



User's Manual EM7-HV Electromagnet

EM7 magnets include:

Models EM7-HV and EM7-HV-O H-Yoke, Variable Gap 7-inch Electromagnet, Horizontal Field



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Lake Shore certifies that this product has been inspected and tested in accordance with its published specifications and that this product met its published specifications at the time of shipment. The accuracy and calibration of this product at the time of shipment are traceable to the United States National Institute of Standards and Technology (NIST); formerly known as the National Bureau of Standards (NBS).

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CHAPTER 1

INTRODUCTION

1.0 GENERAL

The EM7-HV electromagnet is a compact electromagnet suited for many applications such as susceptibility measurements, Hall effect studies, magneto-optical studies, and magnetic resonance demonstrations.

We welcome comments concerning this manual. Although we try to keep it error-free, some may occur. When reporting a problem, describe it briefly and include the manual title and page number. Send your comments to Lake Shore Cryotronics, Inc., Attn: Technical Publications, 575 McCorkle Blvd., Westerville, Ohio 43082-8888.

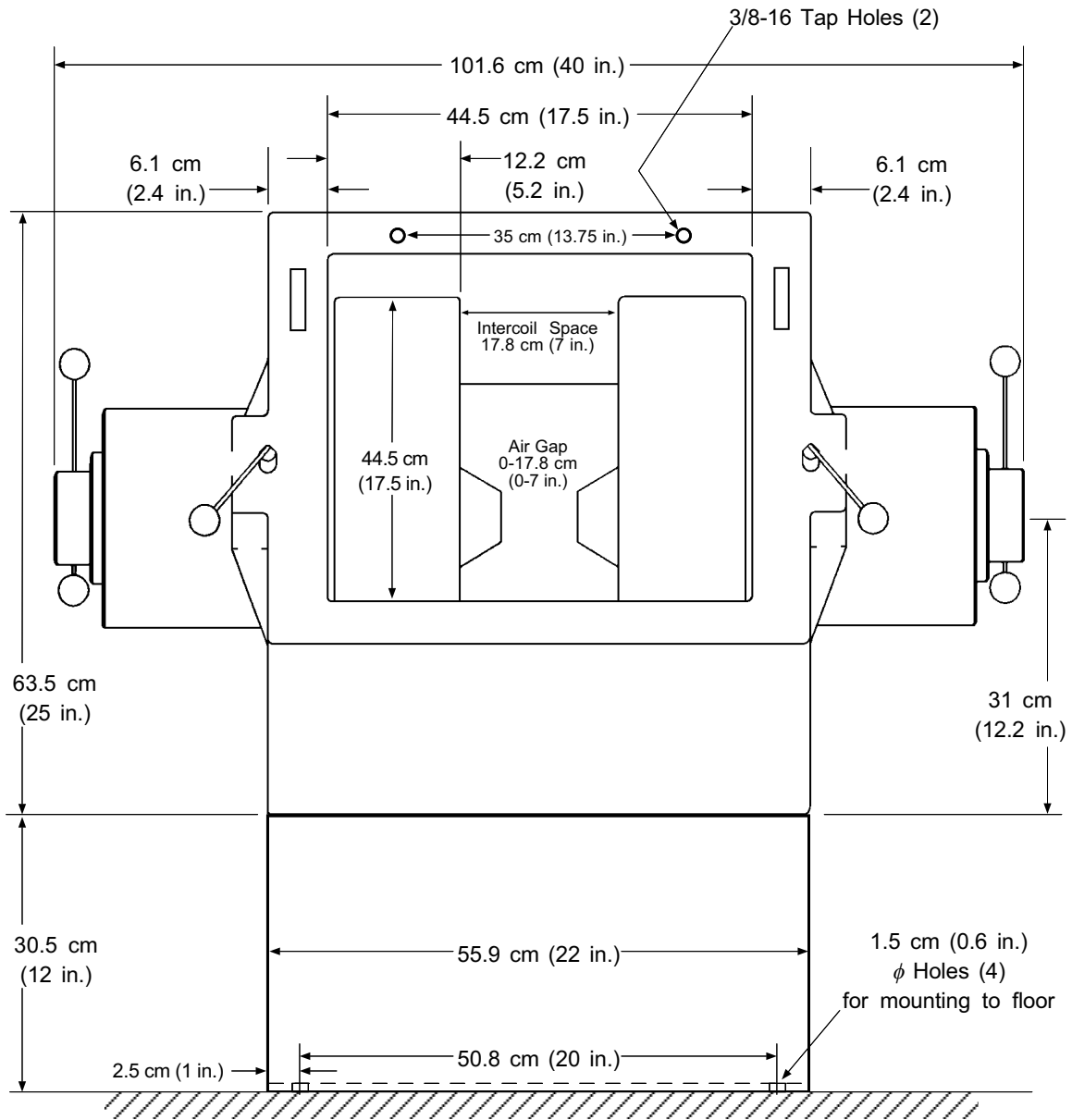
1.1 GENERAL DESCRIPTION

Refer to Table 1-1 for detailed specifications. For dimensional diagrams, see Figures 1-1 and 1-2.

- Continuously adjustable air gap, by means of rotating hand spokes or moveable poles, allowing rapid air gap changes to suit individual experiments assures magnet versatility. The poles lock in place by locking levers on each side of the electromagnet frame.
- Use air gaps up to 17.8 cm (7 inches) with cylindrical or tapered pole caps.
- Water-cooled coils provide excellent field stability and uniformity when high power is required to achieve the maximum field capability for the electromagnet.
- Easy pole cap exchange by 4-bolt pole caps, for variations in pole face diameters.
- Accurate pole alignment by precise construction of the air gap adjustment mechanism.
- Precision cast yokes of magnetically soft, ultra-pure steel assure precise pole face alignment critical for good homogeneity and reproducibility. The yoke incorporates large radius corners to reduce stray magnetic fields and reduce residual magnetic forces for more linear operation. The H-Yoke is at a 45° angle for optimum air gap accessibility.
- Couple the EM7-HV with a Model 648 magnet power supply (MPS) to form a versatile laboratory electromagnet characterization system. The Model 648 MPS provides rapid, uniform magnetic field reversal to avoid discontinuities that often occur during zero cross-over when using non-bipolar power supplies.

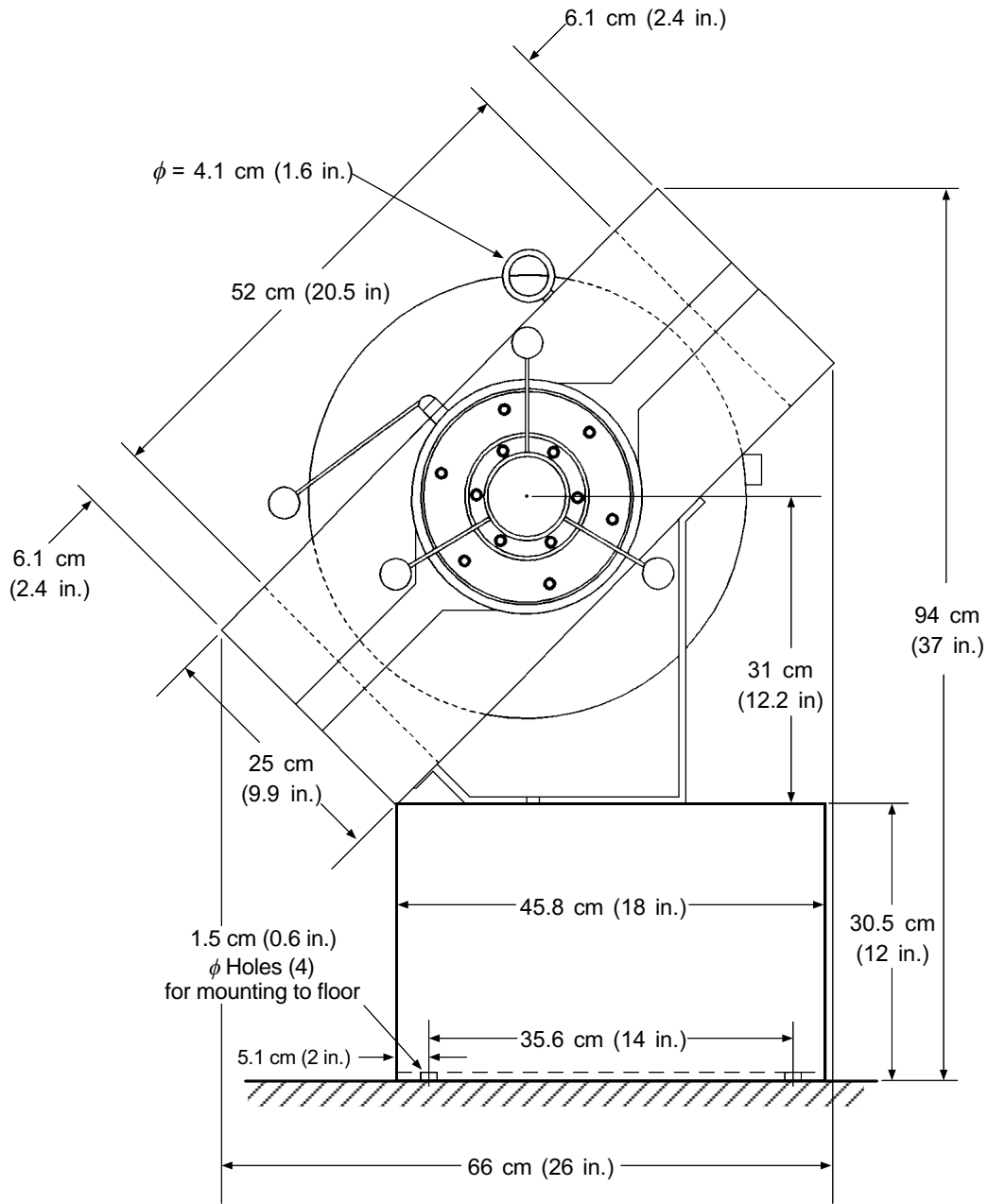
Table 1-1. Model EM7 Electromagnet Specifications

Specifications	EM7
Air Gap	Up to 17.8 cm (7 in.) continuously variable.
Coil Resistance (Type)	1 Ω per coil, at equilibrium temp., wired in parallel (0.5 Ω total).
Water Flow Rate	11.4 liters per minute (3.0 gallons per minute)
Water Chiller Cooling Capacity	8.3 kW (28250 BTU/Hr)
Coil Spacing	17.8 cm (7 in.)
Coil Width	13.2 cm (5.2 in.)
Coil Diameter	44.5 cm (17.5 in.)
Turns per Coil	624
Amp-Turns	31,200
Current (Max. Continuous Operating)	± 135 A
Width	101.6 cm (40 in.) at max. 17.8 cm (7 in.) gap
Height	Magnet: 63.5 cm (25 in.) set at 45° Stand: 30.5 cm (12 in.)
Depth	66 cm (26 in.)
Weight	636 kg (1400 lbs.)
Shipping Weight	682 kg (1500 lbs.)
Shipping Size	122 cm (48 in.) x 119 cm (47 in.) x 86 cm (34 in.)
Magnet Power Supply	Model 648
Operating Current	± 135 A
Operating Voltage	± 68 volts nominal
Power Consumption	9.2 kW nominal



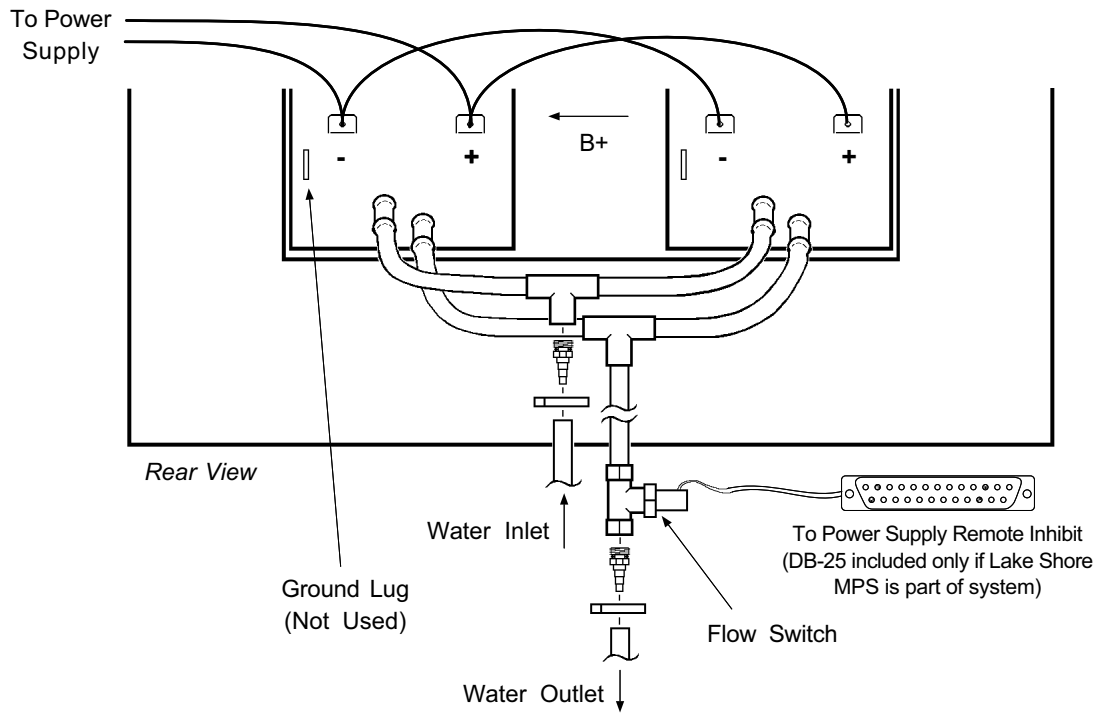
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Figure 1-1. Model EM7-HV Electromagnet Front View



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Figure 1-2. Model EM7-HV Electromagnet Side View



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Figure 1-3. Model EM7-HV Electromagnet Rear View Wiring and Connections

EM7-HV 51 mm (2 in) Pole Face Field Plot

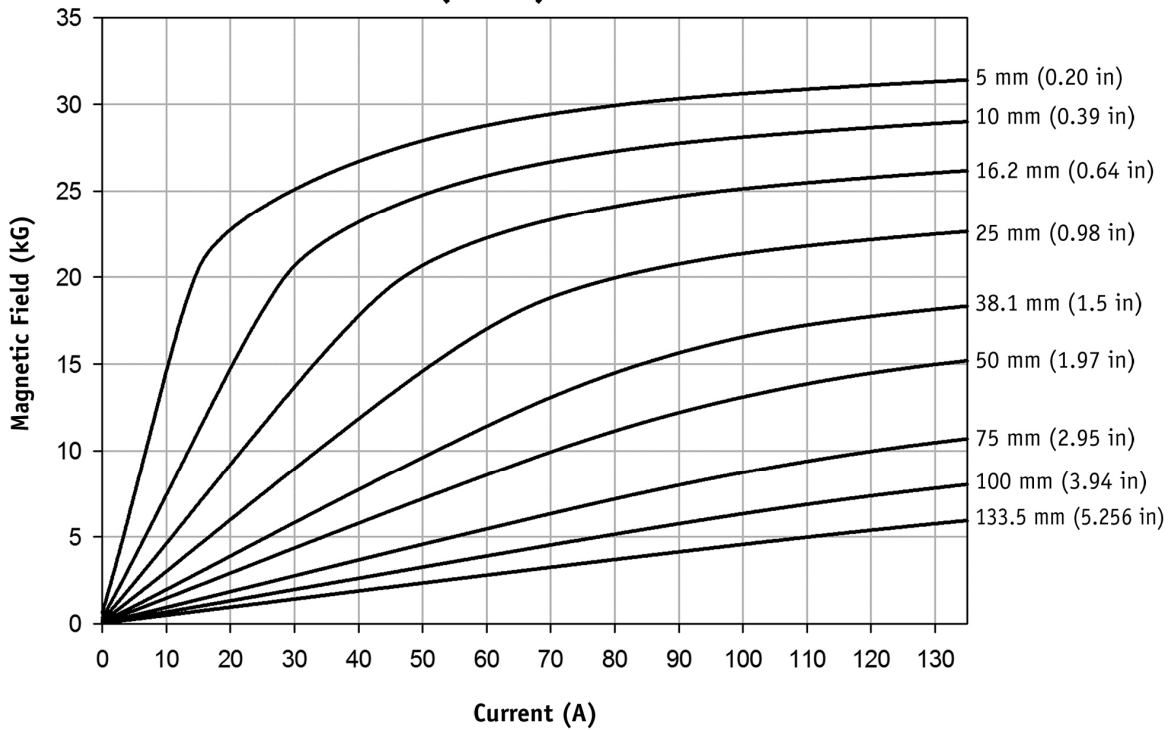


Figure 1-4. Model EM7-HV Magnetic Field Versus Current for a 2 inch pole face

EM7-HV 76 mm (3 in) Pole Face Field Plot

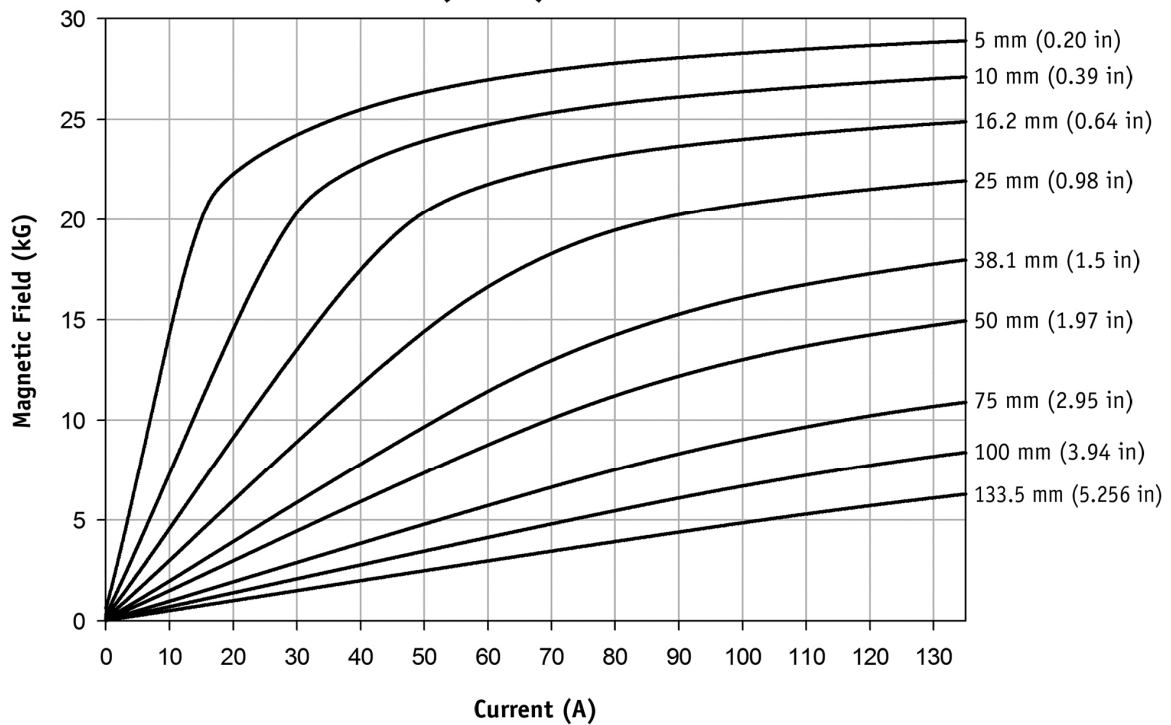


Figure 1-5. Model EM7-HV Magnetic Field Versus Current for a 3 inch pole face

EM7-HV 102 mm (4 in) Pole Face Field Plot

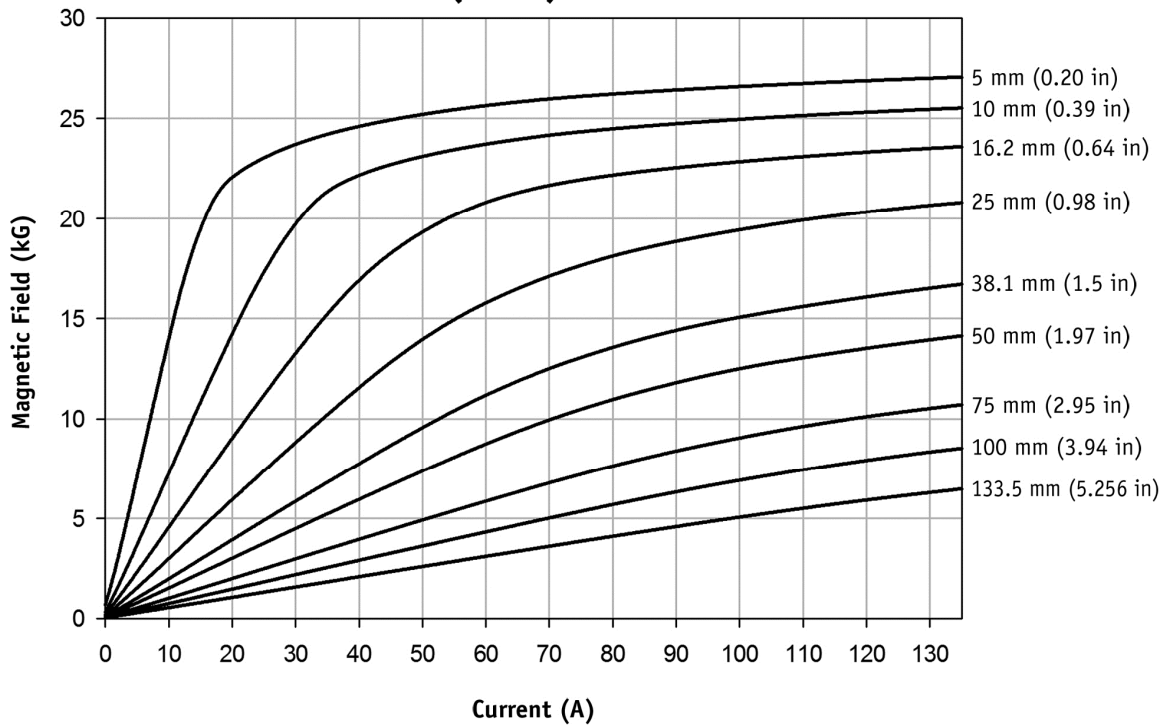


Figure 1-6. Model EM7-HV Magnetic Field Versus Current for a 4 inch pole face

EM7-HV 152 mm (6 in) Pole Face Field Plot

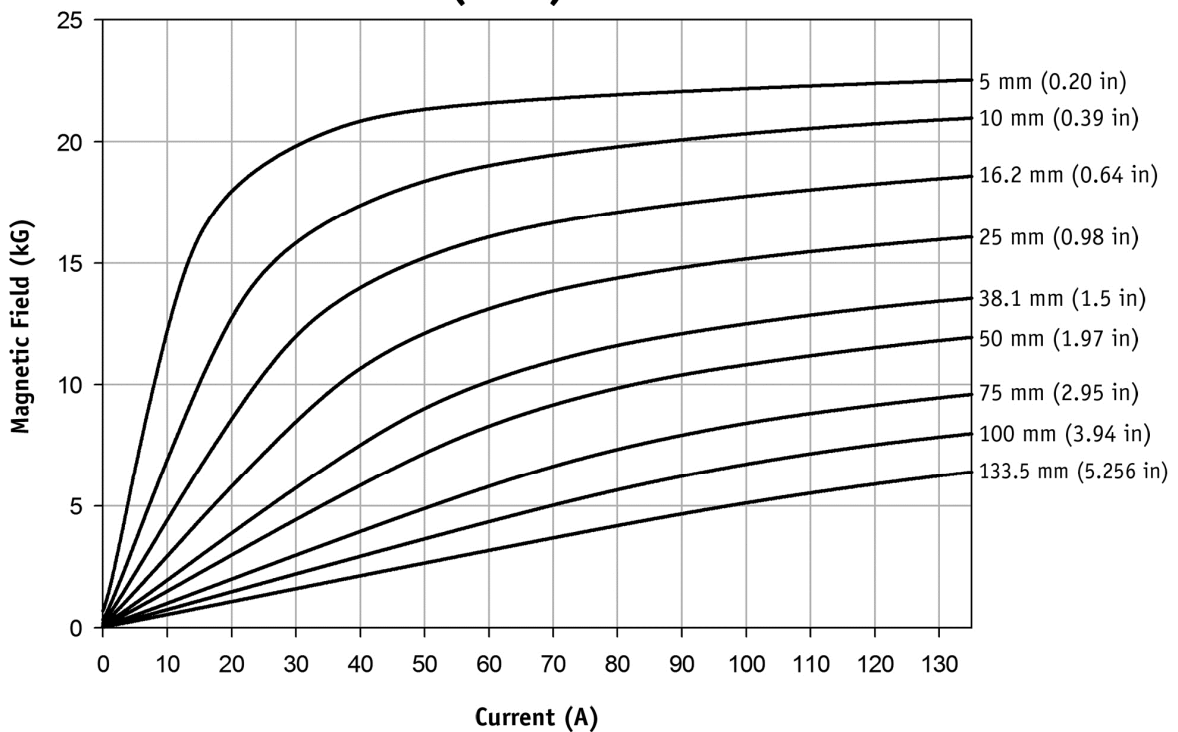


Figure 1-4. Model EM7-HV Magnetic Field Versus Current Charts for a 6 inch pole face

CHAPTER 2

INSTALLATION

2.0 GENERAL

This chapter covers electromagnet installation: Site planning in Paragraph 2.1, cooling water requirements in Paragraph 2.2, unpacking in Paragraph 2.3, accessories in Paragraph 2.4, installation procedure in Paragraph 2.5, and the return and shipping procedure in Paragraph 2.6.

2.1 SITE PLANNING

Consider these things when choosing the installation site:

Magnetic Environment – Minimize environmental magnetic fields. Common sources of interference are fluctuating loads on adjacent power lines, heavy-duty power transformers, elevator motors and similar electromagnetic devices.

Structural Support/Floor Strength – Allow for adequate support of components and handling equipment. The floor must be sufficiently rigid for minimum vibration from adjacent dynamic loads.

Service Utilities – Maintain room temperature and cooling water specifications.

Ambient Temperature – Magnet cooling water system operates at designed thermal efficiency when room temperature is within normal bounds.

Equipment Handling – Ensure adequate moving equipment, transportation route clearances, and supervision by qualified personnel.

Ventilation – Ensure adequate ventilation, especially during use of cryogenes.

Other Factors – Existing or planned facilities; local safety, electrical, and building codes; access to all sides of the equipment for operating and servicing.

2.2 COOLING WATER REQUIREMENTS

Standard municipal water systems are generally suitable to cool the magnet, provided proper flow is maintained (do not use distilled water). Use a water filter, flowmeter, and pressure gauges to monitor coolant water flow. If the water temperature is well above 32 °C (90 °F), install a water cooling device at the magnet water inlet. To avoid moisture condensation on the magnet, adjust the cooling system to keep the magnet coils several degrees above ambient air temperature.

2.3 UNPACKING

Inspect shipping container for damage. If it is damaged or the inside cushioning material appears stressed, check the shipment for completeness and proper operation (following procedures outlined in this manual). Keep all packing material in case of return.

If components are missing from your shipment, or if there is mechanical damage or defect (apparent or concealed), notify Lake Shore. If the shipping container or cushioning material shows signs of stress, notify the carrier as well as Lake Shore. Keep the shipping materials for inspection by the carrier.

2.4 ACCESSORIES

The standard Model EM7 electromagnet includes the following accessories:

Quantity	Description
2	Power Cables (Attached)
1	Flow Switch Kit (Refer to Appendix A)

Refer to Chapter 5 for a complete list of electromagnet accessories.

2.5 INSTALLATION PROCEDURE

CAUTION: The coils are not designed to rigidly attach to the magnet yoke. Damage may result if the magnet tilts without bracing between the coils. During shipment, dense packing foam or wedges between the coils hold them firmly in place. Do not remove this material until the magnet is installed in the final location.

1. Leave magnet bolted to shipping pallet during transportation to the installation site; it protects the magnet from vibration and the effects of an uneven floor. Do not subject the magnet to sudden bumps or jolts.

WARNING To avoid danger to personnel and equipment damage, bolt magnet to the stand, and bolt the stand to the floor. If not using the stand, bolt magnet directly to floor.

2. Remove shipping pallet and use appropriate lifting equipment to position the magnet and stand at the planned location. Mark the bolt holes, move the magnet, and drill the bolt holes. Insert bolt studs in the holes and secure. Replace the magnet and stand over the studs and bolt in place.
3. Connect the water supply to the fittings on the magnet rear (see Appendix A for flow switch installation). The inlet is located on one of the coils with the outlet located on the other coil. There is no distinction between the inlet and outlet.
4. Adjust the pole gap to the desired setting. To do this, unlock the pole pieces with locking levers, then rotate the spokes to move the poles to set the air gap. Lock the pole pieces in place.
5. Ground the yoke to the power supply chassis for safety.

WARNING: Do not connect or disconnect the electromagnet to or from the magnet power supply without first reducing output current to zero amperes and turning off the supply.

6. The power supply connections are located on the rear of the coils (if the cables are already connected, check screw tightness). To access the electrical connection, remove the safety cover plates. Connect the power supply cables to the terminal blocks on the rear of the coils. Use two jumpers between the two coils for parallel operation. Replace safety cover plates before operating the magnet.
7. Turn on the cooling water and adjust the flow rate to 11.4 liters per minute (3 gallons per minute). Readjust the fittings if any leaking is observed.

2.6 RETURN AND SHIPPING PROCEDURE

If the electromagnet appears to operate incorrectly, contact Lake Shore or a factory representative for a Returned Goods Authorization (RGA) Number. Returns may not be accepted without an RGA number. Attach a tag with the following information when returning:

1. RGA Number.
2. Model and Serial Number.
3. User's Name, Company, Address, Phone Number, and Fax Number.
4. Malfunction Symptoms.

CAUTION: Any water left in the cooling lines may freeze during shipping and cause irreversible damage to the magnet coils.

Pack the magnet in the original shipping crate (if possible). Fasten it upright to a pallet large enough and rated to handle the magnet weight. Use compressed air to force water out of the cooling lines in the coils.

CAUTION: The coils freely rest on the poles. To prevent damage, fix coils in place during shipment.

Wedge padded wood blocks or high density foam between the coils to hold them against the magnet frame.

Protect the magnet by wrapping in heavy paper or plastic. Seal with plastic tape. Make a wood box large enough to cover the whole magnet without touching it and fasten it to the pallet.

Affix shipping labels, **FRAGILE** warnings, **UPRIGHT** labels, and weight of the shipment on the outside of the crate. Also write the RGA number on the outside of the shipping crate and on packing slip. Use a shipping company that can handle the weight.

CHAPTER 3

OPERATION

3.0 GENERAL

Read the entire manual and check all instruments for proper operation prior to operating the system. This chapter covers a general check in Paragraph 3.1, operation in Paragraph 3.2, pole caps in Paragraph 3.3, and locking screws in Paragraph 3.4.

3.1 GENERAL CHECK

Before operating the magnet, verify proper electrical connections cooling water flow, inlet pressure, and temperature.

3.2 OPERATION

The magnet power supply provides current to the magnet. There are no operating controls on the magnet. The rotating hand knobs on the side of the magnet allow users to vary the air gap from 0 to 17.8 cm (0 to 7 inches).

WARNING: Always set current to zero amps and turn off the power supply before adjusting the magnet. After adjusting the pole spacing, lock the poles in place by securing the locking levers on the EM7.

3.3 POLE CAP REPLACEMENT

The Model EM7-HV electromagnet uses replaceable pole caps. If another geometry of pole cap is desired, the existing pole caps can be unbolted and another pair can be installed. Most pole caps are of either a straight or a tapered design, focusing the magnetic flux from the 178 mm (7 in) pole core to the diameter of the installed pole cap's face. Generally, pole caps with a larger pole face diameter will give higher field uniformity and lower magnetic field density, while pole caps focused to a smaller pole face will yield higher fields and lower field uniformity. Standard pole caps are made of high purity iron with a thin electroless nickel finish for corrosion resistance. Pole caps comprised of materials with higher saturation induction, such as FeCo, can also be installed to further increase field strength.

To remove a pole cap, you must unbolt the four pole cap retaining screws, remove the old pole caps, and attach the new pole caps using four socket head cap screws of appropriate length. A hex key kit is provided to assist in fastening the socket head cap screws. Due to changes in the mounting geometry of the pole caps, screw lengths vary with pole cap geometry. See the table below for the correct screw length when attaching standard Lake Shore pole caps.

NOTE: You may wish to Degauss the pole caps before removing them. Residual magnetism may hold the pole caps in contact with the pole with enough force to make it difficult to separate them. You can reduce residual magnetism to a minimum by alternately reversing the magnetic field polarity and gradually reducing the energizing current to near zero. The pole caps are then easily removed from the pole caps using a wrench. Use a light oil on the threads of the pole core.

CAUTION: Handle the pole caps with care. Deep dents or scratches on pole caps can impair the magnetic field homogeneity. When installing the pole caps, place a piece of soft material (cardboard, towel, etc.) beneath them to prevent accidental damage if they fall during installation.

Follow this procedure to replace a pole cap.

1. Set power supply current output to zero.
2. Turn the power supply off.
3. Make certain you have the correct length of screws for the pole cap geometry you will be using. The pole caps you want to install may have a different length than the ones on the electromagnet now. See the table below to make certain you have the correct mounting screws.

Nominal pole cap face diameter		5/16–18 screw length	
175 mm	7 in	70 mm	2.75 in
150 mm	6 in	51 mm	2.00 in
125 mm	5 in	44 mm	1.75 in
100 mm	4 in	29 mm	1.13 in
75 mm	3 in	19 mm	0.750 in
50 mm	2 in	19 mm	0.750 in

4. Unlock the pole-locking levers so the pole caps move in and out freely.
5. Rotate one pole adjuster's spokes to move one pole cap outward until the front of the pole cap is as far out as it can be moved.
6. Rotate the opposite pole adjuster's spokes to move the other pole cap inward until the pole cap is outside of the coil surface. The pole cap is now ready to be removed.
7. Using the hex wrench provided, unscrew the mounting bolts one turn counter-clockwise. Continue carefully unscrewing the pole cap mounting bolts until the pole cap is free.

CAUTION: It is important to hold onto the pole cap when unscrewing the mounting bolts. The pole cap may be damaged if it suddenly disengages from the pole piece and drops against a hard surface.

NOTE: Standard right-hand threads are used in the pole cap to pole core mounting. When installing pole caps, keep the threads and surface free of any foreign material. A thin film of grease on all the surfaces prevents rust.

8. Align the new pole cap with the pole core threaded holes.
9. Using the mounting bolts, attach the new pole cap to the pole core. Before final tightening, turn the pole adjuster to move the pole cap outward by five turns. This will draw the polecap into the pole sleeve and perform a final alignment of pole cap, pole core and sleeve.
10. Use the hex wrench to finally tighten the cap against the pole piece.
11. Rotate the pole adjuster spokes to move the new pole cap's pole outward until the front of the pole cap is as far outward as it can be moved.
12. Repeat Steps 4 thru 11 to change the other pole cap.
13. Rotate the pole adjuster spokes to move the poles to set the air gap. As the final adjustment of airgap, it is preferable to rotate the pole adjuster at least one turn outward to eliminate the backlash in the pole adjuster's screw mechanism.

NOTE: Eliminating the screw backlash will minimize unwanted pole deflection when large pull forces develop due to the large fields in the electromagnet airgap.

14. Lock pole caps in place.

CHAPTER 4

MAINTENANCE

4.0 GENERAL

This chapter describes the pole cap replacement procedure for the Model EM7.

4.1 ADJUSTING THE POLE-LOCKING LEVER MOTION

The pole-locking lever has a ratcheting mechanism which may be used to adjust the movement of the pole locking levers. To change their movement, follow this procedure.

1. Pull up on the central portion of the pole-locking lever. This frees the pole-locking lever from the pole-locking screw.
2. Rotate the pole-locking lever (it should move independently of the screw) to the desired position. You may need to hold the central screw with a hex key to ensure it moves independently.
3. Release the pole locking lever to re-engage the screw. Generally, it is desirable that the pole-locking lever be able to lock and unlock the pole caps in one motion, without having to re-adjust the ratcheting mechanism.

4.2 RUST PREVENTION

Follow these tips to prevent rust on your electromagnet.

- Wipe clean all pole and polecap surfaces with a clean, lint-free cloth lightly oiled with high quality light oil. Maintaining a layer of light oil will prevent rust build-up on the steel parts of the electromagnet. Even corrosion-resistant parts are subject to deterioration.
- To oil the pole and sleeve, retract the left pole fully into the electromagnet coil, extend the right pole fully, and lubricate the extended pole. Repeat for the opposite pole.
- Running the pole adjuster's screw mechanism from end to end is also good for the electromagnet. Verify the motion is smooth and does not jam at any point in the travel. If problems are encountered when moving the mechanism, the lead screw and/or sleeve may need to be cleaned and lubricated. Consult with the factory.
- When exchanging pole caps, be certain to use light oil on the exposed pole core mating surface to keep it rust-free. Keeping these parts oiled and free from contamination is a good preventative measure. If condensation is seen on the exterior of the electromagnet, wipe it away with a soft clean dry cloth to prevent corrosion.

4.3 RUST REMOVAL

Remove all traces of rust with crocus cloth 4/0 grit or finer. Remove all traces of abrasives with a soft clean cloth.

4.4 FOREIGN MATTER

Remove all traces of foreign matter from the pole caps with a soft clean cloth. Do not let foreign material fall into the sleeve of the electromagnet. Due to tight pole-to-sleeve tolerances, any foreign matter introduced into the sleeve when the poles are retracted may cause future operating problems.

CHAPTER 5

OPTIONS AND ACCESSORIES

5.0 GENERAL

This chapter lists EM7 options in Paragraph 5.1 and accessories in Paragraph 5.2.

5.1 SYSTEM OPTIONS

Table 5-1 lists available EM7 electromagnets. The electromagnets can be tailored to fit many custom applications. Consult the factory for assistance in configuring electromagnets for your application.

Table 5-1. Lake Shore Electromagnets

MODEL NUMBER	DESCRIPTION
EM7-HV	7-inch diameter pole caps, H-yoke, variable gap (set by rotating hand spokes).
EM7-HV-O	Same as EM7-HV with optical access.

5.2 ACCESSORIES

Accessories are devices that perform a secondary duty as an aid or refinement to the primary unit. Table 5-2 lists EM7 accessories.

The standard EM7 electromagnet includes the following accessories:

- 2 Sets of pole caps (3 and 6 inch).
- Corresponding pair of lead screws.
- Flow switch.
- Power cables, #4 AWG, 10 feet long.
- Base, 30.5 cm (12 inches) high.

Table 5-2. EM7 Electromagnet Accessories

MODEL #	DESCRIPTION										
Additional Standard Pole Caps (does not include bolts, order separately)											
EM7-2P-FECO	Pole cap, 7-inch tapered to 2-inch face, FeCo										
EM7-2P	Pole cap, 7-inch tapered to 2-inch face										
EM7-3P	Pole cap, 7 inch diameter tapered to 3-inch face										
EM7-4P	Pole cap, 7-inch tapered to 4-inch face										
EM7-6P	Pole cap, 7 inch diameter with 6-inch face										
Additional Pole Caps with Optical Access Hole(s) (does not include bolts, order separately)											
EM7-3P-O-1-2	Pole cap, 7-inch tapered to 3-inch face, optical access 1 pole (1/8 inch diameter)										
EM7-3P-O-2-2	Pole cap, 7-inch tapered to 3-inch face, optical access both poles (1/8 inch diameter)										
EM7-3P-O-1-4	Pole cap, 7-inch tapered to 3-inch face, optical access 1 pole (1/4-inch diameter)										
EM7-3P-O-2-4	Pole cap, 7-inch tapered to 3-inch face, optical access both poles (1/4-inch diameter)										
EM7-6P-O-1-2	Pole cap, 7-inch tapered to 6-inch face, optical access 1 pole (1/8 inch diameter)										
EM7-6P-O-2-2	Pole cap, 7-inch tapered to 6-inch face, optical access both poles (1/8 inch diameter)										
EM7-6P-O-1-4	Pole cap, 7-inch tapered to 6-inch face, optical access 1 pole (1/4-inch diameter)										
EM7-6P-O-2-4	Pole cap, 7-inch tapered to 6-inch face, optical access both poles (1/4-inch diameter)										
Bolts											
EM7-BOLT-V	Pair of lead screws for EM7-HV Variable gap electromagnets										
EM7-BOLT-V-O	Pair of lead screws for EM7-HV Variable gap electromagnets, with optical access holes										
Other Accessories											
EM7-BASE	Magnet Base, 30.5 cm (12 inches) high										
EM7-CABLE	Cable from magnet to supply (4# AWG, 3 m [10 ft])										
EM7-FLOW	Flow switch, replacement										
651-533	Coolant Connector Kit – This kit includes parts that complete the installation of the Water Flow Switch, which is partially installed at the factory. The kit contains: <table border="0" style="width: 100%;"> <tr> <td style="text-align: right;">Quantity</td> <td>Description</td> </tr> <tr> <td style="text-align: right;">1</td> <td>Hose, 5/8-inch I.D.</td> </tr> <tr> <td style="text-align: right;">4</td> <td>Hose clamps</td> </tr> <tr> <td style="text-align: right;">1</td> <td>Adapter, Male Garden Hose Threads to 5/8-inch barbed</td> </tr> <tr> <td style="text-align: right;">1</td> <td>Adapter, Female Garden Hose Threads to 5/8-inch barbed, with washer</td> </tr> </table>	Quantity	Description	1	Hose, 5/8-inch I.D.	4	Hose clamps	1	Adapter, Male Garden Hose Threads to 5/8-inch barbed	1	Adapter, Female Garden Hose Threads to 5/8-inch barbed, with washer
Quantity	Description										
1	Hose, 5/8-inch I.D.										
4	Hose clamps										
1	Adapter, Male Garden Hose Threads to 5/8-inch barbed										
1	Adapter, Female Garden Hose Threads to 5/8-inch barbed, with washer										

APPENDIX A

FLOW SWITCH INSTALLATION

A1.0 GENERAL

This appendix details installation of the cooling water flow switch kit (Lake Shore P/N 651-523) for the Model EM7 electromagnet and the Model 648 magnet power supply (or any power supply with an external prohibit/interlock feature). Refer to Paragraphs A2.0 to A5.0 for EM7 flow switch installation.

A2.0 EM7 COOLANT CONNECTOR KIT LIST OF PARTS

The coolant connector kit (P/N 651-533) includes parts that complete the installation of the water flow switch, which is partially installed at the factory. The kit contains:

<i>Quantity</i>	<i>Description</i>
1	Hose, 5/8 inch I.D., 4 foot section
4	Hose clamps
1	Adapter, male garden hose thread to 5/8 inch barb
1	Adapter, female garden hose thread to 5/8 inch barb, with washer

A3.0 EM7 FLOW SWITCH SPECIFICATIONS

The factory adjusts the EM7 flow switch to close at 2 gallons per minute (gpm) and to operate normally open (N.O.). It can be field adjusted to a different flow rate (refer to Paragraph A5.0).

The flow switch operates with both normally closed (N.C.) and normally opened (N.O.) contacts. The flow switch incorporates a single pole single throw (SPST) switch set to activate by a moving magnet at a flow rate of 2 gallons (8 liters) per minute. The contacts are rated at 60 VA. All necessary fittings are provided to connect the switch to the coolant outlet of most electromagnets. (For additional information, see the flow switch users manual.)

A4.0 EM7 FLOW SWITCH INSTALLATION

For proper switch operation, keep it out of the field generated by the electromagnet. In general, connecting the switch at the end of a 10-inch long hose is sufficient to avoid any interference. During normal operation, cooling water flows through the magnet at a minimum rate of 2 gallons per minute, which allows the power supply to be turned on. To prevent damage to the electromagnet, connect the flow switch to the system before operating the power supply.

CAUTION: Do not manually bypass the interlock feature on the MPS.

The power supply interlock needs a closed contact to operate with the Lake Shore Model 648 MPS. Connect the two wires to the remote inhibit terminals. In this setup, the flow switch contacts close when the flow is above 2 gallons per minute to allow the power supply to provide current for the magnet. If additional interlock is to be connected externally to the unit, it can be one or more N.C. contacts connected in series, such as an emergency stop pushbutton. See Figure A-1.

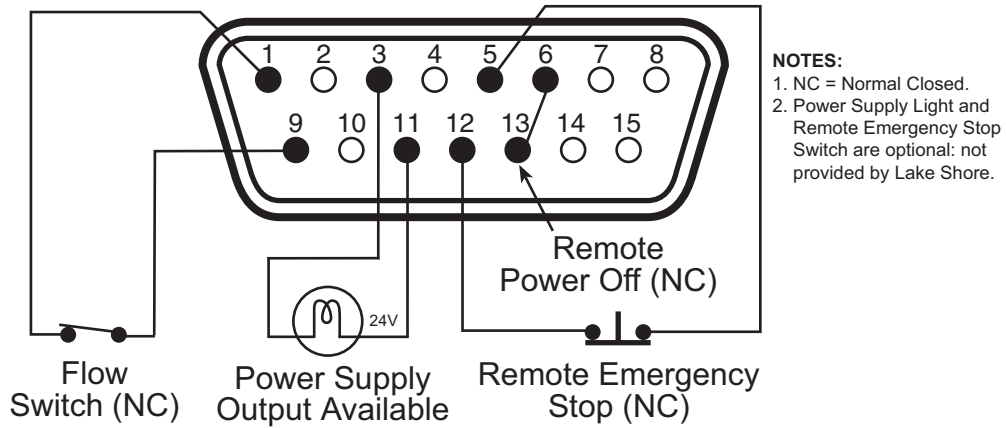
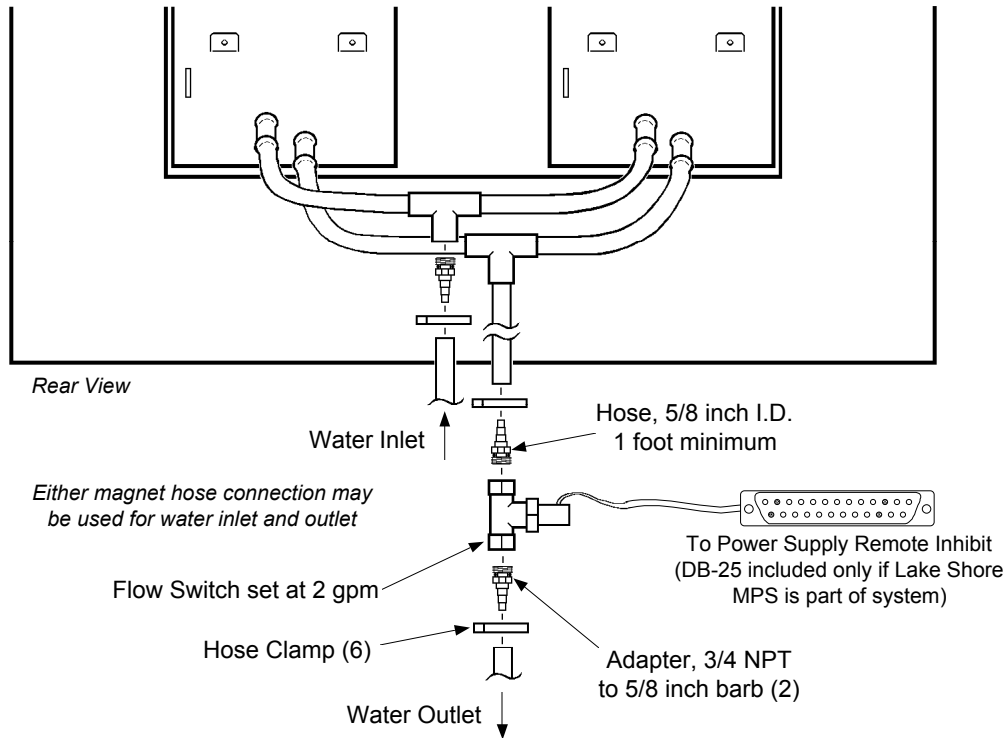


Figure A-1. EM7 Flow Switch Wiring Diagram

NOTE: Both the flow switch and emergency circuits must be closed for the power supply to operate.

For non-Lake Shore power supplies, consult the power supply manual for details on where to connect flow switch leads. If required, the flow switch can be reconfigured for a normally closed (N.C.). Consult the flow switch manual for the procedure to accomplish changing the switch.



C-EM-A-4.eps

Figure A-2. EM7 Flow Switch Installation

A5.0 EM7 FLOW SWITCH ADJUSTMENT

The flow switch is set at the factory for 2 gpm and normally open (N.O.) operation. The flow rate can be adjusted in the field using the following procedure. See Figure A-3.

1. Loosen the friction plate screws to allow movement of the reed contact.

NOTE: Very small millimeter increments (in either direction) are all that is necessary to change flow cutoff point settings.

2. To reduce the flow cutoff point, push the contact housing further into the housing.
3. To increase the flow cutoff point, pull the contact housing out from the housing.

Please consult the flow switch users manual for additional details.

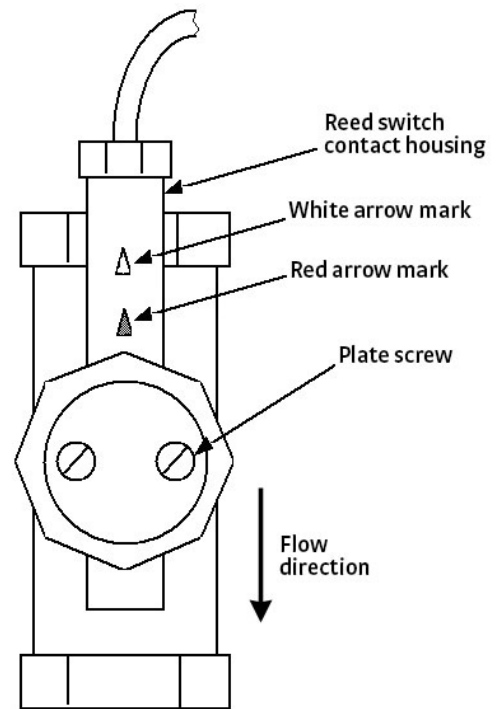


Figure A-3. Flow Switch Rate Adjustment

APPENDIX B

UNITS FOR MAGNETIC PROPERTIES

Conversion from CGS to SI Units				
Quantity	Symbol	Gaussian & CGS emu ^a	Conversion Factor, C ^b	SI & Rationalized mks ^c
Magnetic flux density, Magnetic induction	B	gauss (G) ^d	10^{-4}	tesla (T), Wb/m ²
Magnetic Flux	ϕ	maxwell (Mx), G•cm ²	10^{-8}	weber (Wb), volt second (V•s)
Magnetic potential difference, magnetomotive force	U, F	gilbert (Gb)	$10/4\pi$	ampere (A)
Magnetic field strength, magnetizing force	H	oersted (Oe), ^e Gb/cm	$10^3/4\pi$	A/m ^f
(Volume) magnetization ^g	M	emu/cm ^{3h}	10^{-3}	A/m
(Volume) magnetization	$4\pi M$	G	$10^3/4\pi$	A/m
Magnetic polarization, intensity of magnetization	J, I	emu/cm ³	$4\pi \times 10^{-4}$	T, Wb/m ²ⁱ
(Mass) magnetization	σ , M	emu/g	$\frac{1}{4\pi \times 10^{-7}}$	A•m ² /kg Wb•m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	A•m ² , joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	Wb•m ^l
(Volume) susceptibility	χ , κ	dimensionless emu/cm ³	$(4\pi)^2 \times 10^{-7}$	Henry per meter (H/m), Wb/(A•m)
(Mass) susceptibility	χ_ρ , κ_ρ	cm ³ /g, emu/g	$\frac{4\pi \times 10^{-3}}{(4\pi)^2 \times 10^{-10}}$	m ³ /kg H•m ² /kg
(Molar) susceptibility	χ_{mol} , κ_{mol}	cm ³ /mol, emu/mol	$\frac{4\pi \times 10^{-6}}{(4\pi)^2 \times 10^{-13}}$	m ³ /mol H•m ² /mol
Permeability	μ	dimensionless	$4\pi \times 10^{-7}$	H/m, Wb/(A•m)
Relative permeability ^j	μ_r	not defined	-	dimensionless
(Volume) energy density, energy product ^k	W	erg/cm ³	10^{-1}	J/m ³
Demagnetization factor	D, N	dimensionless	$1/4\pi$	dimensionless

NOTES:

- a. Gaussian units and cgs emu are the same for magnetic properties. The defining relation is $B = H + 4\pi M$.
- b. Multiply a number in Gaussian units by C to convert it to SI (e.g. $1 \text{ G} \times 10^{-4} \text{ T/G} = 10^{-4} \text{ T}$).
- c. SI (Système International d'Unités) has been adopted by the National Bureau of Standards. Where two conversion factors are given, the upper one is recognized under, or consistent with, SI and is based on the definition $B = \mu_0(H + M)$, where to $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$. The lower one is not recognized under SI and is based on the definition $B = \mu_0 H + J$, where the symbol I is often used in place of J.
- d. $1 \text{ gauss} = 10^5 \text{ gamma } (\gamma)$.
- e. Both oersted and gauss are expressed as $\text{cm}^{-1/2} \cdot \text{g}^{1/2} \cdot \text{s}^{-1}$ in terms of base units.
- f. A/m was often expressed as "ampere-turn per meter" when used for magnetic field strength.
- g. Magnetic moment per unit volume.
- h. The designation "emu" is not a unit.
- i. Recognized under SI, even though based on the definition $B = \mu_0 H + J$. See footnote c.
- j. $\mu_r = \mu/\mu_0 = 1 + \chi$, all in SI. μ_r is equal to Gaussian μ .
- k. $B \cdot H$ and $\mu_0 M \cdot H$ have SI units J/m^3 , $M \cdot H$ and $B \cdot H/4\pi$ have Gaussian units erg/cm^3 .

R.B. Goldfarb and F.R. Fickett, U.S. Department of Commerce, National Bureau of Standards, Boulder, Colorado 80303, March 1985, NBS Special Publication 696. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

