply are accessed using a single button press. The keypad can be locked in order to secure either all changes or just the instrument setup parameters allowing the supply output to be changed.

Model 643 specifications

Output

Type: Bipolar, 4-quadrant, DC current source
Current generation: Fully linear regulation with digital setting and analog control
Current range: ±70 A
Compliance voltage (DC): ±35 V nominal
Power: 2450 W nominal
Nominal load: 0.5 Ω, 0.5 H
Maximum load resistance: 0.6 Ω for ±70 A DC operation at +10% to -5% line voltage
Minimum load resistance: 0.4 Ω for ±70 A DC operation at +5% to -10% line voltage
Load inductance range: 0 H to 1 H
Current ripple: 5 mA RMS (0.007%) at 70 A into nominal load
Current ripple frequency: Dominated by the line frequency and its harmonics
Temperature coefficient: ±15 ppm of full scale/°C
Line regulation: ±60 ppm of full scale/10% line change
Stability (1 h): 1 mA/h (after warm-up)
Stability (24 h): 5 mA/24 h (typical, dominated by temperature coefficient and line regulation)
Isolation: Differential output is optically isolated from chassis to prevent ground loops
Slew rate: 50 A/s into nominal load, 100 A/s maximum into a resistive load
Compliance voltage (AC): ±43 V at +10% to -5% line
Settling time: <1 s for 10% step to within 1 mA of output into nominal load
Modulation response: ≤0.17 Hz at ±70 A sine wave into nominal load, <0.02% THD; ≤1 Hz at ±10 A sine wave into nominal load, <0.05% THD; ≤10 Hz at ±1 A sine wave into nominal load, <0.10% THD
Attenuation: -0.5 dB at 10 Hz
Protection: Short circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, and over temperature
Connector: Two lugs with 6.4 mm (0.25 in) holes for M6 or 0.25 in bolts

Output programming

Internal current setting

Resolution: 0.1 mA (20-bit)
Settling time: 600 ms for 1% step to within 1 mA (of internal setting)
Accuracy: ±10 mA ±0.05% of setting
Operation: Keypad, computer interface
Protection: Programmable current setting limit

Internal current ramp

Ramp rate: 0.0001 A/s to 50.0000 A/s (compliance limited)
Update rate: 23.7 increments/s
Ramp segments: 5
Operation: Keypad, computer interface
Protection: Programmable ramp rate limit

External current programming

Sensitivity: 10 V/70 A
Resolution: Analog
Accuracy: ±10 mA ±1% of setting
Input resistance: 20 kΩ
Operation: Voltage program through rear panel, can be summed with internal current setting
Limits: Internally clamped at ±10.1 V and bandwidth limited at 40 Hz to protect output
Connector: Shared 15-pin D-sub

Readings

Output current

Resolution: 0.1 mA
Accuracy: ±10 mA ±0.05% of rdg
Update rate: 2.5 rdg/s display, 10 rdg/s interface

Output voltage (at supply terminals)

Resolution: 1 mV
Accuracy: ±5 mV ±0.05% of rdg
Update rate: 2.5 rdg/s display, 5 rdg/s interface

Front panel

Display type: 8-line by 40-character graphic vacuum fluorescent display module
Display readings: Output current, output voltage, and internal water temperature
Display settings: Output current and ramp rate
Display annunciators: Status and errors
LED annunciators: Fault, Compliance, Power Limit, Ramping, Remote
Audible annunciator: Errors and faults
Keypad type: 26 full-travel keys
Keypad functions: Direct access to common operations, menu-driven setup
Power: Green flush ON and red extended OFF push buttons

Interface

IEEE-488.2 interface

Features: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Reading rate: To 10 rdg/s
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

USB interface

Function: Emulates a standard RS-232 serial port
Baud rate: 57,600
Reading rate: To 10 rdg/s
Connector: B-type USB connector
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

Output current monitor

Sensitivity: 7 V/70 A
Accuracy: ±1% of full scale
Noise: 1 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Output voltage monitor

Sensitivity: 3.5 V/35 V
Accuracy: 1% of full scale
Noise: 1 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Power supply cooling water

Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block; Flow switch and water valve optional

Magnet cooling water

Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block
Flow, temperature switch, and water valve not included

Auxiliary

Emergency stop: Requires 1 A, 24 VAC normally closed (NC) contact to enable power-up; jumper required if unused
Fault output: Relay with normally open (NO) or normally closed (NC) contact, 30 VDC at 1 A
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Connector: Shared 8-pin detachable terminal block
Emergency stop and inhibit switches not included

General

Line power

Power: 5500 VA max
Voltage and current: 200/208 VAC ±10%, 13 A/phase; 220/230 VAC ±10%, 12 A/phase; 380 VAC ±10%, 7 A/phase; 400/415 VAC ±10%, 6.5 A/phase
Protection: 3-phase thermal relay with adjustable current setting; two class CC 0.25 A fuses; over-voltage lockout circuit
Frequency: 50 Hz or 60 Hz
Configuration: 3-phase delta
Connector: 4-pin terminal block
Features: Soft start circuit, rear panel voltage selection indicator
Line voltage must be specified at time of order but is field reconfigurable; cable from power supply to facility power not included

Cooling water

Flow rate: 5.7 L (1.5 gal)/min minimum
Pressure range: 34 kPa (5 psi) to 552 kPa (80 psi)
Pressure drop: 10 kPa (1.5 psi) at 5.7 L (1.5 gal)/min minimum for power supply only
Temperature: 15 °C to 30 °C (non-condensing)
Connection: Two 10 mm (0.38 in) hose barbs
CAUTION: Internal condensation can cause damage to the power supply
Enclosure type: 7 U high, 19 in rack mount with integral rack mount ears (25 mm (1 in) air space required on each side for ventilation)
Size: 483 mm W × 310 mm H × 572 mm D (19 in × 12.2 in × 22.5 in) with handles removed
Weight: 74 kg (163 lb)
Shipping size: 635 mm W × 559 mm H × 736 mm D (25 in × 22 in × 29 in)
Shipping weight: 103.4 kg (228 lb)
Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C at reduced accuracy
Humidity: Non-condensing
Warm-up: 30 min at output current setting
Approvals: CE mark—low voltage compliance to EN61010-3, EMC compliance to EN55022-1

Model 648 bipolar magnet power supply



Model 648 features

- Low noise
- CE mark certification
- ±135 A/±75 V, 9.1 kW
- Built-in fault protection
- Bipolar, linear, 4-quadrant output
- 1 mA of programmed current resolution
- Analog programming and IEEE-488 and USB interfaces

Introduction

The Model 648 electromagnet power supply is a robust, fault-tolerant 9 kW supply optimized for powering large 7 or 10 in research electromagnets. It is specifically designed for high precision laboratory use requiring extremely low electrical noise. The linear design removes undesirable higher frequency noise typical of switch mode power supplies. Eliminating the need for external switching or operator intervention to reverse current polarity, the Model 648 uses convenient bipolar, 4-quadrant operation. It is capable of supplying ±135 A/±75 V to a nominal 0.5 Ω, 0.5 H load. The Model 648 is built to last with a rugged design, integrated fault protection, and a simple, clean interior electronic design.

This robust power supply is developed to minimize downtime. It uses worry-free water cooling for quiet efficient operation compared to air-cooled power supplies. The seamless water lines only have external junctions, eliminating internal water leaks. In addition, safety interlocks ensure that cooling water is always flowing to the supply while operating. Magnet water can also be interlocked into the power supply if desired. Internal software controls manage water usage intelligently.

Output architecture

The low electrical noise design of the Model 648 makes it the ideal power supply for use with large electromagnets in high precision laboratory settings, ensuring greater resolution and finer detail in data taken during highly sensitive measurements. Because low noise is critical to measurement systems, the Model 648 implements both a linear design and bipolar architecture. Linear magnet power supplies have several advantages over switch mode power supplies, primarily smooth field generation that is nearly free from offending electromagnetic signatures. The bipolar, 4-quadrant operation required to safely operate an inductive load provides clean transitions through zero without discontinuities.

Output programming

The Model 648 output current is programmed internally via the keypad or the computer interface, externally by analog programming input, or by the sum of the external and internal settings. External programming via analog input signal provides analog resolution. The Model 648 generates extremely smooth and continuous ramps — the digitally generated constant current ramp rate is variable between 0.1 mA/s and 50.000 A/s. To ensure a smooth ramp rate, the power supply updates the high-resolution DAC 12.3 times per second.

Output reading

The Model 648 provides high-resolution output current readings that reflect the actual current in the magnet, and have a resolution of 1 mA. The output voltage reading reports the voltage at the output terminals with a resolution of 1 mV. All output readings can be prominently displayed on the front panel and read over the computer interface.

Protection

The Model 648 provides built-in protection against short circuit, open circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, over temperature, and abrupt change of the external programming input. A proprietary circuit limits the power dissipated in the water-cooled cold plate should low resistance and high line conditions exist. The Model 648 protects itself if operated into resistances outside of nominal limits. By limiting current output, it will safely operate into a shorted load, and operate safely into high resistance loads by limiting voltage output. The Model 648 is also protected against power loss under full operation and nominal magnet load. Both low and high power line conditions are reported on the front panel display.

Output

Type: Bipolar, 4-quadrant, DC voltage/current source
Current generation: Fully linear regulation with digital setting and analog control
Current range: ±135 A nominal
Compliance voltage (DC): ±75 V
Power: 9.1 kW nominal
Nominal load: 0.5 Ω, 0.5 H
Maximum load resistance: 0.55 Ω for ±135 A DC operation at +10% to -5% line voltage
Minimum load resistance: 0.41 Ω for ±135 A DC operation at +5% to -10% line voltage
Load inductance range: 0 H to 1 H
Current ripple: 10 mA RMS (0.007%) at 135 A into nominal load
Current ripple frequency: Dominated by the line frequency and its harmonics
Temperature coefficient: ±50 ppm of full scale/°C
Line regulation: ±75 ppm of full scale/10% line change
Stability (1 h): 2 mA/h (after warm-up, internal setting)
Stability (24 h): 10 mA/24 h (typical, internal setting, dominated by temperature coefficient and line regulation)
Isolation: Differential output is optically isolated from chassis to prevent ground loops
Slew rate: 50 A/s into nominal load (dominated by magnet characteristics), 100 A/s maximum into a resistive load
Settling time: <1 s for 10% step to within 1 mA of output into nominal load
Harmonic distortion: ≤0.1 Hz at ±135 A sine wave into resistive load, <0.02% THD; ≤10 Hz at ±10 A sine wave into resistive load, <0.30% THD
Attenuation: -0.5 dB at 10 Hz (external programming input)
Protection: Short circuit, line loss, low line voltage, high line voltage, output over voltage, output over current, and over temperature
Connector: Two lugs with 8.64 mm (0.34 in) holes for M8 or 5/16 in bolts

Output programming

Internal current setting

Resolution: 1.0 mA (20-bit)
Settling time: 600 ms for 1% step to within 1 mA (of internal setting)
Accuracy: ±20 mA ±0.05% of setting
Operation: Keypad, computer interface
Protection: Programmable current setting limit

Internal current ramp

Ramp rate: 0.1 mA/s to 50.000 A/s (compliance limited)
Update rate: 12.3 increments/s
Ramp segments: 5
Operation: Keypad, computer interface
Protection: Programmable ramp rate limit

External current programming

Sensitivity: 10 V/135 A
Resolution: Analog
Accuracy: ±20 mA ±1% of setting
Input resistance: 20 kΩ differential, 50 kΩ common-mode
Operation: Voltage program through rear panel, can be summed with internal current setting
Limits: Internally clamped at ±10.1 V and bandwidth limited -3 dB at 40 Hz (2 pole, low pass filter)
Connector: Shared 15-pin D-sub

Readings

Output current

Resolution: 1.0 mA
Accuracy: ±20 mA ±0.05% of rdg
Update rate: 2.5 rdg/s display, 10 rdg/s interface

Output voltage (at supply terminals)

Resolution: 1.0 mV
Accuracy: ±10 mV ±0.05% of rdg
Update rate: 2.5 rdg/s display, 5 rdg/s interface

Front panel

Display type: 8-line by 40-character graphic vacuum fluorescent display module
Display readings: Output current, output voltage, and internal water temperature
Display settings: Output current and ramp rate
Display annunciators: Status and errors
LED annunciators: Fault, Compliance, Power Limit, Ramping, Remote
Audible annunciator: Errors and faults
Keypad type: 20 full-travel keys
Keypad functions: Direct access to common operations, menu-driven setup
Power: Green flush ON and red extended OFF push buttons

Interface

IEEE-488.2 interface

Features: SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Reading rate: To 10 rdg/s
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

USB interface

Function: Emulates a standard RS-232 serial port
Baud rate: 57,600
Reading rate: To 10 rdg/s
Connector: Type B USB connector
Software support: National Instruments LabVIEW™ driver (consult Lake Shore for availability)

Output current monitor

Sensitivity: 7 V/135 A
Accuracy: ±1% of full scale
Noise: 5 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Output voltage monitor

Sensitivity: 7 V/70 V
Accuracy: 1% of full scale
Noise: 2 mV RMS
Source impedance: 20 Ω
Connector: Shared 15-pin D-sub

Power supply cooling water

Remote enable input: TTL low or contact closure to enable output; used for mandatory 1 gal/min flow switch (included)
Connector: 2-pin detachable terminal block connector
Valve power output: 24 VAC at 1.5 A maximum, automatic or manual control
Connector: 2-pin detachable terminal block connector
Water valve optional

Magnet cooling water

Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Valve power output: 24 VAC at 1.5 A maximum, automatic or manual control
Connector: Shared 4-pin detachable terminal block
Flow, temperature switch, and water valve not included

Auxiliary

Emergency stop: Requires 1 A, 24 VAC normally closed (NC) contact to enable power-up; jumper required if unused
Fault output: Relay with normally open (NO) or normally closed (NC) contact, 30 VDC at 1 A
Remote enable input: TTL low or contact closure to enable output; jumper required if unused
Connector: Shared 8-pin detachable terminal block; Emergency stop and inhibit switches not included

General

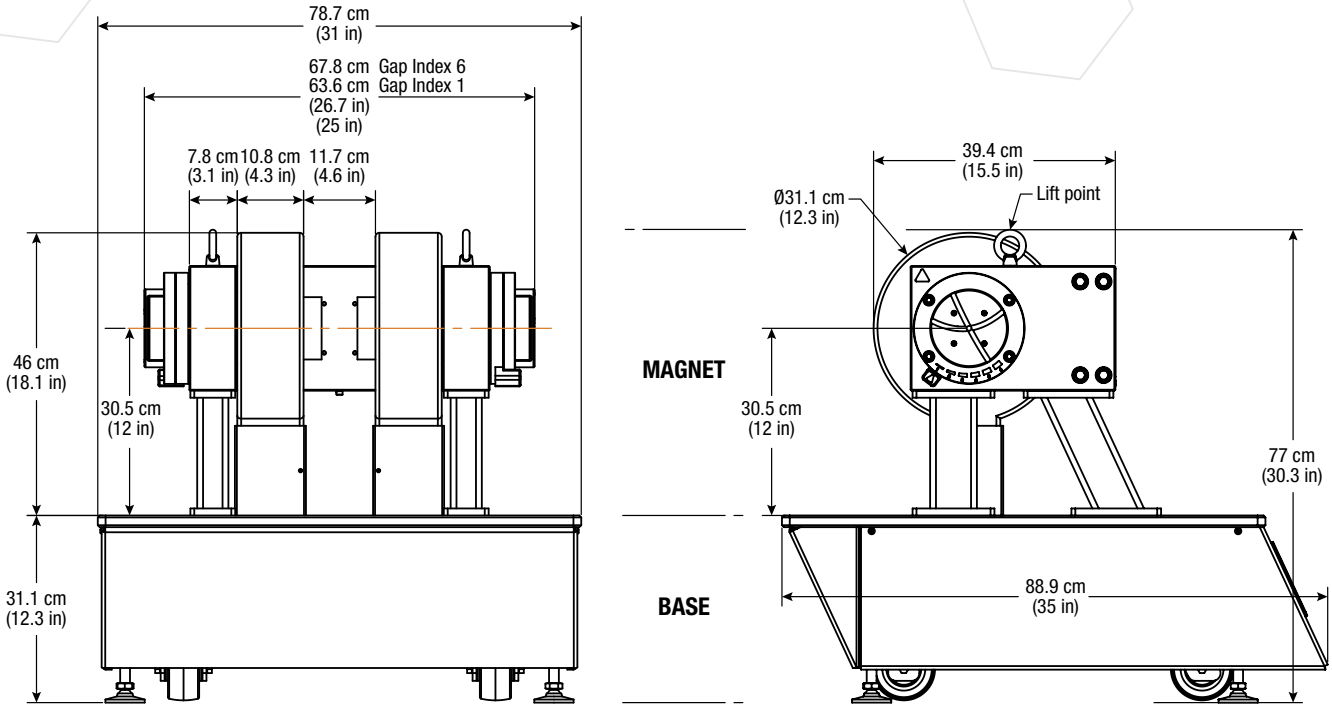
Line power

Power: 15.5 kVA max
Voltage and current: 200 VAC ±5%, 41 A/phase; 208 VAC ±5%, 40 A/phase; 220 VAC ±5%, 38 A/phase; 230 VAC ±5%, 37 A/phase; 380 VAC ±5%, 23 A/phase; 400 VAC ±5%, 21 A/phase; 415 VAC ±5%, 21 A/phase
Protection: 3-phase thermal relay with adjustable current setting; two class CC 2 A fuses; over-voltage lockout circuit
Frequency: 50 Hz or 60 Hz
Configuration: 3-phase delta
Connector: 4-pin terminal block;
Line voltage must be specified at time of order but is field reconfigurable; cable from power supply to facility power not included

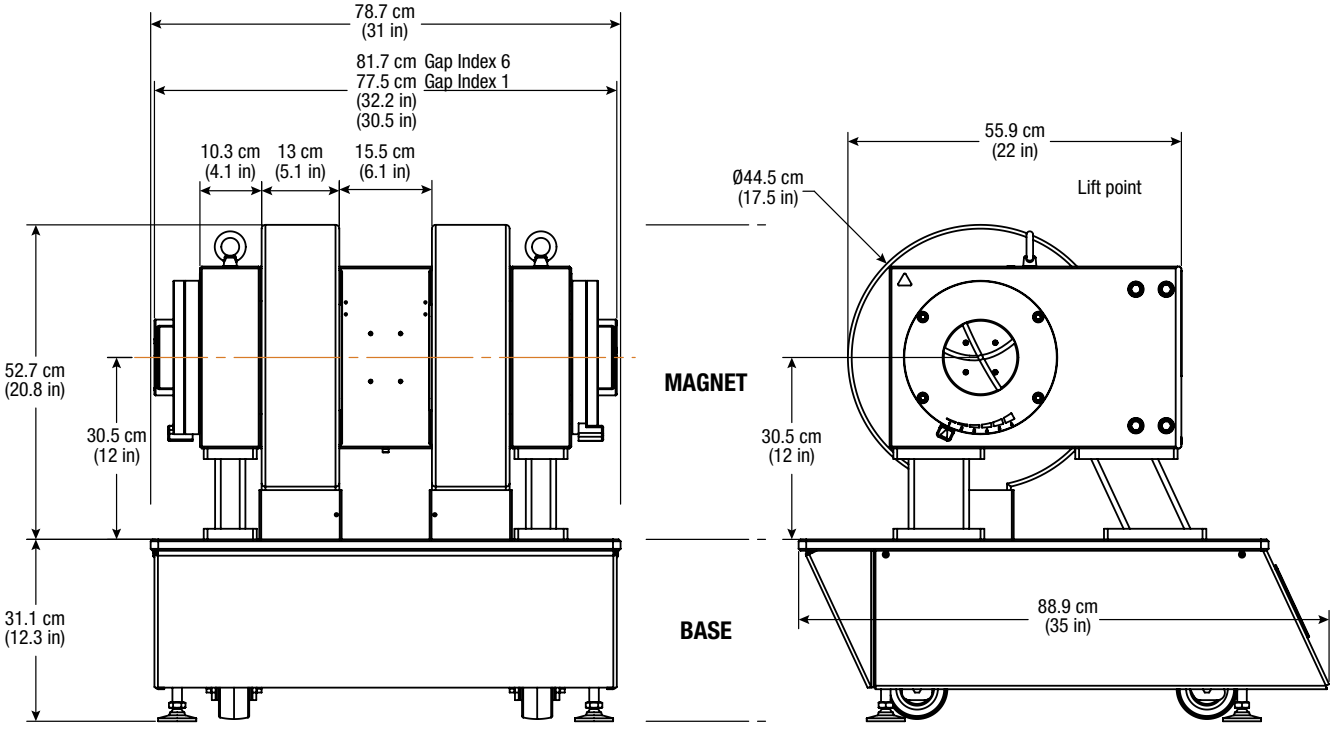
Cooling water

Flow rate: 7.6 L (2.0 gal)/min minimum
Maximum pressure: 552 kPa (80 psi)
Pressure drop: 159 kPa (23 psi) at 7.6 L (2.0 gal)/min minimum for power supply and mandatory flow switch
Temperature: 15 °C to 30 °C (non-condensing)
Connection: Two 12.7 mm (0.5 in) hose barbs
CAUTION: Internal condensation can cause damage to the power supply
Enclosure type: Custom 19 in rack cabinet
Size: 559 mm W × 673 mm D × 1054 mm H (22 in × 26 in × 42 in)
Weight: 225 kg (495 lb)
Shipping size: 914 mm W × 1168 mm D × 1219 mm H (36 in × 46 in × 48 in)
Shipping weight: 281 kg (620 lb)
Ambient temperature: 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C at reduced accuracy
Humidity: Non-condensing
Warm-up: 30 min at output current setting
Approvals: CE mark—low voltage compliance to EN61010-1, EMC compliance to EN61326-1

EM-4V


78.7 cm
(31 in)
67.8 cm Gap Index 6
63.6 cm Gap Index 1
(26.7 in)
(25 in)
7.8 cm
(3.1 in)
10.8 cm
(4.3 in)
11.7 cm
(4.6 in)
46 cm
(18.1 in)
30.5 cm
(12 in)
31.1 cm
(12.3 in)
MAGNET
BASE
39.4 cm
(15.5 in)
Ø31.1 cm
(12.3 in)
Lift point
30.5 cm
(12 in)
77 cm
(30.3 in)
88.9 cm
(35 in)

EM-7V


78.7 cm
(31 in)
81.7 cm Gap Index 6
77.5 cm Gap Index 1
(32.2 in)
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15.5 cm
(6.1 in)
52.7 cm
(20.8 in)
30.5 cm
(12 in)
31.1 cm
(12.3 in)
MAGNET
BASE
55.9 cm
(22 in)
Ø44.5 cm
(17.5 in)
Lift point
30.5 cm
(12 in)
88.9 cm
(35 in)

Ordering information

Electromagnets

EM-4V	4 in electromagnet with base and standard 4 in to 2 in pole caps; includes water manifold and cables
EM-4V-O	4 in electromagnet with base and optical access 4 in to 2 in pole caps; includes water manifold and cables
EM-7V	7 in electromagnet with base and standard 4 in to 2 in pole caps; includes water manifold and cables
EM-7V-O	7 in electromagnet with base and optical access 4 in to 2 in pole caps; includes water manifold and cables

Power supplies

648	7 in electromagnet power supply; specify AC power in configurator
643	4 in electromagnet power supply; specify AC power in configurator

Accessories

MCS-EMP-HF	High field non-optical pole caps
MCS-EMP-HF-O	High field optical access pole caps

For additional or custom pole caps, please contact Lake Shore

TPS-FRG-100/120V	Compact turbo pumping system; includes V-84 turbo pump (NW 40) with oil free dry scroll backing pump, FRG-700 full range gauge, controller, and interface cable to USB port; includes Agilent 24 month warranty NOTE: requires SYS-TP-KIT
TPS-FRG-220/240V-CE	Compact turbo pumping system; includes V-84 turbo pump (NW 40) with oil free dry scroll backing pump, FRG-700 full range gauge, controller, and interface cable to USB port; includes Agilent 24 month warranty NOTE: requires SYS-TP-KIT
SYS-TP-KIT	Includes all components necessary to connect NW 40 turbo pumping system to the vacuum port of any Lake Shore system (except probe stations)
1220-50	50 L LN_2 Dewar with ½ in top withdraw port and 10 psi pressure relief valve
E2M-110/120V	Two-stage rotary vacuum pump with mist filter; 110 to 120 VAC NOTE: requires SYS-RP-KIT
E2M-220/240V	Two-stage rotary vacuum pump with mist filter; 220 to 240 VAC NOTE: requires SYS-RP-KIT
EMP-SHIMS-4	Shim kit for 4 in electromagnet (not compatible with the 8600 Series)
EMP-SHIMS-7	Shim kit for 7 in electromagnet (not compatible with the 8600 Series)

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11/03/2026