User's Manual

EM4 Series & EM7 Electromagnets

The EM4 Series consists of:

Model EM4-CS C-Yoke, Settable Gap 4-inch Electromagnet, Horizontal Field
Model EM4-CV C-Yoke, Variable Gap 4-inch Electromagnet, Horizontal Field
Model EM4-HV H-Yoke, Variable Gap 4-inch Electromagnet, Horizontal Field

EM7 magnets include:

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

LakeShore®

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Revision 1.6 P/N 119-622 **5 April 2004**

LIMITED WARRANTY STATEMENT
WARRANTY PERIOD: ONE (1) YEAR

1. Lake Shore warrants that this Lake Shore product (the "Product") will be free from defects in materials and workmanship for the Warranty Period specified above (the "Warranty Period"). If Lake Shore receives notice of any such defects during the Warranty Period and the Product is shipped freight prepaid, Lake Shore will, at its option, either repair or replace the Product if it is so defective without charge to the owner for parts, service labor or associated customary return shipping cost. Any such replacement for the Product may be either new or equivalent in performance to new. Replacement or repaired parts will be warranted for only the unexpired portion of the original warranty or 90 days (whichever is greater).
2. Lake Shore warrants the Product only if it has been sold by an authorized Lake Shore employee, sales representative, dealer or original equipment manufacturer (OEM).
3. The Product may contain remanufactured parts equivalent to new in performance or may have been subject to incidental use.
4. The Warranty Period begins on the date of delivery of the Product or later on the date of installation of the Product if the Product is installed by Lake Shore, provided that if you schedule or delay the Lake Shore installation for more than 30 days after delivery the Warranty Period begins on the 31st day after delivery.
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CERTIFICATION

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 EM4 Series and EM7 are compact electromagnets 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.

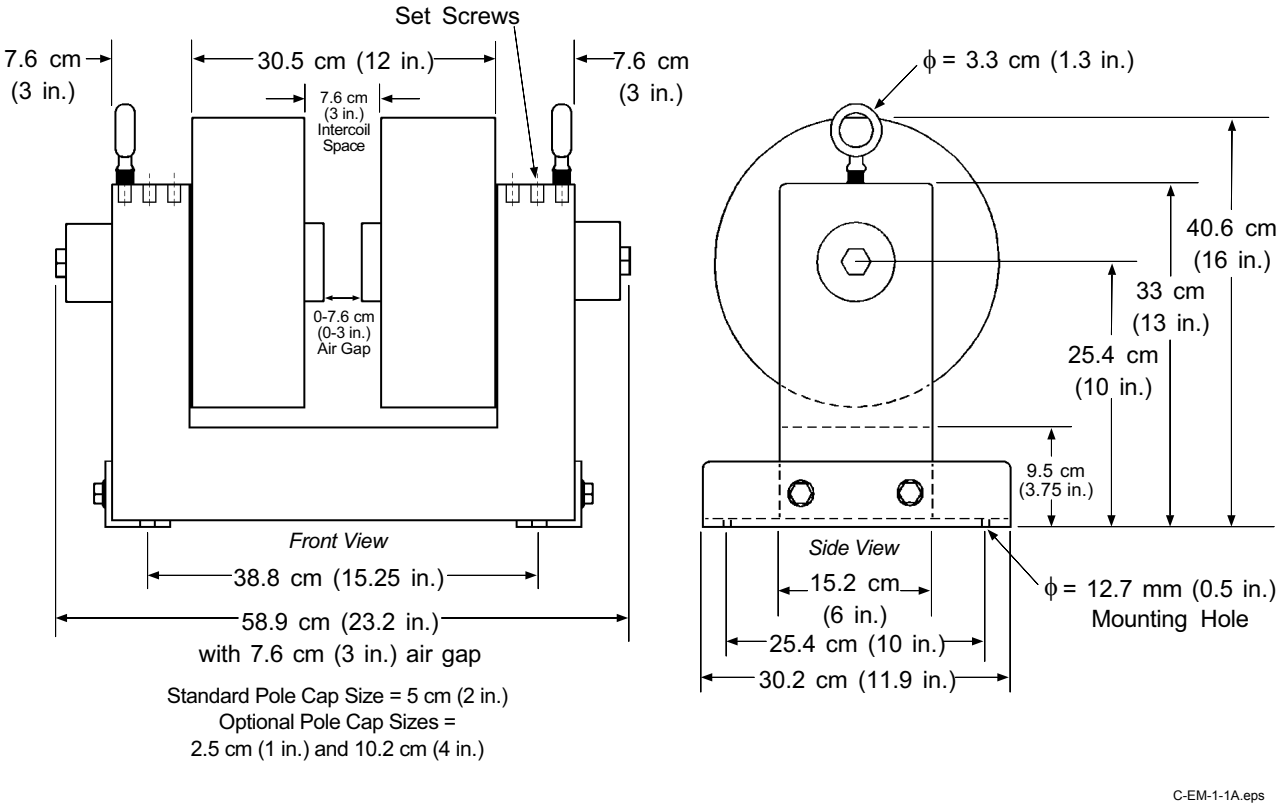
1.1 GENERAL DESCRIPTION

Refer to Table 1-1 for detailed specifications. For dimensional diagrams, see Figure 1-1 for Model EM4-CS, Figure 1-2 for Model EM4-CV, Figure 1-3 for Model EM4-HV, and Figures 1-5 and 1-6 for the EM7.

- 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. On Models EM4-HV and EM7, the poles lock in place by locking levers on each side of the electromagnet frame.
- EM4 Models achieve unmatched field intensities in air gap widths up to 10.2 cm (4 inches), or up to 7.6 cm (3 inches) for the Model EM4-CS, with cylindrical or tapered pole caps. For the EM7, 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 threaded pole pieces, facilitates variations in air gap configurations.
- 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.
- Compact size of EM4 Models permits convenient bench-top mounting.
- Couple EM4 Models with a Lake Shore Model 647 Magnet Power Supply (MPS) and the EM7 with a Model 665 MPS to form a versatile Laboratory Electromagnet Characterization System. The true, four-quadrant bidirectional power output of the Model 647 MPS allows for rapid, uniform magnetic field reversal resulting in enhanced Hall effect measurement of semi-conductors and other materials, and improved four-quadrant hysteresis loops with shortened integration intervals. The Model 665 MPS also 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 EM4 Series and EM7 Electromagnet Specifications

Specifications	EM4-CS	EM4-CV		EM4-HV		EM7
Air Gap	Up to 7.6 cm (3 in.) settable.	Up to 10.2 cm (4 in.) continuously variable.		Up to 10.2 cm (4 in.) continuously variable.		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)	0.16 Ω per coil, at equilibrium temp., wired in series (0.32 Ω total)	0.96 Ω per coil, at equilibrium temp., wired in parallel (0.48 Ω total)	0.16 Ω per coil, at equilibrium temp., wired in series (0.32 Ω total)	0.96 Ω per coil, at equilibrium temp., wired in parallel (0.48 Ω total)	1 Ω per coil, at equilibrium temp., wired in parallel (0.5 Ω total).
Cooling Water	Tap water or closed cooling system					
Water Flow Rate	3.8 liters per minute (1.0 gallon per minute)					11.4 liters per minute (3.0 gallons per minute)
Supply Pressure	240 – 700 kPa (35 - 100 psig)					
Water Chiller Cooling Capacity	1.8 kW (6,142 BTU/Hr)	2.5 kW (8,530 BTU/Hr)				5 kW (17,060 BTU/Hr)
Inlet Temperature	15 – 24 °C (59 – 75 °F)					
Coil Operating Temperature	60 °C (140 °F) Maximum					
Coil Spacing	7.6 cm (3 in.)	10.2 cm (4 in.)				17.8 cm (7 in.)
Coil Width	10.9 cm (4.3 in.)	11.2 cm (4.4 in.)				13.2 cm (5.2 in.)
Coil Diameter	30.2 cm (11.9 in.)	32.4 cm (12.75 in.)				44.5 cm (17.5 in.)
Turns per Coil	5,544	1,960	5,082	1,960	5,082	624
Amp-Turns	—	19,600	25,410	19,600	25,410	31,200
Current (Max. Continuous Operating)	±70 A					±100 A
Width	58.4 cm (23 in.) at max. 7.6 cm (3 inch) gap	81.3 cm (32 in.)				101.6 cm (40 in.) at max. 17.8 cm (7 in.) gap
Height	40.6 cm (16 in.)	45.7 cm (18 in.)		40.6 cm (16 in.) set at 45° angle		Magnet: 63.5 cm (25 in.) set at 45° Stand: 30.5 cm (12 in.)
Depth	30.5 cm (12 in.)	35.6 cm (14 in.)		40.6 cm (16 in.)		66 cm (26 in.)
Weight	147.4 kg (325 lbs.)	190.5 kg (420 lbs.)		201.9 kg (445 lbs.)		636 kg (1400 lbs.)
Shipping Weight	165.6 kg (365 lbs.)	206.4 kg (455 lbs.)		215.5 kg (475 lbs.)		682 kg (1500 lbs.)
Shipping Size	61 cm (24 in.) x 30.5 cm (12 in.) x 45.7 cm (18 in.)	96.5 cm (38 in.) x 71.1 cm (28 in.) x 55.9 cm (22 in.)		96.5 cm (38 in.) x 58.4 cm (23 in.) x 55.9 cm (22 in.)		122 cm (48 in.) x 119 cm (47 in.) x 86 cm (34 in.)
Magnet Power Supply	Model 647 or 662	Model 647	Model 662	Model 647	Model 622	Model 665
Operating Current	±55 A	±70 A				±100 A
Operating Voltage	±27.5 volts available	±28 volts nominal (±28.6 volts available)	±35 volts nominal	±28 volts nominal (±28.6 volts available)	±35 volts nominal	±50 volts nominal
Power Consumption	1.5 kVA nominal (2 kVA available)	1.6 kVA nominal (2 kVA available)	2.4 kVA nominal	1.6 kVA nominal (2 kVA available	2.4 kVA nominal	5 kVA nominal



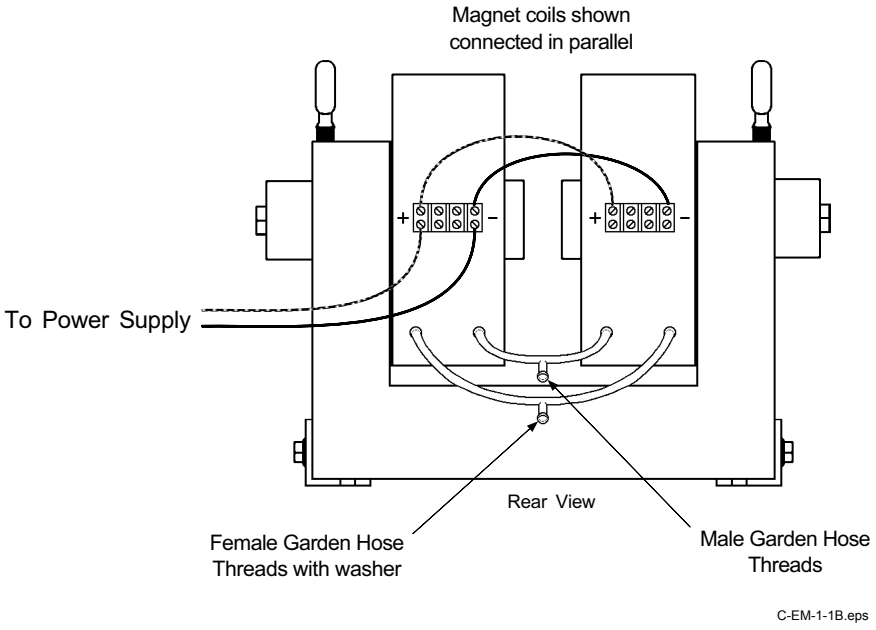


Figure 1-1. Model EM4-CS Electromagnet Dimensions & Connections

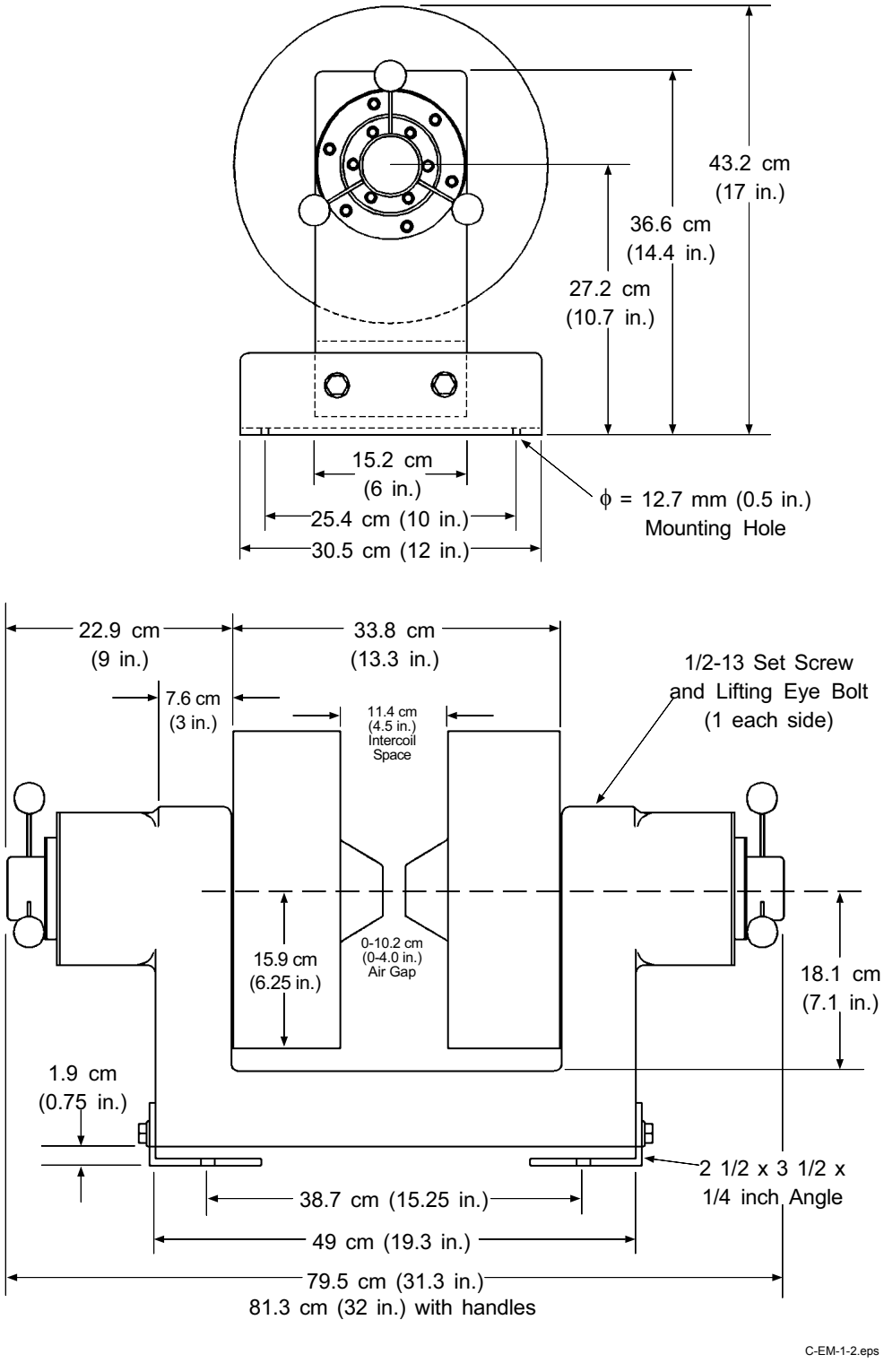


Figure 1-2. Model EM4-CV Electromagnet Dimensions

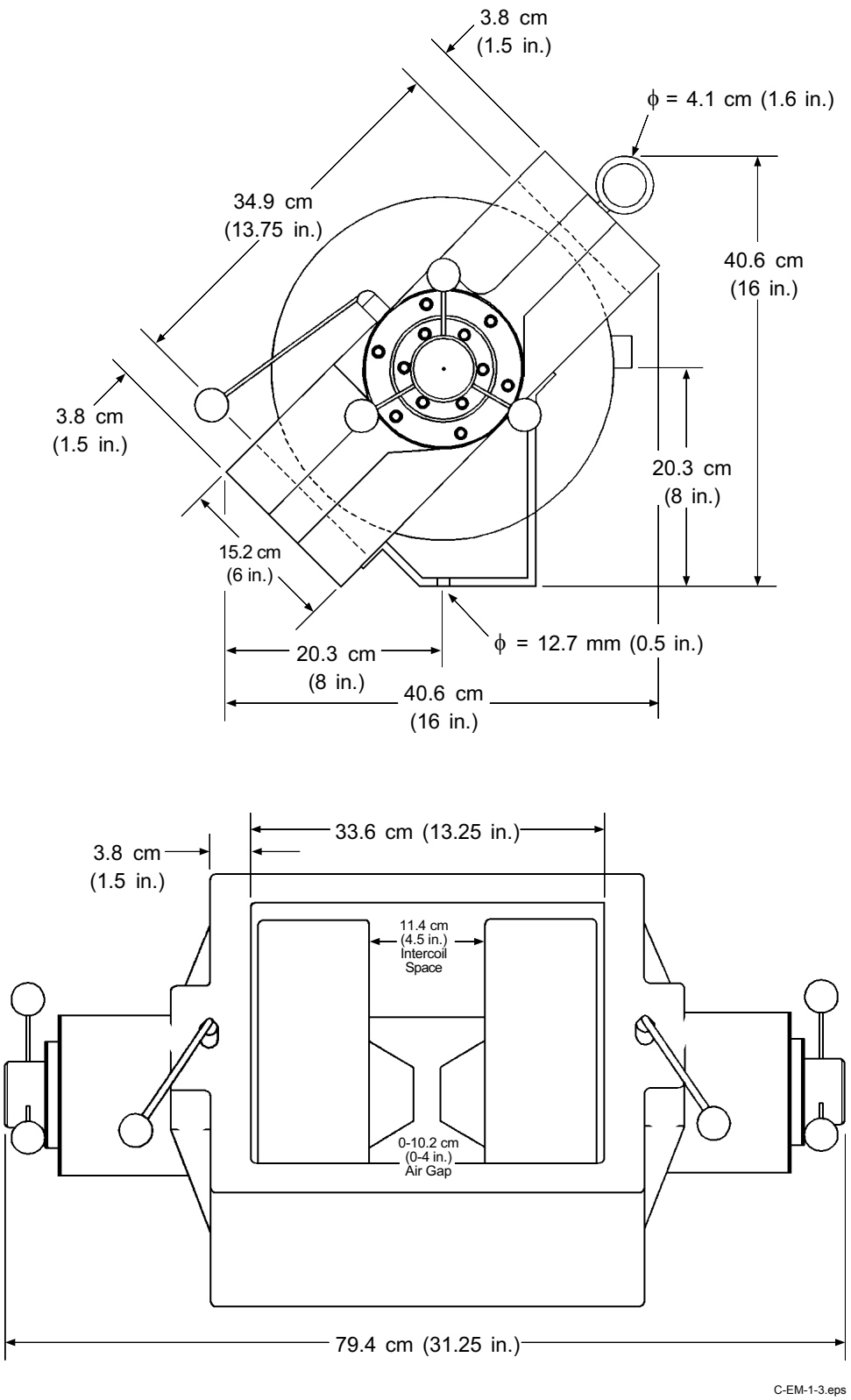


Figure 1-3. Model EM4-HV Electromagnet Dimensions

1.2 MODEL EM-4-CV AND -HV WIRING

Though mounted in different frames, the Model EM-4-HV and -CV have identical coils. Typical coil wiring is shown in Figure 1-4. Water inlet and outlet are also shown. Direction of field is normally determined at the factory and will be indicated by a sticker on the rear of the magnet.

NOTE: The wiring in Figure 1-4 assumes coils wound in a certain direction. If you wire the magnet and get a zero field at the center, the coils are wound backwards. You must reverse one of the magnet leads.

NOTE: The magnet coils in Figure 1-4 are shown connected in series (0.16 Ω). See Figure 1-1 for an example of coils connected in parallel (0.96 Ω).

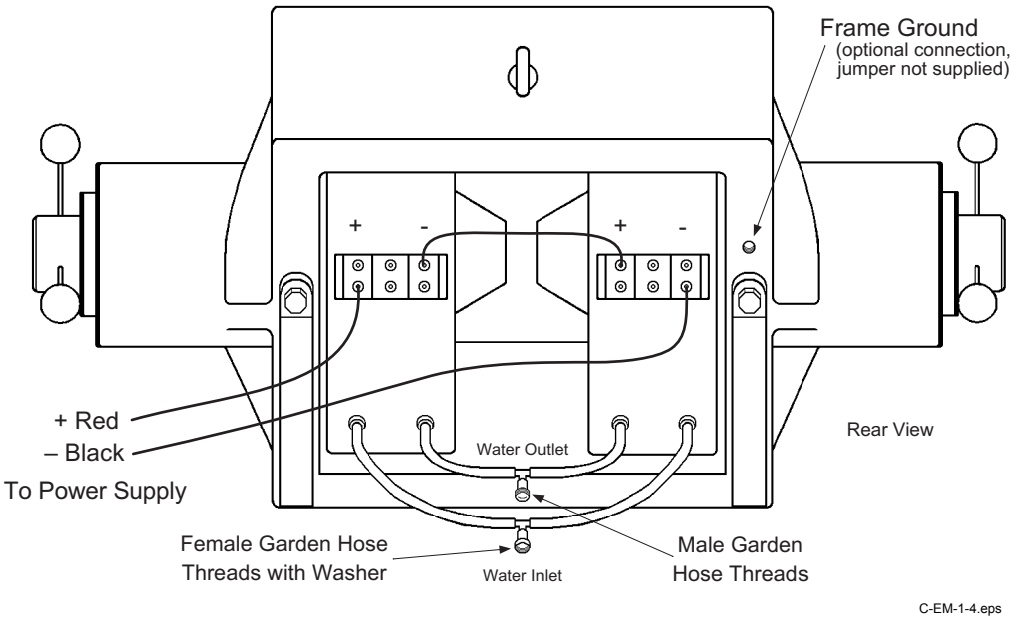


Figure 1-4. Typical Model EM4-CV and EM4-HV Electromagnet Wiring

1.3 TYPICAL FIELD UNIFORMITY

Table 1-2 lists typical field uniformity for EM4 Series magnets. These specifications represent only typical performance and are subject to variations from magnet to magnet and operating field. The third column gives uniformity over a cubical 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.

Table 1-2. Typical EM4 Series Field Uniformity

Magnet Configuration		Uniformity	1% Cylindrical Volume	
Pole Face	Air Gap	over 1 cm^3	Diameter	Length
10 cm (4 in.)	7.6 cm (3 in.)	±0.2%	2.5 cm	1.9 cm
10 cm (4 in.)	5 cm (2 in.)	±0.1%	3.8 cm	5.0 cm
10 cm (4 in.)	2.5 cm (1 in.)	±0.05%	6.4 cm	2.5 cm
5 cm (2 in.)	2.5 cm (1 in.)	±0.3%	1.9 cm	2.5 cm
5 cm (2 in.)	1.3 cm (0.5 in.)	±0.2%	3.2 cm	1.2 cm
2.5 cm (1 in.)	1.3 cm (0.5 in.)	±1.7%	1.0 cm	0.8 cm

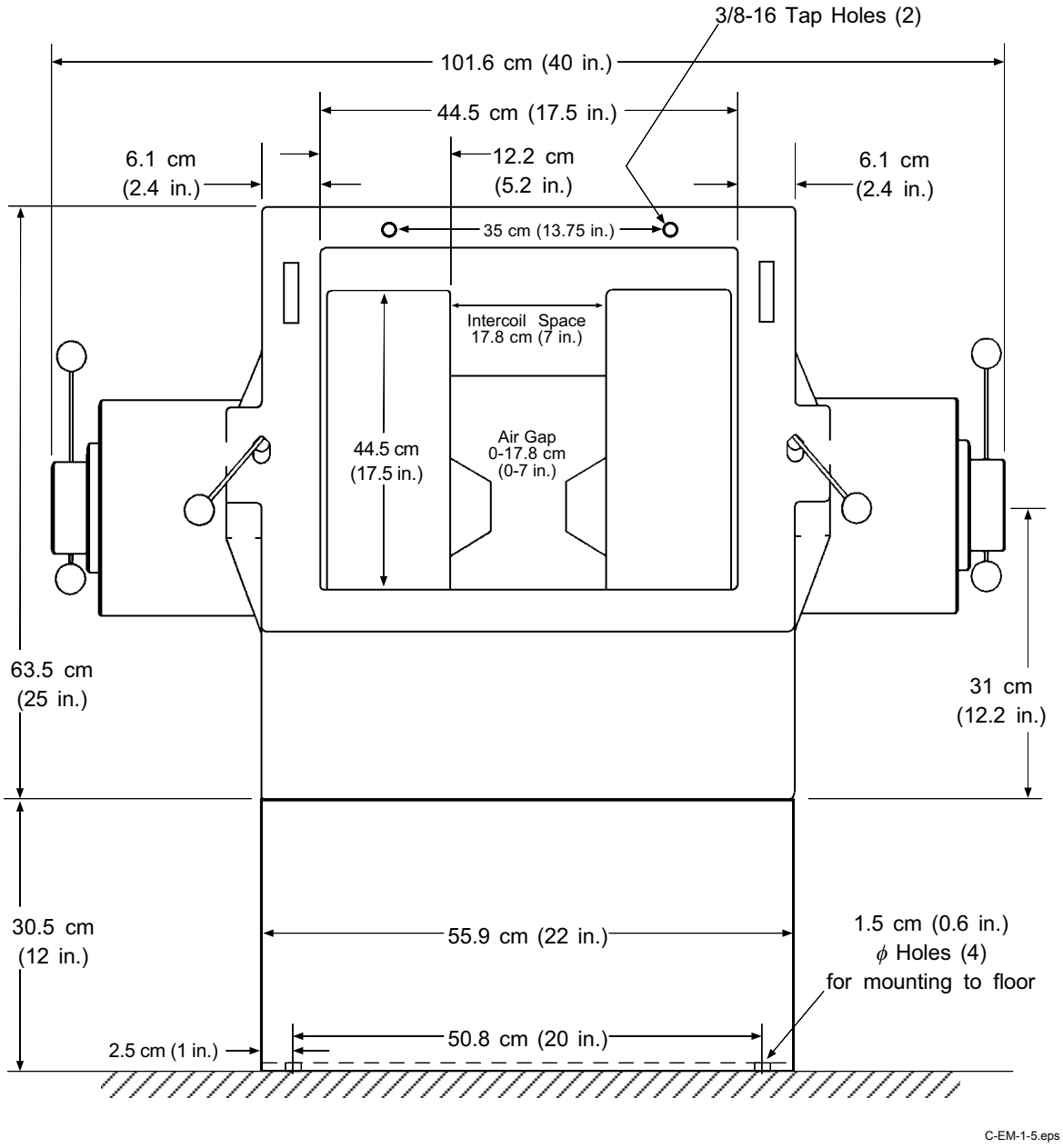


Figure 1-5. Model EM7-HV Electromagnet Front View

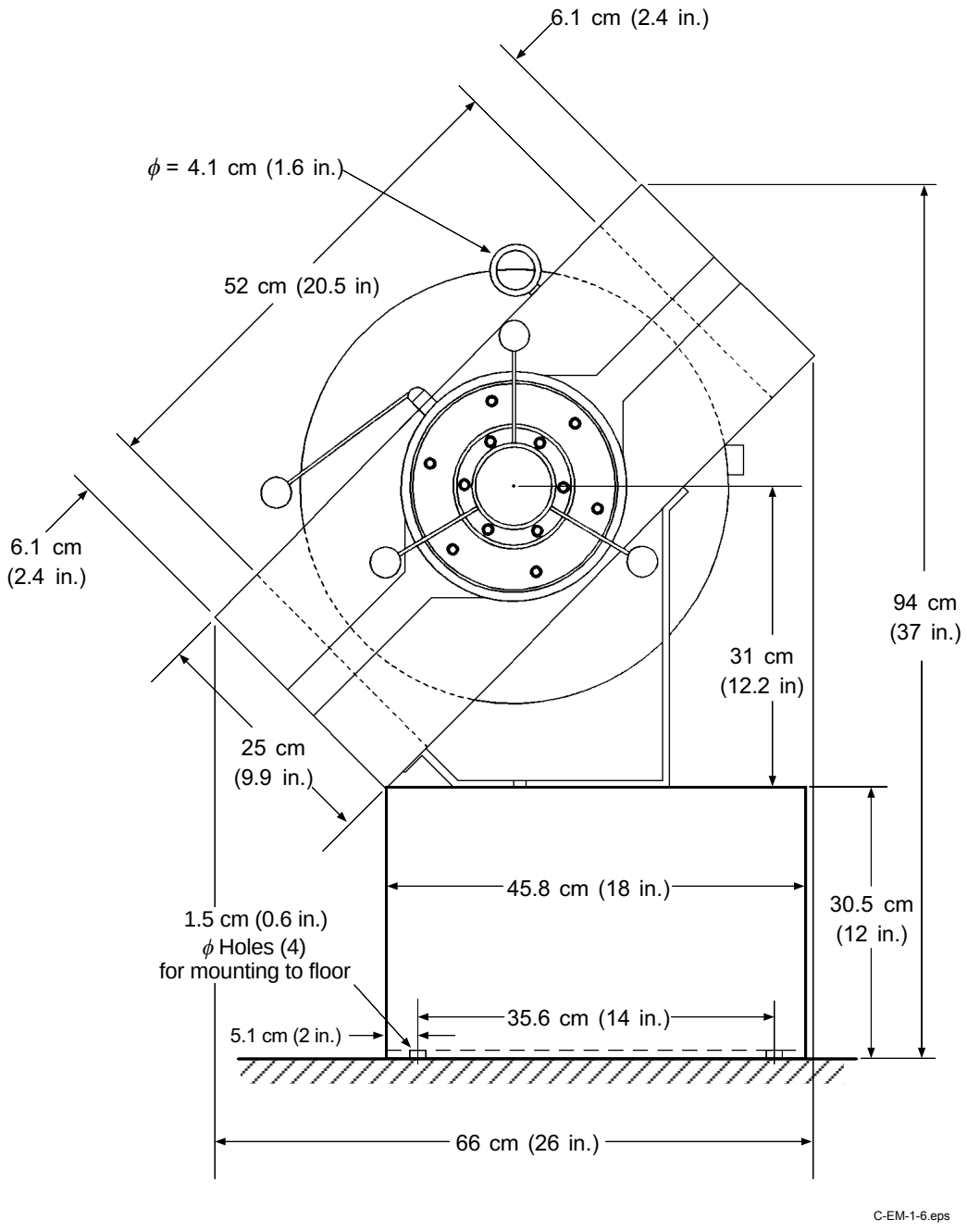


Figure 1-6. Model EM7-HV Electromagnet Side View

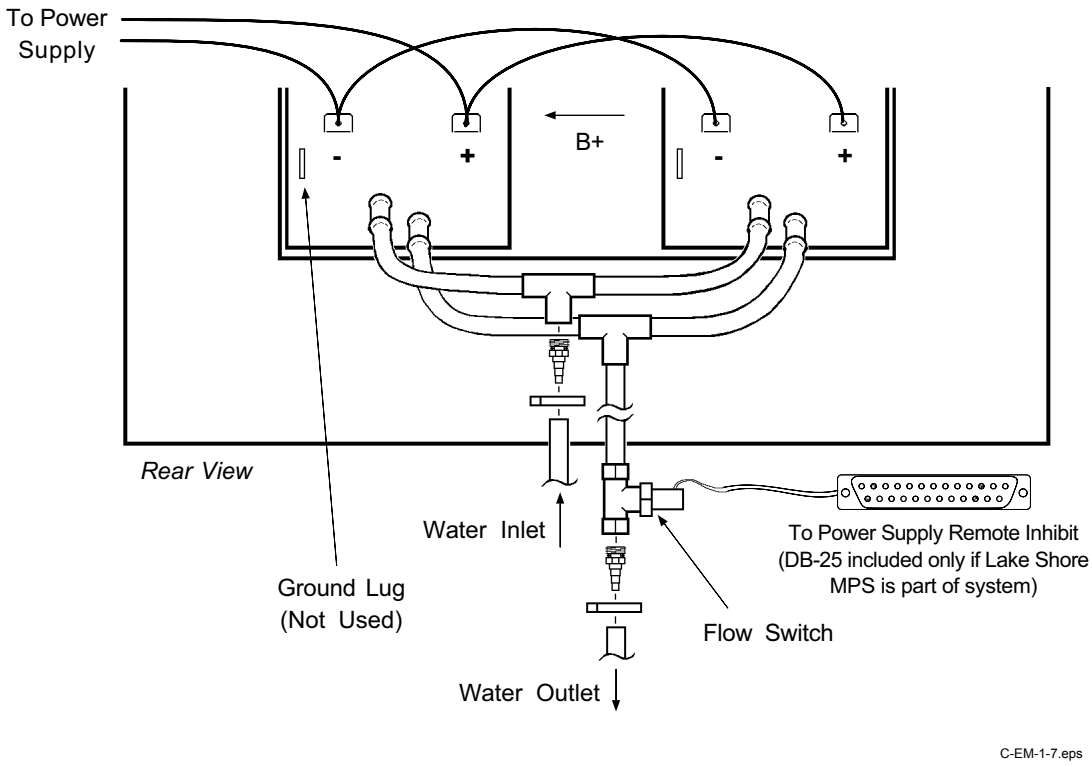


Figure 1-7. Model EM7-HV Electromagnet Rear View Wiring and Connections

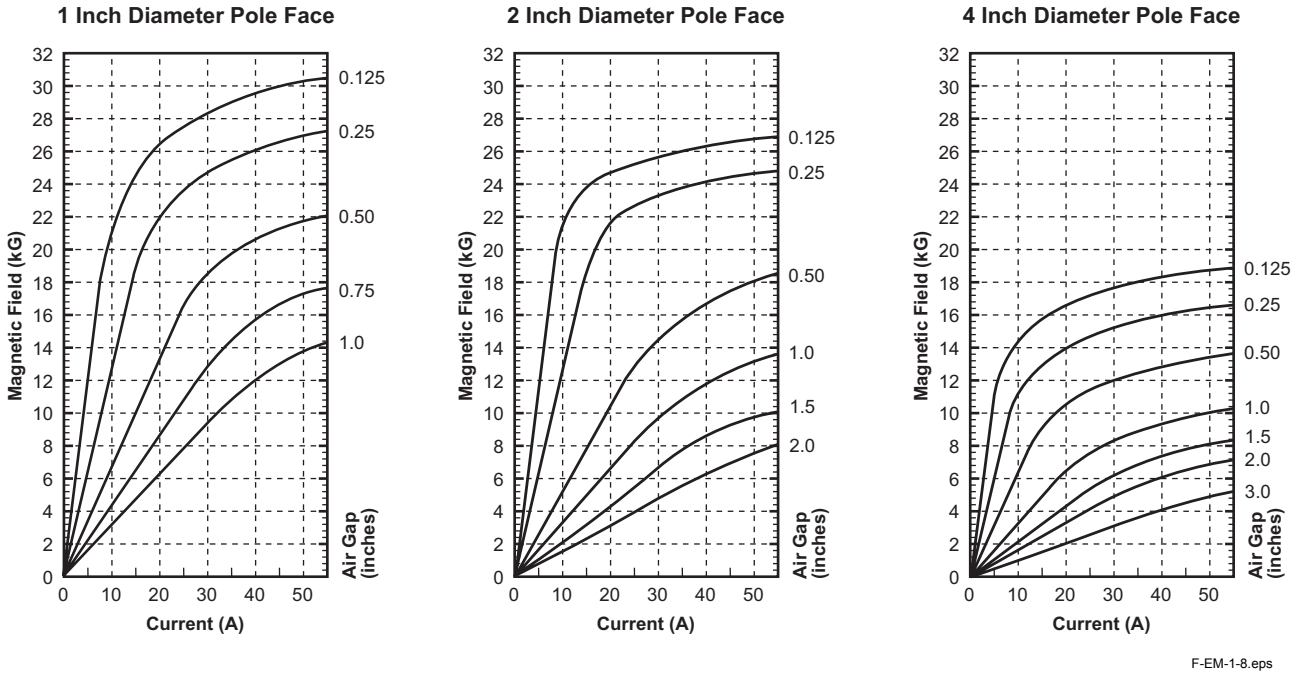


Figure 1-8. Model EM4-CS Magnetic Field Versus Current Charts

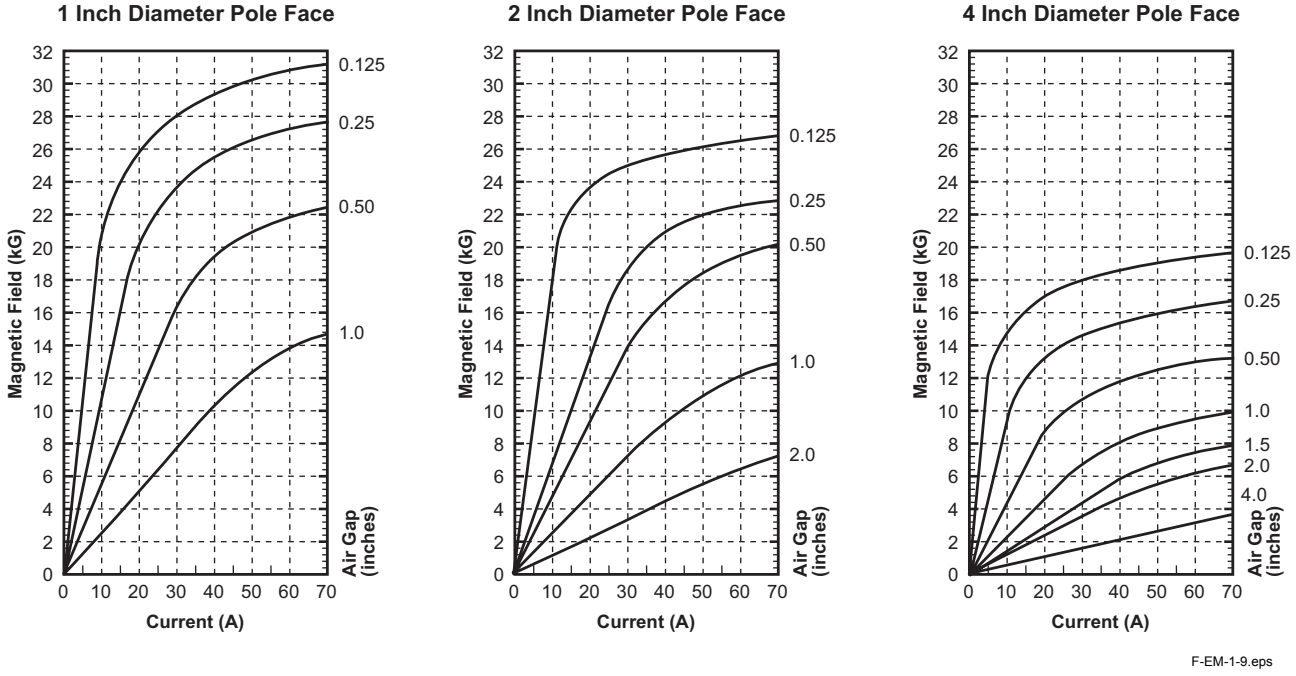


Figure 1-9. Model EM4-CV Magnetic Field Versus Current Charts

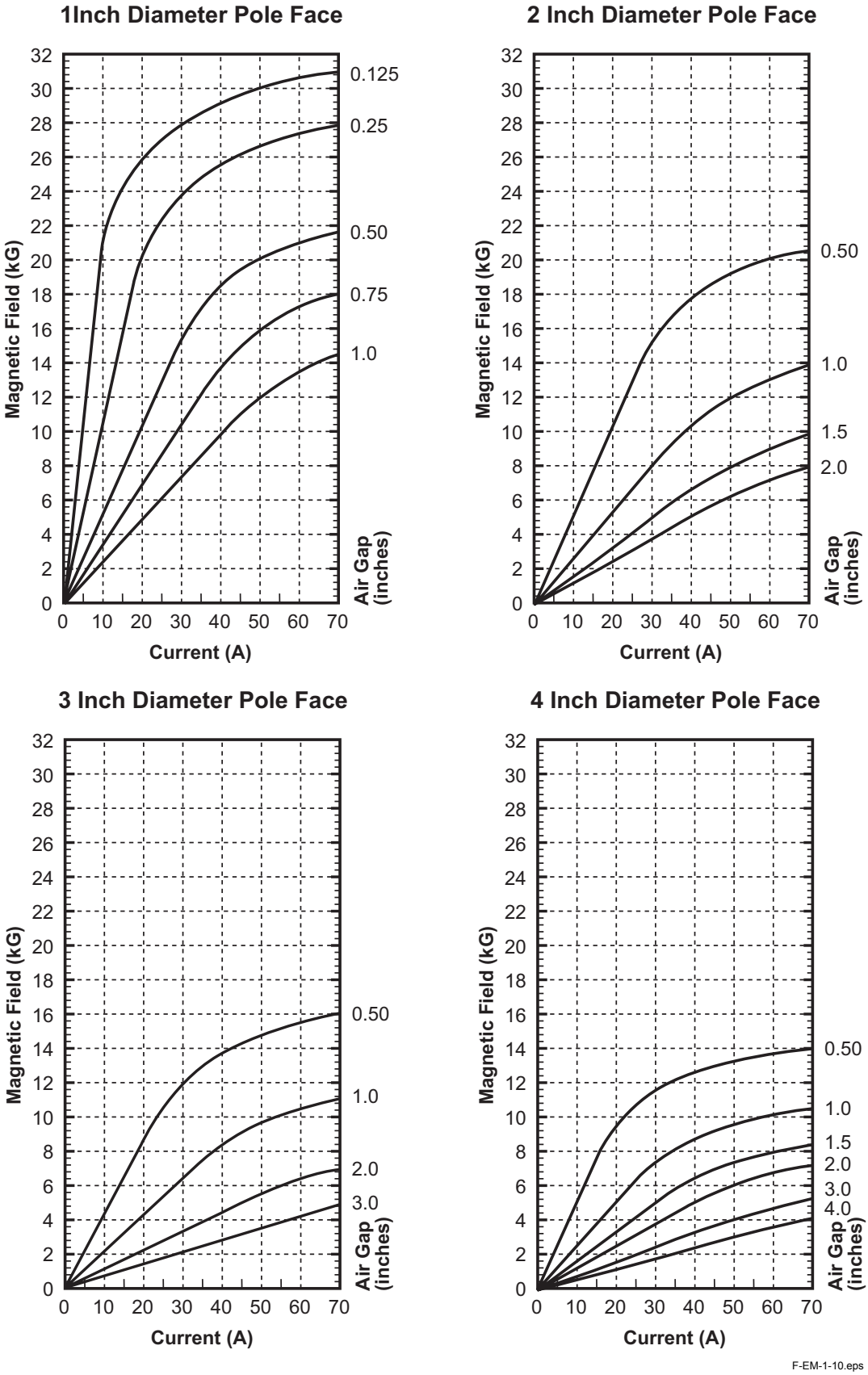


Figure 1-10. Model EM4-HV Magnetic Field Versus Current Charts (Series Coils = 0.16 Ω)

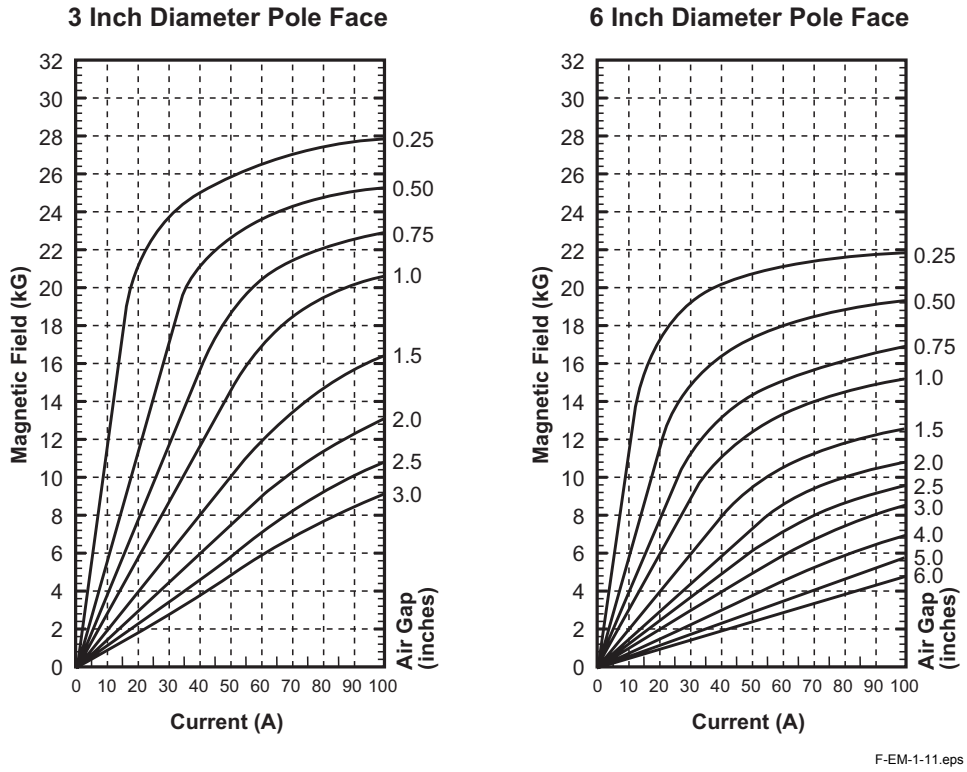
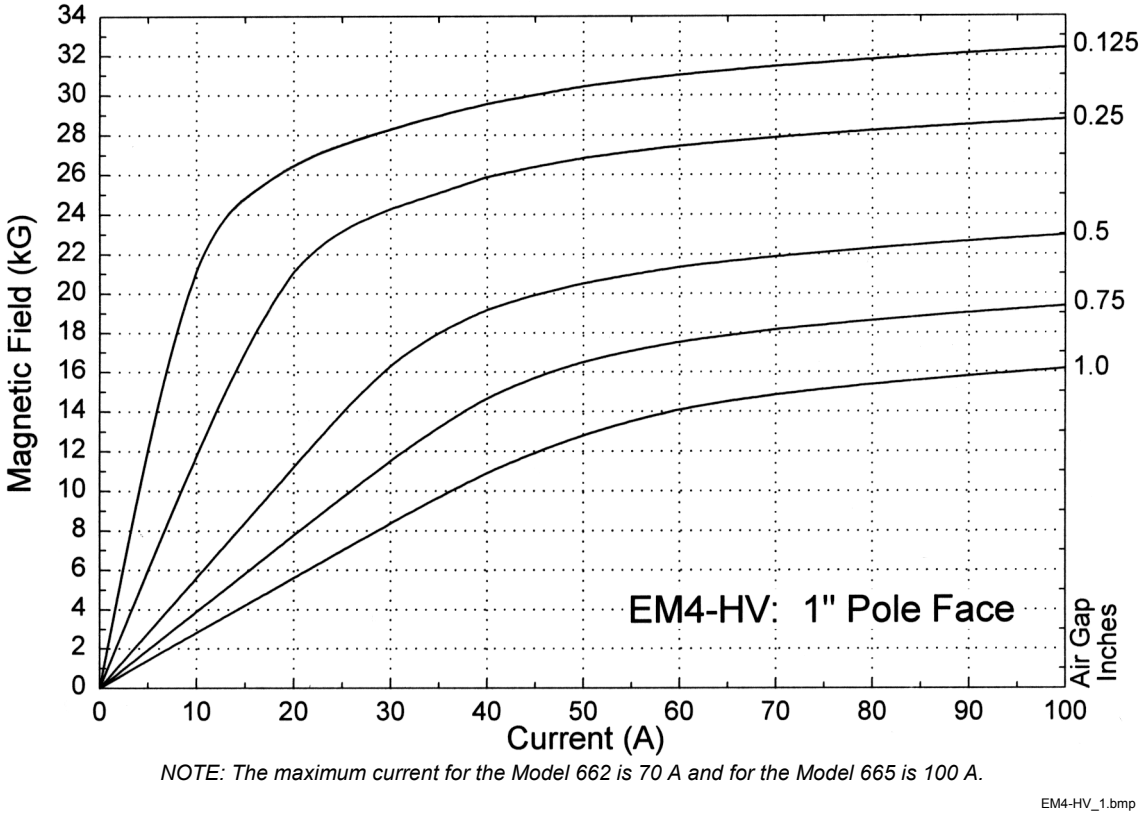
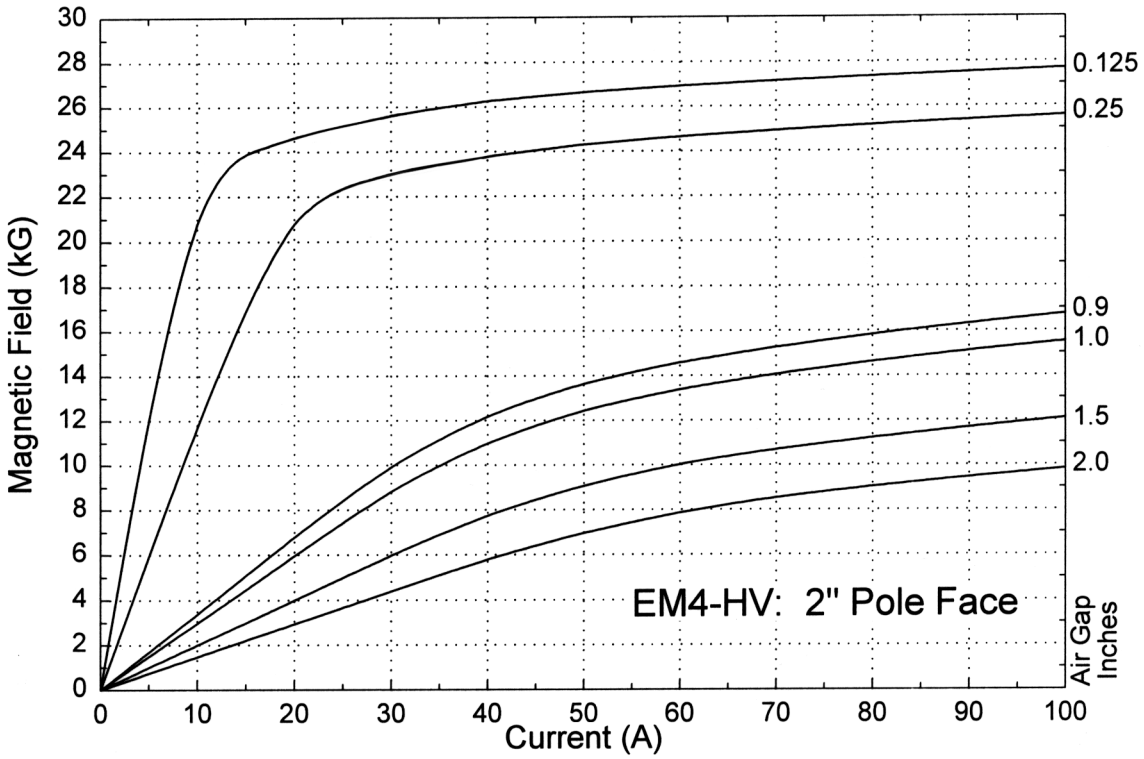


Figure 1-11. Model EM7-HV Magnetic Field Versus Current Charts (Parallel Coils = 0.96 Ω)



NOTE: The maximum current for the Model 662 is 70 A and for the Model 665 is 100 A.

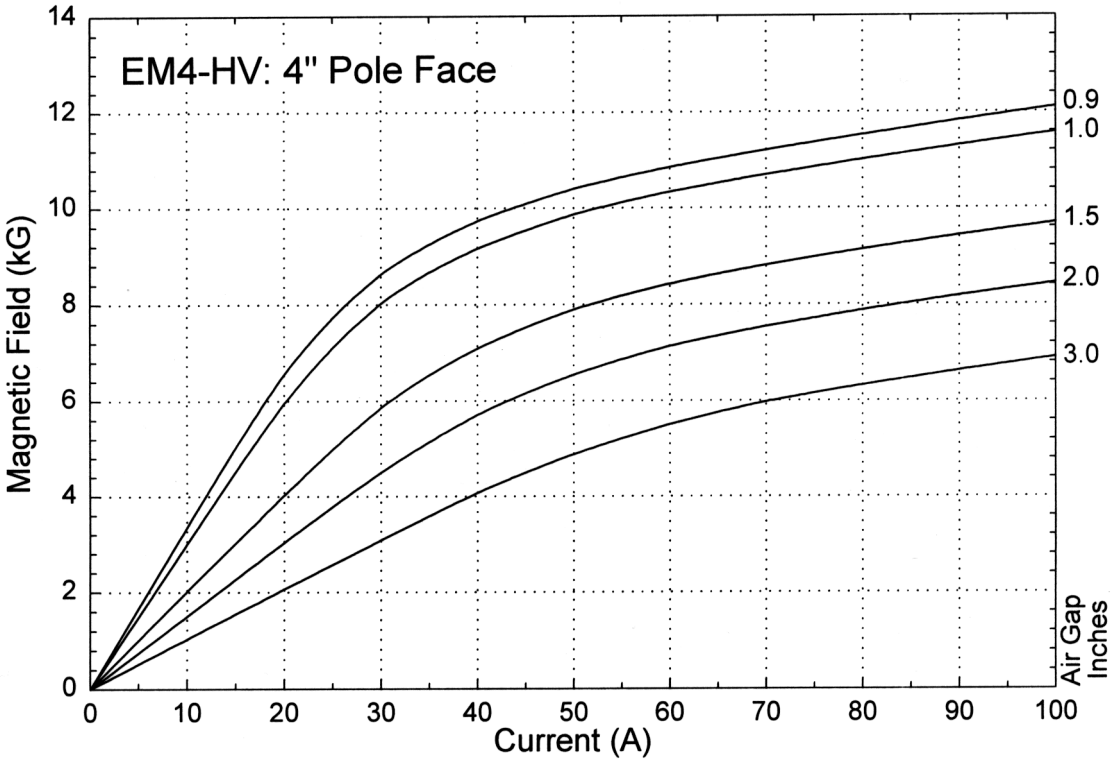
Figure 1-12. Model EM4-HV Magnetic Field Versus Current Charts, 1-inch Pole Face (Parallel Coils = 0.96 Ω)



NOTE: The maximum current for the Model 662 is 70 A and for the Model 665 is 100 A.

EM4-HV_2.bmp

Figure 1-13. Model EM4-HV Magnetic Field Versus Current Charts, 2-inch Pole Face (Parallel Coils = 0.96 Ω)



NOTE: The maximum current for the Model 662 is 70 A and for the Model 665 is 100 A.

EM4-HV_4.bmp

Figure 1-14. Model EM4-HV Magnetic Field Versus Current Charts, 4-inch Pole Face (Parallel Coils = 0.96 Ω)

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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 cryogens.

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 EM4 and EM7 electromagnets include the following accessories:

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

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 FOR EM7 ONLY: 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, if EM7) 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, if EM7) over the studs and bolt in place.
3. Connect 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. For the Model EM4-CS, Loosen the set screws which hold the two pole pieces in place with the L-shaped hex key provided. Use the U-shaped pole tool to adjust to the proper gap. Tighten all the set screws. For the Model EM4-CV, EM4-HV, and EM7, unlock pole pieces with locking levers, then rotate spokes to move the poles to set the air gap. Lock 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 safety cover plates. Connect the power supply cables to the terminal blocks on the rear of the coils. For the Model EM4-CS and the EM7, use two jumpers between the two coils for parallel operation. For Model EM4-CV, EM4-HV, use one jumper between the two coils for series operation. Replace safety cover plates before operating magnet.

7. Turn on the cooling water and adjust the flow rate:

Model EM4	3.8 liters per minute (1 gallon per minute)
Model EM7	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.

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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 provided current to the magnet. There are no operating controls on the magnet. Rotating hand knobs on the side of the magnet allow users to vary the air gap from 0 to 7.6 cm (0 to 3 inches) on the Model EM4-CS, from 0 to 10.2 cm (0 to 4 inches) on the Model EM4-CV and -HV, and from 0 to 17.8 cm (0 to 7 inches) on the Model EM7.

WARNING: Always set current to zero amps and turn off power supply before adjusting the magnet. After adjusting pole spacing, lock poles in place by tightening the Allen head locking set screws on top of the EM4-CS and -CV yoke, or the securing the locking levers on the EM4-HV and EM7.

3.3 POLE CAPS

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.

The pole cap threads mate with threads on the pole pieces. To mount the pole caps, turn them in a clockwise direction on the pole pieces. Secure the pole caps by tightening them with the supplied spanner wrench, except for the EM4-CS which uses an adjustable wrench (not provided) on the bolts at the end of the pole piece. Degauss pole caps before removing them from the pole pieces. Residual magnetism may hold the pole caps in contact with the pole pieces with enough force to make it difficult to separate them. 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 pieces using a wrench. Use a light oil on the threads of the pole piece.

Whether in use or storage, inspect all pole caps occasionally for foreign matter and any indication of rust. Remove all traces of foreign matter from pole caps with a soft clean cloth. Remove all traces of rust with crocus cloth 4/0 grit or finer and remove all traces of abrasive with a soft clean cloth. Wipe clean all pole cap surfaces with a clean, lint-free cloth lightly oiled with a high quality light oil.

3.4 EM4-CS AND EM4-CV LOCKING SCREWS

WARNING: Eye bolts are for lifting only. Replace them with the provided set screws before operating the magnet.

After positioning the magnet at its permanent location, remove the lifting rings and replace them with the locking screws provided.

After setting the pole gap, fix the poles into position with the locking screws to prevent accidental movement of the pole pieces due to the magnetic field generated. This is especially true for the Model EM4-CS. To prevent harm to the user and damage to the equipment, tighten all locking screws before applying current to the magnet. Loosen the screws to adjust the air gap between the pole caps.

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CHAPTER 4

MAINTENANCE

4.0 GENERAL

This chapter describes the pole cap replacement procedure for the Model EM4-CS in Paragraph 4.1 and the Model EM4-CV, EM4-HV, and EM7 in Paragraph 4.2.

4.1 MODEL EM4-CS POLE CAP REPLACEMENT

CAUTION: Handle the pole caps with care. Deep dents or scratches on pole caps can impair the magnetic field homogeneity.

1. Set power supply current output to zero. Turn the power supply off.
2. Use an open end wrench to loosen the bolts one turn at the end of the two pole pieces.
3. Loosen set screws holding the two pole pieces in place with the L-shaped hex key provided. With the U-shaped pole tool, pull one pole piece outward until the front of the pole cap is flush with the coil surface.
4. Using the same U-shaped pole tool, push the other pole inward until the holes on the side of the pole cap are visible. This pole cap is now ready to be removed.

CAUTION: When installing pole caps, place soft material (cardboard, towel, etc.) beneath them to prevent accidental damage if they fall during installation.

5. Using one hand to hold on to the pole cap, unscrew the bolt from the other end of the pole piece. Remove the pole cap. If the pole cap is still trapped in the center of the coil, reinsert the bolt and tap lightly at one end to loosen the cap. It is important to hold onto the cap while tapping.
6. Using one hand, line up the new pole cap and use the same bolt to fasten the cap to the pole piece. Rotate the bolt by hand only to prevent rotation of the pole piece.

NOTE: The key way on the pole pieces are machined with a slope downward toward the center of the magnet. It is sometimes necessary to re-adjust the set screws while setting the pole gap.

7. Using the U-shaped pole tool, pull the pole piece outward until the front of the pole cap is flush with the front of the coil. The key way in the pole should line up with the set screw in the top of the frame (yoke).
8. Use the L-shaped hex key to lightly tighten the set screws.
9. Repeat Steps 4 thru 7 to change the other pole cap.

NOTE: Always tighten all the set screws with the L-shaped hex key after adjusting the pole air gap and before turning on the power supply.

10. Loosen the set screws and use the U-shaped pole tool to adjust to the proper gap. Tighten all set screws.

4.2 MODEL EM4-CV, EM4-HV, AND EM7 POLE CAP REPLACEMENT

CAUTION: Handle the pole caps with care. Deep dents or scratches on pole caps can impair the magnetic field homogeneity.

1. Set power supply current output to zero. Turn the power supply off.
2. Unlock the pole pieces so they move in and out freely.
3. Rotate the spokes to move one pole piece outward until the front of the pole cap is flush with the surface of the coil or as far as it can be moved.
4. Rotate the other spokes to move the other pole piece inward until the pole cap is outside of the coil surface. Lock the pole piece. The pole cap is now ready to be removed.

CAUTION: When installing pole caps, place soft material (cardboard, towel, etc.) beneath them to prevent accidental damage if they fall during installation.

5. Using the spanner wrench provided, rotate the pole cap one turn counter-clockwise. Set the wrench aside. Using both hands, rotate the pole cap off the pole piece. It is important to hold onto the pole cap when rotating. The pole cap may be damaged if it suddenly disengages from the pole piece and drops against a hard surface.

NOTE: Right-hand threads are used in the pole caps. 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.

6. Using both hands, line up the new pole cap squarely with the pole piece and rotate it clockwise on to the pole piece. Use the spanner wrench to tighten the cap against the pole piece.
7. Unlock the pole piece. Rotate the spokes to move the poles outward until the front of the pole cap is flush with the surface of the coil or as far as it can be moved.
8. Lock the pole piece.
9. Repeat Steps 4 thru 6 to change the other pole cap.
10. Unlock the pole pieces with the locking levers then rotate spokes to move the poles to set the air gap. Lock the pole pieces in place.

CHAPTER 5

OPTIONS AND ACCESSORIES

5.0 GENERAL

This chapter lists EM4 and EM7 options in Paragraph 5.1 and accessories in Paragraph 5.2.

5.1 SYSTEM OPTIONS

Table 5-1 lists available EM4 and 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
Model EM4 Series Electromagnets	
EM4-CS	4-inch diameter pole caps, C-yoke, settable gap (set by sliding poles).
EM4-CV	4-inch diameter pole caps, C-yoke, variable gap (set by rotating hand spokes).
EM4-HV	4-inch diameter pole caps, H-yoke, variable gap (set by rotating hand spokes).
EM4-CS-O	Same as EM4-CS with optical access.
EM4-CV-O	Same as EM4-CV with optical access.
EM4-HV-O	Same as EM4-HV with optical access.
Model EM7 Electromagnets	
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 EM4 accessories. Table 5-3 lists EM7 accessories.

Table 5-2. EM4 Series Electromagnet Accessories

MODEL #	DESCRIPTION
Additional Standard Pole Caps (does not include bolts, order separately)	
EM4-1P	Pole cap, 4 inch diameter tapered to 1 inch face
EM4-2P	Pole cap, 4 inch diameter tapered to 2 inch face
EM4-3P	Pole cap, 4 inch diameter tapered to 3 inch face
EM4-4P	Pole cap, 4 inch diameter with 4 inch face
Additional Pole Caps with Optical Access Hole(s) (does not include bolts, order separately)	
EM4-1P-O-1-2	Pole cap, 4-inch tapered to 1-inch face, optical access 1 pole (1/8-inch diameter)
EM4-1P-O-2-2	Pole cap, 4-inch tapered to 1-inch face, optical access both poles (1/8-inch diameter)
EM4-1P-O-1-4	Pole cap, 4-inch tapered to 1-inch face, optical access 1 pole (1/4-inch diameter)
EM4-1P-O-2-4	Pole cap, 4-inch tapered to 1-inch face, optical access both poles (1/4-inch diameter)
EM4-2P-O-1-2	Pole cap, 4-inch tapered to 2-inch face, optical access 1 pole (1/8-inch diameter)
EM4-2P-O-2-2	Pole cap, 4-inch tapered to 2-inch face, optical access both poles (1/8-inch diameter)
EM4-2P-O-1-4	Pole cap, 4-inch tapered to 2-inch face, optical access 1 pole (1/4-inch diameter)
EM4-2P-O-2-4	Pole cap, 4-inch tapered to 2-inch face, optical access both poles (1/4-inch diameter)
EM4-3P-O-1-2	Pole cap, 4-inch tapered to 3-inch face, optical access 1 pole (1/8-inch diameter)
EM4-3P-O-2-2	Pole cap, 4-inch tapered to 3-inch face, optical access both poles (1/8-inch diameter)
EM4-3P-O-1-4	Pole cap, 4-inch tapered to 3-inch face, optical access 1 pole (1/4-inch diameter)
EM4-3P-O-2-4	Pole cap, 4-inch tapered to 3-inch face, optical access both poles (1/4-inch diameter)
EM4-4P-O-1-2	Pole cap, 4-inch diameter with 4-inch face, optical access 1 pole (1/8-inch diameter)
EM4-4P-O-2-2	Pole cap, 4-inch diameter with 4-inch face, optical access both poles (1/8-inch diameter)
EM4-4P-O-1-4	Pole cap, 4-inch diameter with 4-inch face, optical access 1 pole (1/4-inch diameter)
EM4-4P-O-2-4	Pole cap, 4-inch diameter with 4-inch face, optical access both poles (1/4-inch diameter)
Bolts	
EM4-BOLT-S	Pair of bolts for EM4-CS Settable gap electromagnet
EM4-BOLT-V	Pair of lead screws for EM4-CV, or -HV Variable gap electromagnets
EM4-BOLT-S-O	Pair of bolts for EM4-CS Settable gap electromagnet, with optical access holes
EM4-BOLT-V-O	Pair of lead screws for EM4-CV or -HV Variable gap electromagnets, with optical access holes
Other Accessories	
EM4-BENCH	Bench with leveling feet 25 inches (63.5 cm) x 16.5 inches (41.9 cm) x 14 inches (35.6 cm)
EM4-WBASE	Wheeled Base
651-523	Flow Switch Kit – Contains the following: ***Quantity*** ***Description*** 1 Flow switch, 1 gpm flow rate 1 Hose, 1/2 inch I.D., 3 foot section 4 Hose clamps 2 Adapter, 9/16–18 UNF 2B to 1/2 inch barbed with O-ring 1 Adapter, Male Garden Hose Threads to 1/2 inch barbed 1 Adapter, Female Garden Hose Threads to 1/2 inch barbed, with washer 1 "T" Adapter, 3/8–3/8–1/2 inch barbed

Table 5-3 lists EM7 accessories. The standard EM7 System 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 5-3. EM7 Electromagnet Accessories

MODEL #	DESCRIPTION
Additional Standard Pole Caps (does not include bolts, order separately)	
EM7-3P	Pole cap, 7 inch diameter tapered to 3-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
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: **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

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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 EM4 Series Electromagnet and Model 647 Magnet Power Supply (or any power supply with an external prohibit/interlock feature), and the Model EM7 Electromagnet and Model 665 Magnet Power Supply (or any power supply with an external prohibit/interlock feature). Refer to Paragraphs A2.0 to A4.0 for EM4 Flow Switch Installation, and Paragraphs A5.0 to A10.0 for EM7 Flow Switch Installation.

A2.0 EM4 FLOW SWITCH LIST OF PARTS

The Cooling Water Flow Switch Kit (Lake Shore P/N 651-523) contains the following:

Quantity	*Description*
1	Flow switch, 1 gpm flow rate
1	Hose, 1/2 inch I.D., 3 foot section
4	Hose clamps
2	Adapter, 9/16–18 UNF 2B to 1/2 inch barbed with O-ring
1	Adapter, male Garden Hose Thread to 1/2 inch barbed
1	Adapter, female Garden Hose Thread to 1/2 inch barbed, with washer
1	"T" Adapter, 3/8 - 3/8 - 1/2 inch barbed, for alternative hookup.

A3.0 EM4 FLOW SWITCH SPECIFICATIONS

The Flow Switch is calibrated in water with lead wires pointing up. The setpoint accuracy changes slightly in other than vertical position, but for this application, mounting orientation is not critical. The Flow Switch will operate with both normally closed (N.C.) and normally opened (N.O.) contacts. It incorporates a single pole double throw (SPDT) switch set to activate by a moving magnet at a flow rate of 1 gallon (4 liters) per minute. The contacts are rated at 15 VA. All necessary fittings are provided to connect the switch to the coolant outlet of most electromagnets.

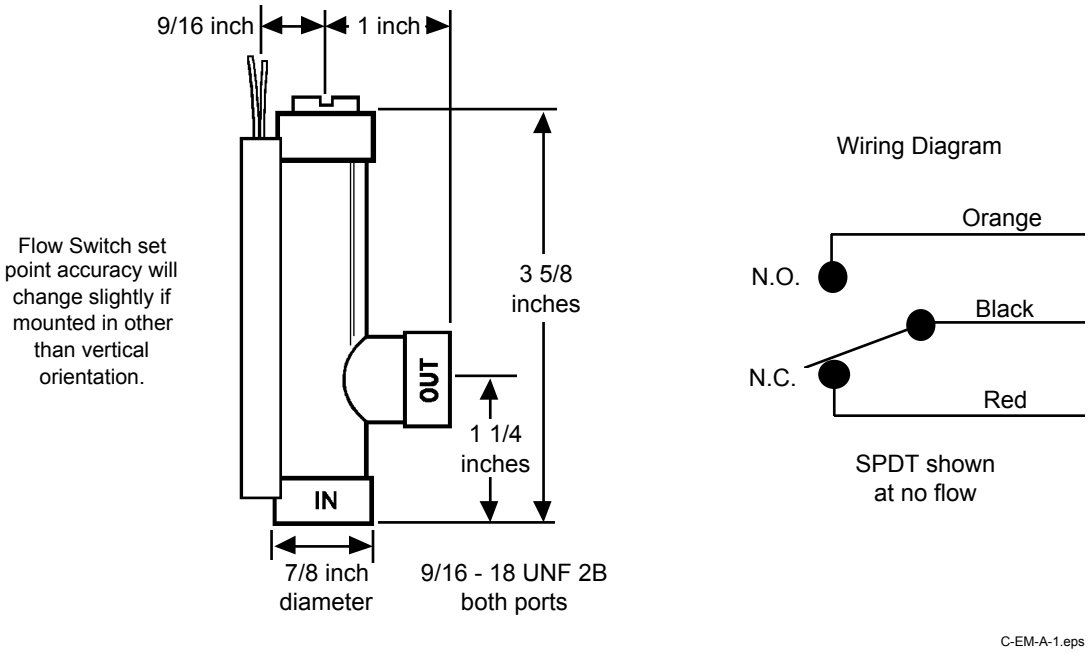

Figure A-1. EM4 Flow Switch Dimensions and Wiring Diagram

A4.0 EM4 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 foot-long hose is sufficient to avoid any interference. During normal operation, cooling water flows through the magnet at a minimum rate of 1 gallon 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.

If the power supply interlock needs an open contact to operate (like the Lake Shore Model 647 Magnet Power Supply), connect the Black wire to Remote Inhibit RI–(2) and the Red wire to Remote Inhibit RI-(1) terminals on the rear panel of the power supply. The Orange wire is not used.

The flow switch contacts open when the flow is above 1 gallon per minute. When the flow drops below that level, the contacts close which reduces power supply output to zero. Add a delay to the activation of the power supply remote inhibit to avoid output current zero reset due to brief reductions in water flow. If additional interlock is to be connected externally to the unit, it can be one or more N.O. contacts connected in parallel, such as an emergency stop pushbutton.

If the power supply interlock needs a closed contact to operate, connect the Black and Orange wires to the remote inhibit terminals. The Red wire is not used. In this setup, the flow switch contacts close when the flow is above 1 gallon 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.

Consult your power supply manual for details on where to connect the flow switch leads.

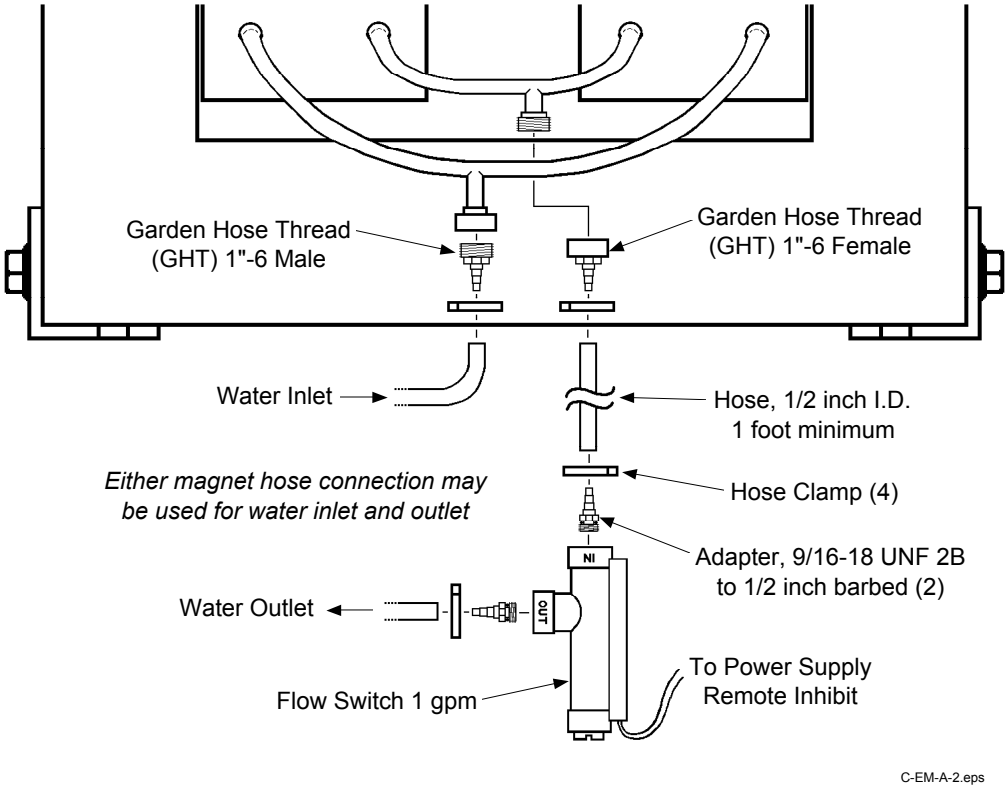

Figure A-2. Flow Switch Installation

A5.0 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:

Quantity	*Description*
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

A6.0 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 A8.0).

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.)

A7.0 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 665/668 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-3.

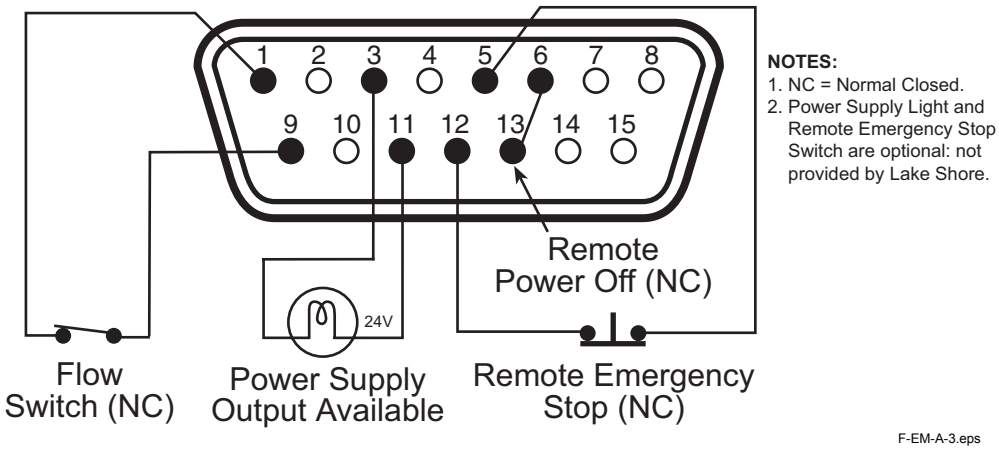

Figure A-3. EM7 Flow Switch Wiring Diagram

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.

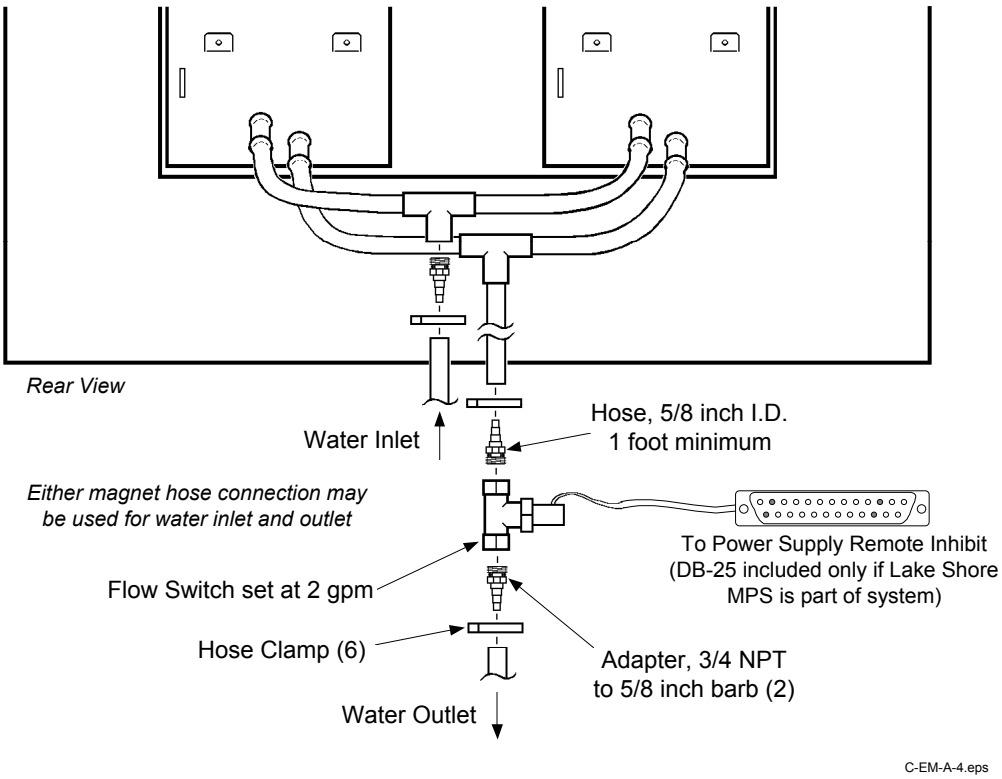

Figure A-4. EM7 Flow Switch Installation

A8.0 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-5.

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.

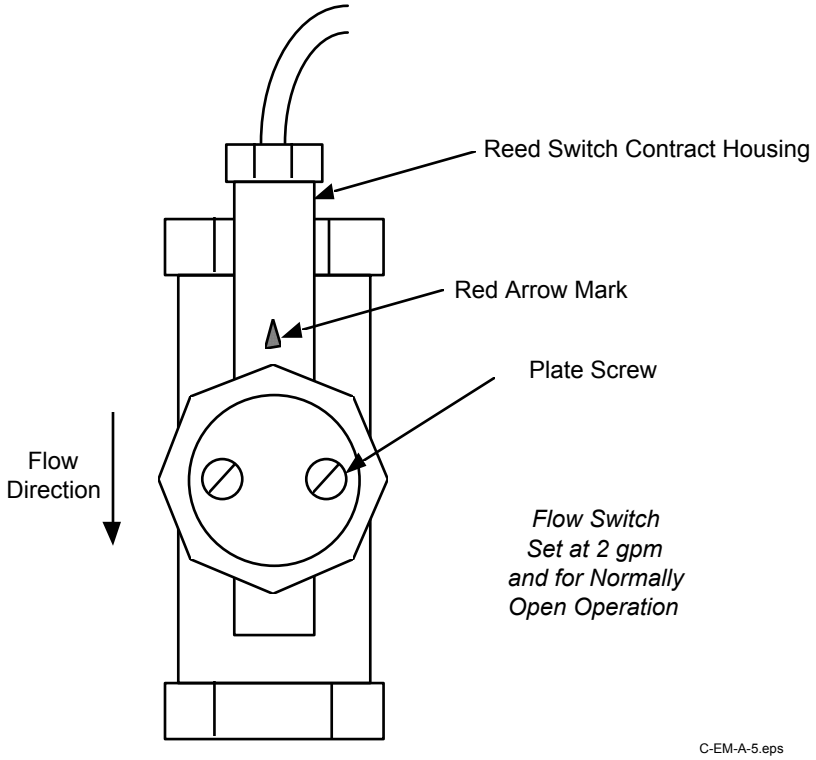

Figure A-5. Flow Switch Rate Adjustment

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), $G \cdot cm^2$	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	$\frac{1}{4\pi \times 10^{-7}}$	$A \cdot m^2/kg$ Wb•m/kg
Magnetic moment	m	emu, erg/G	10^{-3}	$A \cdot m^2$, joule per tesla (J/T)
Magnetic dipole moment	j	emu, erg/G	$4\pi \times 10^{-10}$	$Wb \cdot m^{i}$
(Volume) susceptibility	χ, κ	dimensionless emu/cm^3	$\frac{-}{(4\pi)^2 \times 10^{-7}}$	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 $H \cdot m^2/kg$
(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 $H \cdot m^2/mol$
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 G x 10^{-4} T/G = 10^{-4} 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 $\mu_0 = 4\pi \times 10^{-7}$ 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 gauss = 10^5 gamma (γ).

e. Both oersted and gauss are expressed as $cm^{-½} \cdot g^{½} \cdot s^{-1}$ 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, Bolder, Colorado 80303, March 1985, NBS Special Publication 696. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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