



USER'S MANUAL

MODEL: 3480

C-Frame Dipole Electromagnet

Date Sold: _____

Serial number: _____

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1. SAFETY

1.1. Symbols Used In This Manual



Important information. This label indicates important information that must be read and understood prior to operation.



Warning relating to the presence of magnetic field.



Warning relating to a trip hazard.



Warning relating to hot surfaces.



Warning relating to the potential for electrical shock.



Warning relating to the potential of injury due to lifting heavy weight.

1.2. Installation, Operation and Service Precautions



During installation or servicing this magnet must be locked out following the Lockout/Tagout procedure defined in section 1.3.



This product is designed for use in accordance with SOP39. Hazardous voltages are present within this product during normal operation. The product should never be operated with any of the covers removed.



When operated at peak direct current of 63A the surface temperature of the coils of the electromagnet can rise as high as 80°C. Care must be taken not to touch the coils for extended periods.

1.3 Lockout/Tagout Procedures

Purpose:

To protect personnel and ensure that machines and equipment are isolated from potentially hazardous electrical energy. Lockout or tagout must occur before employees perform service, maintenance, or renovation. This is important where unexpected start-up could cause personal injury, fire, or equipment damage.

Policy:

All equipment shall be locked out where possible. Where such control is not possible, equipment may be tagged out-of-service. In all instances, equipment shall be made inoperable to protect against possible operation where such operation may cause personal injury or damage. Employees must not attempt to operate any switch or source of energy which is locked out or tagged out.

Procedures:

- 1. When working on systems which could accidentally be activated, the system shall be locked out or tagged out by use of a safety lockout device and padlock. In addition, a tag shall be used to identify the purpose of the shutdown, the employee involved, the date the unit was removed from service, and when the system may operate again.**
- 2. If more than one source of energy is present, all such sources must be locked out or tagged out. Special procedures must be followed to ensure that the equipment is disconnected from an energy management system or emergency generator system that may start or energize the equipment.**
- 3. A lockout is required on all systems where possible. A tagout is an acceptable means of protection on systems which are less hazardous. An example of less hazardous is a device, if started accidentally, would not cause personal injury.**
- 4. If more than one person is involved in the repair, each person shall install a lock and or tag to the equipment energy source. An employee may not use the tag or lock of another employee.**
- 5. After servicing, renovation, or maintenance is complete, the area must be checked for tools, parts, removed guards, and assurance that no personnel are in the danger zone. Then the lockout or tagout will be removed by the same employee who initially locked it out so energy may be restored to the equipment.**
- 6. If the employee who locked out or tagged out the equipment is unavailable, the supervisor may remove the lock or tag if the following conditions are met:**
 - 1. Verification that the employee who applied the device has left for the duration of the shift and is not at the job site.**
 - 2. Made reasonable efforts to reach the employee.**
 - 3. Inform the employee that the lock or tag has been removed and the system is no longer de-energized, before the employee resumes work.**

7. Employee's using lockout/tagout devices shall have training about this program, and shall have annual retraining to ensure that the employee understands and follows this program. The training and retraining shall be documented with the training records maintained by the training coordinator.
8. Outside contractors are required to follow this policy or provide a similar policy that is in compliance with Occupational Safety and Health Administration (OSHA) Standard 1910.147. Under no circumstances are outside contractors authorized to remove a lockout/tagout device nor are they allowed to energize a locked out/tagged out system.

Lockout/Tagout Procedures Checklist:

The following steps must be followed in sequence to properly lockout/tagout and re-establish energy:

I. Understand the hazard:

Electrical

Electrical Shock and or burn could result from contact with the exposed conductors line voltage or high voltage equipment. Flying parts or fire could result if this circuit were shorted. Electricity should be controlled at the circuit breaker, main switch, or fuse box.

Mechanical

Equipment or machinery can inflict tissue or skeletal injury through crushing, laceration or impalement. This can be controlled through the main electrical switch, plug, circuit breaker or anti-motion pin.

Thermal

Can cause burns or fires. It can be controlled by the main electrical switch, electrical plug control, electrical circuit breaker, electrical fuse box, steam valve, fluid line valve or shielding.

II. Shutdown:

Know what type of energy the machine uses.

Identify its potential hazards.

Find the switches or other devices that control energy and need to be locked out.

Let employees know that you will be locking or tagging out the equipment and why.

Turn off the machine or equipment.

III. Isolate the source of energy

Electrical

- Locate the main switch box or circuit breaker.
- Open the breaker, open the switch or remove the plug.

- **Attach a lockout enabling device if the circuit cannot otherwise accommodate a padlock.**
- **Place plug in a plug lock box.**

Mechanical/Storage Potential Energy

- **Lockout enabling device.**
- **Secure the energy controlling lockout by attaching a personal lock and completed tag to the lockout enabling device. If more than one person will be performing the work, each must apply their own lock to a multiple lock device.**
- **Release all stored energy.**
- **If there is a heat exposure, allow to cool.**

Release from Lockout/Tagout

- 1. Inspect the surrounding area following completion of work for loose tools, parts, correct valve settings, system integrity, exposed conductors.**
- 2. Check that all machine guards are in place and reconnected if applicable.**
- 3. Notify others in the area that the equipment is about to be made operational and returned to service.**
- 4. Remove personal lock, tag, and lockout enabling device. This step must be performed by the same person who applied the tag and lock.**

Lockout/Tagout Training

The lockout/tagout program is designed to train employees on disabling powered equipment from their power sources before beginning any servicing or maintenance work.

Lockout/tagout training is required for all employees who may possibly need to lockout and tagout equipment.

Employees will receive annual training in the following areas:

- 1. Recognition of applicable hazardous energy sources.**
- 2. Methods and Means necessary for energy isolation and control.**
- 3. Restrictions and limitations of lockouts.**

2. SPECIFICATIONS

2.1. General Specifications

Magnet Field at (X, Y, Z= 0, 0, 0mm)

Max triangle wave current $60A_{\text{peak}}$, 2.0kW

$B_z = \pm 2.15T$ (20,150G)

Max sinusoidal wave current $50A_{\text{peak}}$, 2.0kW

$B_z = \pm 2.11T$ (20,110G)

Max DC current 35A, 2.0kW

$B_z = \pm 2.00T$ (20,000G)

Coils (series connection)

Coil Resistance (20°C)

1.42 Ohm

Max Resistance (60°C)

1.66 Ohm

Max Power (water cooled @ 2 lpm)

35A/58V (2.0kW)

Self Inductance (low field)

216mH

Self Inductance (high field)

80mH

Water Cooling (18°C)

1.0 bar (15 psid), 4 liters/min (1.06 US GPM)

Over-temperature Interlock

Selco 802L-065 thermostat
Contact rating 120VAC, 1.0A. Closed below 65°C

Dimensions

Drawing 11907-0355-0_B
285 mm W x 197 mm D x 213 mm H
(11.22 inch W x 7.76 inch D x 8.39 inch H)

Mass

32 kg (70 lb)



CAUTION - The value of maximum coil resistance given should not be exceeded. At this resistance the coils are at maximum safe temperature for continuous operation.

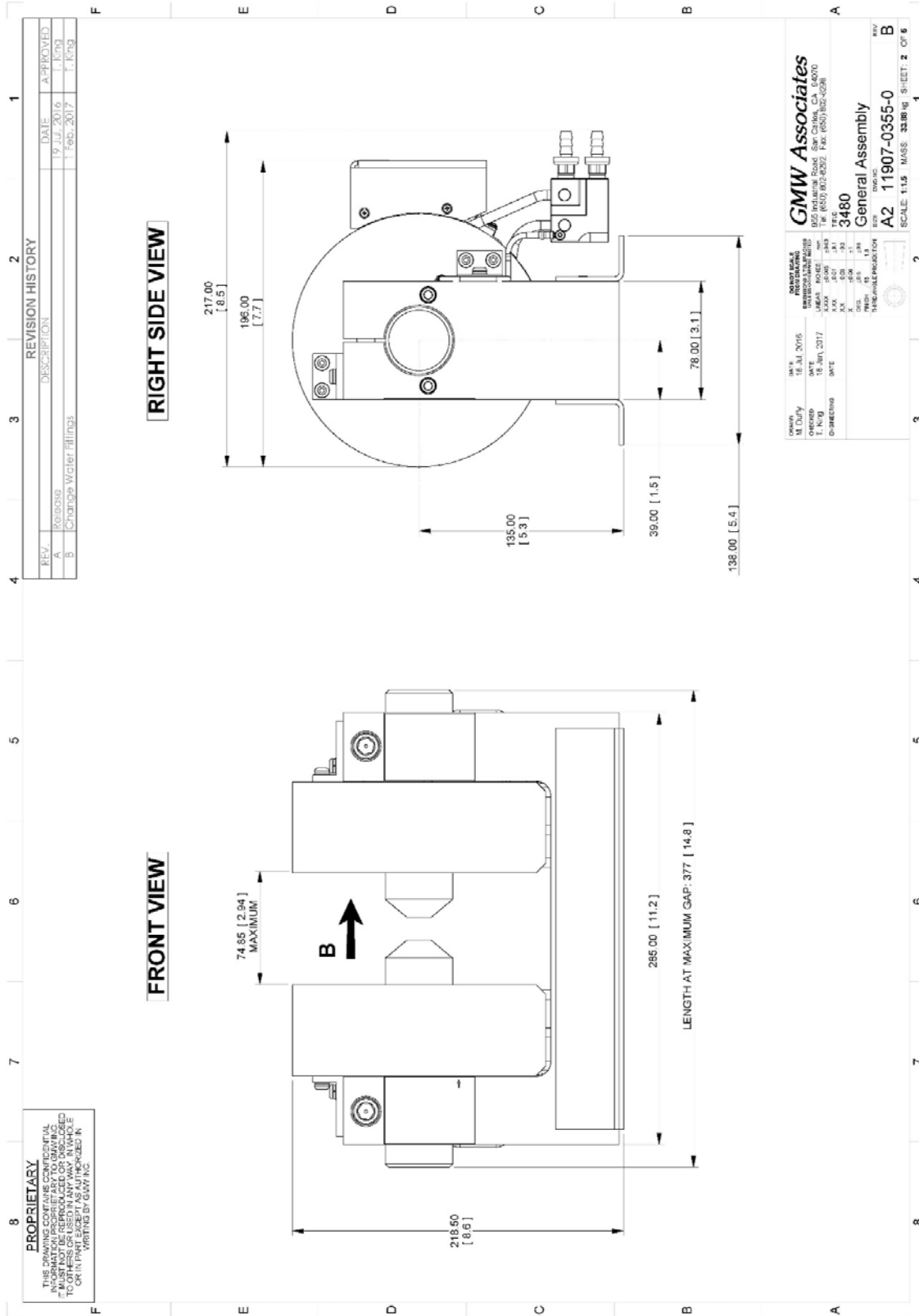
2.2. Model 3480 Electrical and Water Connections

DC Current	The 3480 electromagnet is shipped with the power and water connections not connected. The connections for the power supplies are made according to the particular power supply being used. The 3480 electromagnet is shipped with the coils connected in series requiring connection to a power supply for installation. Refer to section 11 for connection details.
Ground	The coil cooling plates and magnet body are all earthed through the power supply earth.
Interlocks (refer Section 8)	The Model 3480 is fitted with four thermostats, Selco part no 802L-065. Two thermostats are fitted to each coil, underneath the terminal covers. The thermostat is normally closed, opening when the coil heatsink temperature exceeds 65°C, ± 5°C.
Water	<p>Clean, cool (16°C - 20°C) water at 2.0 lpm at 1.0 bar (15 psid) should be used to cool the 3480 magnet. This can be provided by house water supply or from a recirculating chiller. An appropriate recirculating chiller is the TF90 from Thermofisher for 900W of time-averaged power dissipation or the TF150 for 1500W of time-averaged dissipated power. If house water supply is used, an in-line 5 micron water filter should be used for the supply line to the magnet. Also, 10m of hose is provided to give two 5m lengths for connection between the magnet and the recirculating chiller (if ordered), brass fittings on the chiller are already provided. Note that 4 hose clamps have also been provided for fitting these water hoses.</p> <p>Outlet: 1/8 inch NPT hose barb Inlet: 1/8 inch NPT hose barb</p>



Ensure that the high current connections are tight. Loose connections may lead to oxidation and overheating. The field stability may be degraded and the current terminations damaged.

2.3. Drawing 11907-0355-0_S2_B_3480_General_Assembly



2.4. Drawing 11907-0355-0_B_3480_General_Assembly_Exploded

REV.	DESCRIPTION	DATE	APPROVED
A	Revisions	19 Jul 2016	T. King
B	Note 2: Delete Items, Renumber, Change revisions, Add Ground Lead	1 Feb 2017	T. King

EXPLODED VIEW

ITEM	QTY	PART NUMBER	DESCRIPTION
21	2	307360	Button Head Cap Screw, M4 x 8
20	2	DIN125A	Flat Washer, M4, SS
19	2	307360	Button Head Cap Screw, M3 x 8
18	2	DIN125A	Flat Washer, M3, SS
16	2	1907-0355-0	Coil Washer, NG, SS
14	4	1907-0355-0	Pole Wdg. Cap. 1.5µF 100V 1/4 Horse, Bronze
15	1	10900720	Label - Contact, Rev. A
14	1	10907-0171-0	Label - Contact, Rev. B
13	1	10907-0170-0	Label - Specification, Rev. B
12	12	DIN125A	Flat Washer, M5, SS
11	12	307360	Button Head Cap Screw, M5 x 12, SS
10	12	DIN1273	Split Lock Washer, M5, SS
9	4	BN792	Ribbed Lock Washer, M6
8	4	DIN912	Socket Head Cap Screw, M6 x 50, SS
7	4	BN792	Ribbed Lock Washer, M12
6	2	DIN912	Socket Head Cap Screw, M12 x 60, SS
5	2	17907-0230-0	Pole, 1.6mm & 42mm, Rev. B
4	4	17601560	Coil Bracket, Rev. A
3	2	17907-0650-0	Pole Sleeve, Rev. B
2	2	17907-0356-0	Coil Assembly, Rev. B
1	1	17907-0650-0	Yoke Weldment, Rev. B

REVISION HISTORY

REV.	DESCRIPTION	DATE	APPROVED
A	Revisions	19 Jul 2016	T. King
B	Note 2: Delete Items, Renumber, Change revisions, Add Ground Lead	1 Feb 2017	T. King

PROPERTY

THIS DRAWING CONTAINS CONFIDENTIAL INFORMATION. IT MUST NOT BE REPRODUCED OR DISCLOSED TO OTHERS OR USED IN ANY WAY THAT WOULD BE DETRIMENTAL TO THE INTERESTS OF GMW ASSOCIATES, INC.

GMW Associates
1907-0355-0
1907-0355-0 Rev. B (2017-02-01)
Tel: (850) 622-8352 Fax: (850) 622-8386
3480
General Assembly
A2 11907-0355-0
SCALE: 1:1.5 MASS: 35.00g | SHEET: 6 OF 6

NOTE:

- APPLY LOCTITE 561 THREAD SEALANT TO ALL FITTING THREADS. REMOVE EXCESS
- GROUND LABEL ALSO SHOWN ON SHEET 2

3 WARNINGS

REFER TO WARNINGS BELOW BEFORE OPERATING ELECTROMAGNET

1 Personnel Safety



The Model 3480 has a low level of fringe field. In operation the magnet fringing field can be in excess of 0.5mT (5G). This can cause malfunctioning of heart pacemakers and other medical implants. We recommend that the fringing field should be mapped and warning signs be placed outside the 0.5mT (5G) contour. Entry to this region of higher field should be restricted to qualified personnel.

2 Ferromagnetic Objects



During operation the magnet exerts strong magnetic attraction towards ferromagnetic objects in the near vicinity. Loose objects can be accelerated to sufficient velocity to cause severe personnel injury or damage to the coils. Keep ferromagnetic tools clear.

3 Arcing



This magnet stores considerable energy in its field during operation. Do not disconnect any current lead while under load or the magnetic field energy will be discharged across the interruption causing hazardous arcing.

4 Coil Hot Resistance



Do not exceed the maximum coil hot resistance given in the specifications or coil overheating and possible damage may occur.

5 Interlocks



These should always be connected if the magnet is to be operated unattended, to avoid the possibility of coil overheating caused by excessive power dissipation or inadequate cooling.

6 Watches, Credit Cards, and Magnetic Disks



Do not move magnetically sensitive items into the close vicinity of the magnet. Even some anti-magnetic watches can be damaged when placed in close proximity to the magnet during operation. Credit cards, and magnetic disks are affected by magnetic fields as low as 0.5mT (5G).

7 Trip Hazards



Caution must be taken when moving around the magnet as there are potentially cables on the floor that will present a trip hazard. It is highly advised that floor conduit be purchased that will cover the cables. This will also protect the cables from potential damage.

4 INSTALLATION



Caution: Take care when handling system. All movement, lifting and installation of the 3480 Electromagnet must be under the supervision of an experienced person to prevent the possibility of serious injury or damage to the electromagnet and associated equipment.

4.1. Unpacking Instructions and Damage Inspection

To unpack the electromagnet please follow the procedure below.

1. Inspect the shipping crate for obvious signs of damage or mishandling. Inspect whether the TiltWatch and/or ShockWatch sensors have been activated. If damage is evident report the damage in detail to the shipper for claim and simultaneously notify GMW in case assessment of the damage must be made. If no damage has occurred proceed with uncrating and installation.
2. First remove the steel banding and tek screws from the shipping crate cover. Lift the cover clear of the magnet and set aside, taking care to avoid tripping the TiltWatch or ShockWatch.
3. Remove the nut and washer stack securing the magnet to the base of the crate.
4. Take care in lifting the magnet from the crate for installation. Use assistance or lifting equipment if required.

4.2. Siting Considerations



The Model 3480 is not magnetically shielded. Ferro-magnetic material in the vicinity of the magnet will modify the magnitude and uniformity of the central region magnetic field. As a general rule avoid magnetic material closer than approximately 1 meter of the central region.

Background fields such as the geomagnetic field and alternating field from 60Hz power sources are not shielded by the magnet and will add to the field produced by the magnet. If possible these background fields should be measured and their effects evaluated before the Model 3480 magnet is installed. It may be necessary to orient the Model 3480 axis to minimize the effects of external fields, to relocate ac power sources or to install suitable magnetic shielding.

The 3480 Electromagnet features six clearance slots in its mounting feet suitable for mounting to metric or imperial optical tables. In addition to the slots, the mounting feet feature four M10 clearance holes at spacing 225 x 116mm. Refer to Drawing 11907-0355-0_S4_B in section 4.6

4.3. Electrical Circuit



Never connect or remove cables from the magnet with the power supply connected. The stored energy in the magnet can cause arcing resulting in severe injury to personnel or equipment damage.

Because the magnet stores a significant amount of energy in its magnetic field, special care should be taken to ensure that the current terminations are secure and cannot work loose in operation. Local heating at the terminations can cause rapid oxidation leading to a high contact resistance and high power dissipation at the terminals. If left unattended this can cause enough local heating to damage the terminals and the coils.

The brass current terminals of the coil are hexagonal in section. When tightening the terminal bolts these should be held with a wrench. The torque setting for these terminal bolts is 4Nm (3 ft.lb).

4.4. The 3480 Interlocks

The Model 3480 has four Selco 802L-065 thermostats. Two are mounted on each coil underneath the terminal covers. The thermostats are normally closed, opening when the coil temperature exceeds 65°C, $\pm 5^\circ\text{C}$.

In the event of any one of these interlocks open, the power is cut from the Kepco power supplies and the system is de-energized. The temperature switches automatically reset once the proper operating conditions have been met.



In the event of an interlock tripping it is strongly recommended that the root cause of the trip be determined. In the event that the root cause cannot be determined please contact Tom King (tom@gmw.com) for technical support.

4.5. Cooling

The Model 3480 can be operated up to an average coil temperature of 65°C. Assuming an ambient laboratory temperature of 20°C and a temperature coefficient of resistivity for copper of 0.0039/°C, the hot resistance of the coil should not exceed 25% more than the ambient temperature "cold" resistance. The coil thermostat will open when any coil temperature exceeds approximately 65°C. Clean, cool (16°C - 20°C) water at 2 l/min and 1 bar (15 psid) must be used to cool the 3480 magnet.

The copper cooling tubes are electrically isolated from the coils to avoid electrochemical corrosion. A 50 micron filter should be placed before the input to the magnet to trap particulates.

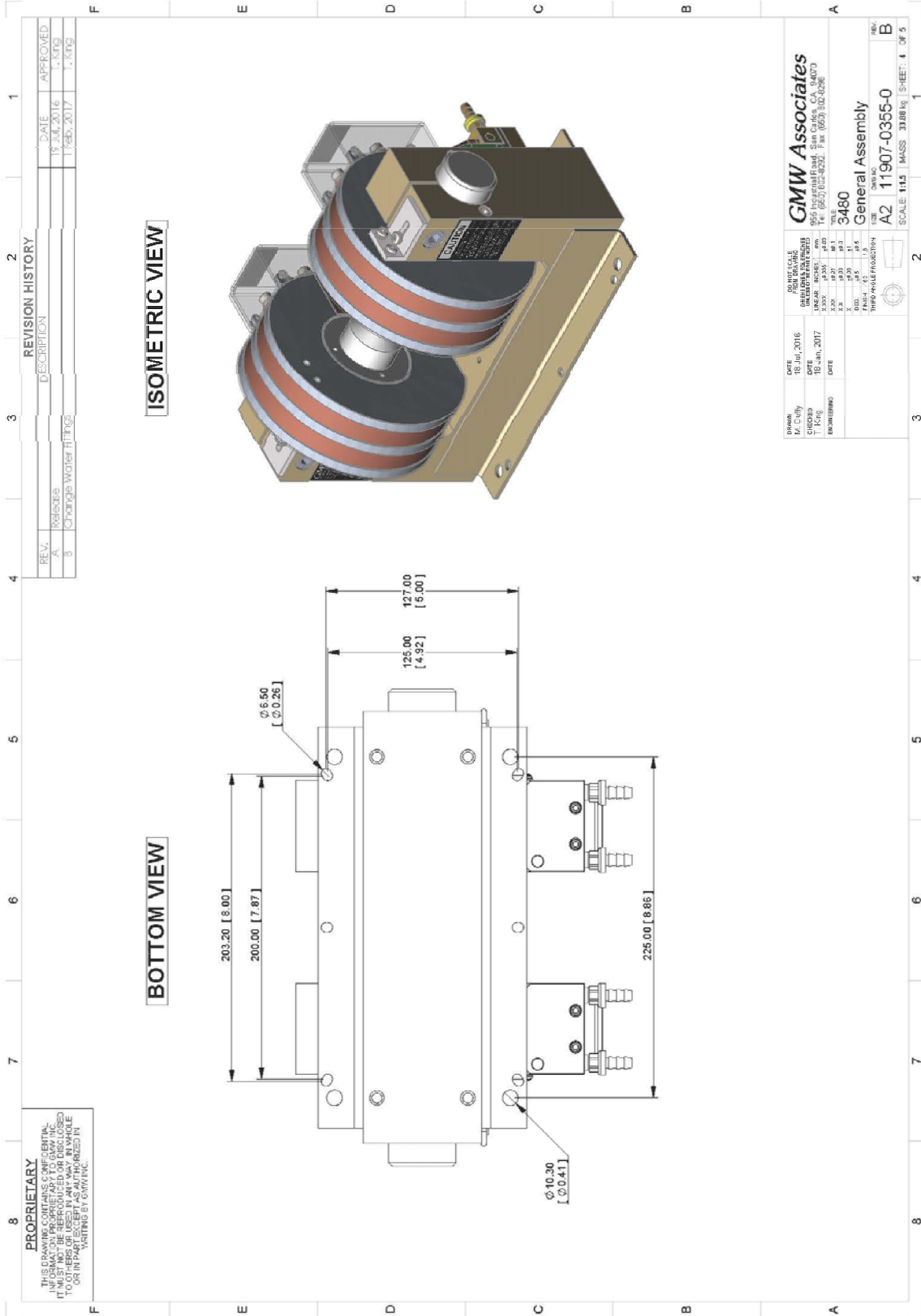
Configuration Suggestion: For continuous operation of the magnet it may be appropriate to use a recirculating chiller to reduce water and drainage costs. The chiller capacity will depend on whether cooling is required for the magnet alone or magnet and power supply. For the Model 3480 Electromagnet with Kepco 1kW BOP power supply a suitable chiller is the Thermo Fisher TF9 recirculating water chiller (900W).

Do not use corrosion inhibitors in high quality electrical systems since the water conductivity is increased which can result in increased leakage currents and electrochemical corrosion.

Avoid cooling the magnet below the dew point of the ambient air. Condensation may cause electrical shorts and corrosion.

During operation the resistance can be checked using a voltmeter across the magnet. The voltage will rise to a constant value once thermal equilibrium has been reached. If it is desired to save water, the flow can be reduced until the hot resistance is approached. **NOTE:** This adjustment must be made slowly enough to allow for the thermal inertia of the coils.

4.6. Drawing 11907-0335-0_S4_B_3480_General_Assembly



5. OPERATION

5.1. General



The 3480 electromagnet is water cooled and should not be operated without water. Attempts to operate the magnet as an air cooled system will most likely result in irreversible damage to the magnet.



This product is an electromagnet and creates significant magnetic fields both within the magnet and in the surrounding area. Make sure that there are no ferromagnetic items, tools or components loose in a 1 meter radius surrounding the magnet.



The Model 3480 is not a shielded electromagnet. In operation the magnet fringing field can be in excess of 0.5mT (5G). This can cause malfunctioning of heart pacemakers and other medical implants. We recommend that the fringing field should be mapped and warning signs be placed outside the 0.5mT (5G) contour. Entry to this region of higher field should be restricted to qualified personnel



Do not move magnetically sensitive items into the close vicinity of the magnet. Even some anti-magnetic watches can be damaged when placed in close proximity to the magnet during operation. Credit cards, and magnetic disks are affected by magnetic fields as low as 0.5mT (5G).

The magnet operates as a conventional water cooled electromagnet.

1. Adjust the cooling water flow to approximately 2 liters/min (0.53 US gpm). For operation at less than maximum power the water flow may be correspondingly reduced. Note that the inlet water temperature will determine the actual flow rate required. The above specified flow rates were determined with a water inlet temperature of approximately 18°C.
2. Turn on the power supply and increase the current until the desired field is reached. Note that constant current operation is preferred for stable field performance. Please refer to the user manual of the selected power supply.

5.2. Field Control Operation

The necessity to use calibration curves can be avoided by using a field controller to sense the magnetic field and provide a corresponding power supply control signal through the power supply programming inputs. Contact GMW for suitable instrumentation and software (Labview) (sales@gmw.com).

6. MAINTENANCE



Whenever performing maintenance on this magnet all electrical plug socket disconnects must be disconnected and a plug lockout device used to properly shut down the electrical system. Refer to Lockout/Tagout procedure defined in section 1.3.

6.1. Cooling Circuit

Check the cooling water circuit to ensure the water is clean and free of debris and bacterial growth. If an in-line water filter is used, ensure the filter is clean. If this magnet is used in conjunction with a closed cycle chiller please refer to the User Manual for details specific to that chiller for cleaning and maintenance.

6.2. Strain Relief Check

During the scheduled maintenance it is recommended that cables at the exit from the terminal cover of the 3480 C-Frame Dipole Electromagnet be inspected for tight connection and absence of corrosion. In particular the strain relief should be checked to confirm that the cables are properly restrained from movement. The Lockout/Tagout procedure from section 1.3 should be followed during this procedure.



When inspecting cables to the magnet the magnet should be de-energized to zero amps and the power supply switched off.

7. STANDARD OPTIONS

7.1. Standard Pole Options

The 3480 electromagnet is supplied with a pole featuring pole faces of $\varnothing 16$ and $\varnothing 40$ mm as standard.

Standard Poles featuring faces of $\varnothing 5$ and $\varnothing 40$ mm or $\varnothing 20$ and $\varnothing 40$ can be ordered additionally to provide different performance characteristics. See Section 9 for performance characteristics of the available pole faces.

EPR poles are available upon request, these are only valid for a pole spacing of 14mm.

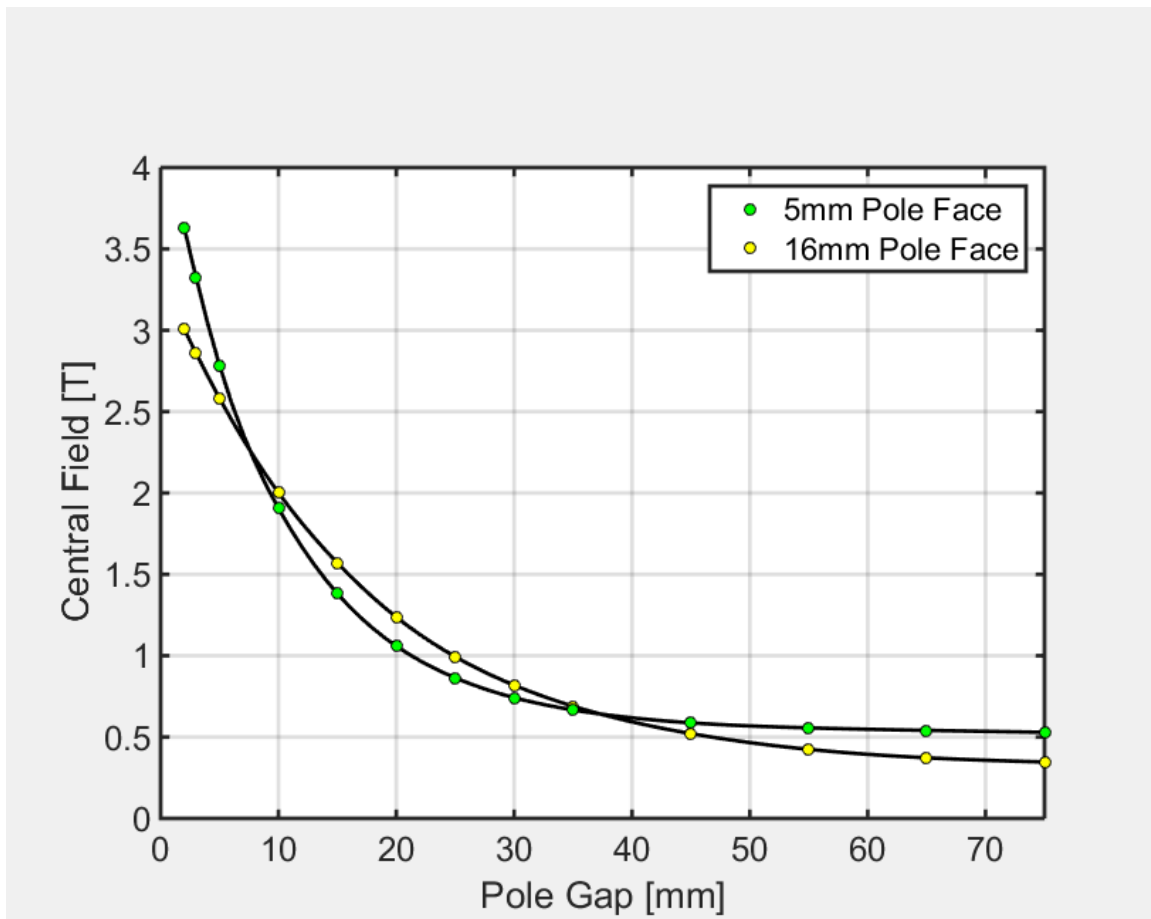
Custom poles are also available. These can be designed to particular customer requirements. Please contact GMW for more information sales@gmw.com.

8. CUSTOM OPTIONS

The model 3480 electromagnet can have customized performance by means of switching out the standard pole with a customized pole. GMW Associates will work with customers to provide the magnetic design of custom poles and will also manufacture such poles. Please direct inquiries to sales@gmw.com

Application Note: Ferromagnetic Resonance

A custom pole is designed to create peak field across a 2mm pole gap for the purposes of FMR analyses. A comparison with the standard 16mm pole is shown below.

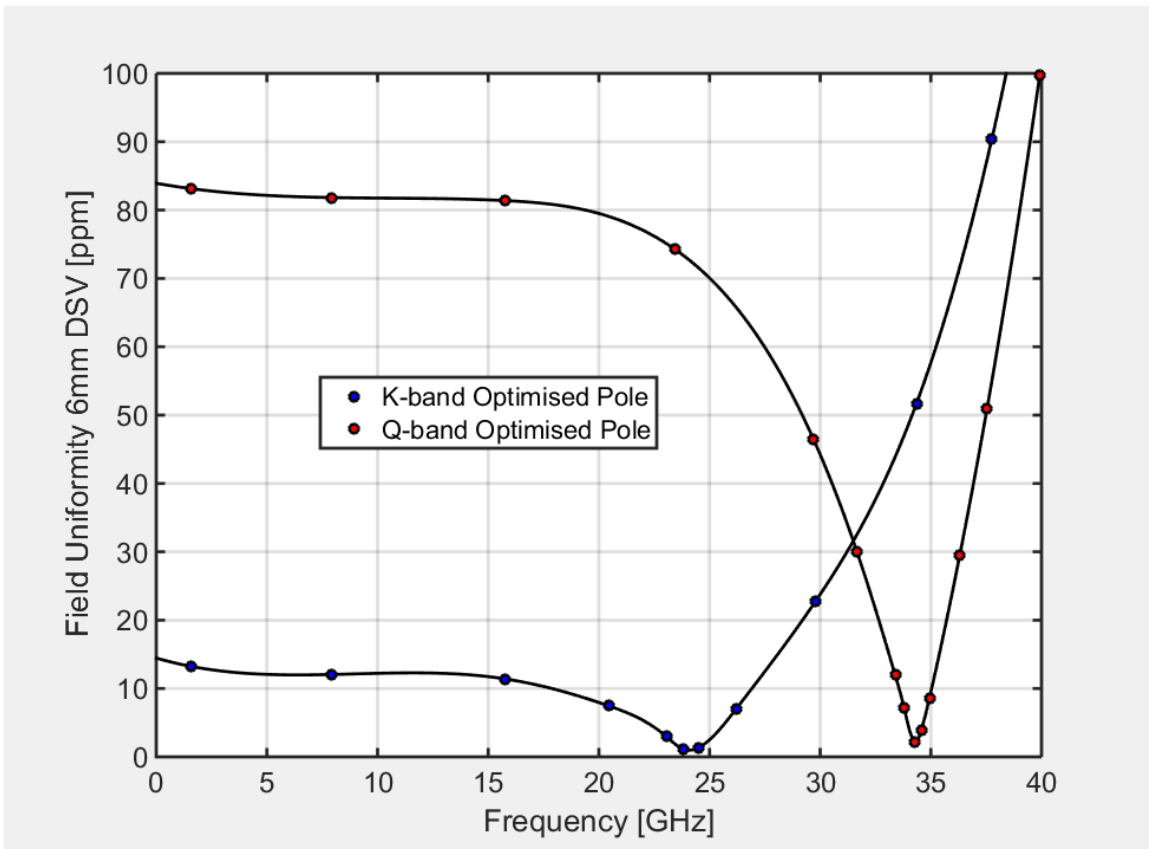


For any pole gap an optimised pole is available, on request, which will provide best performance for any specific pole gap.

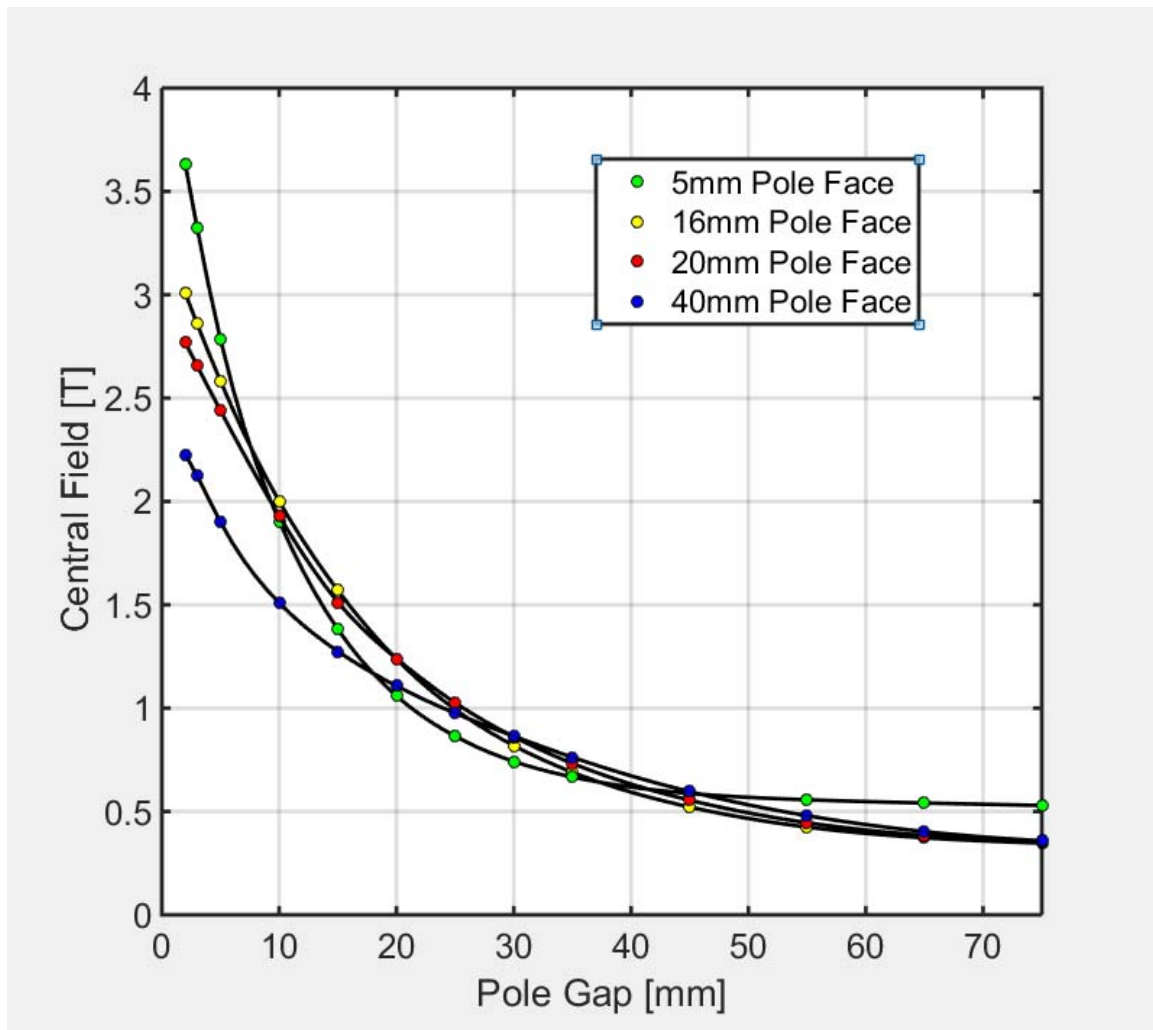
Application Note: EPR Spectroscopy

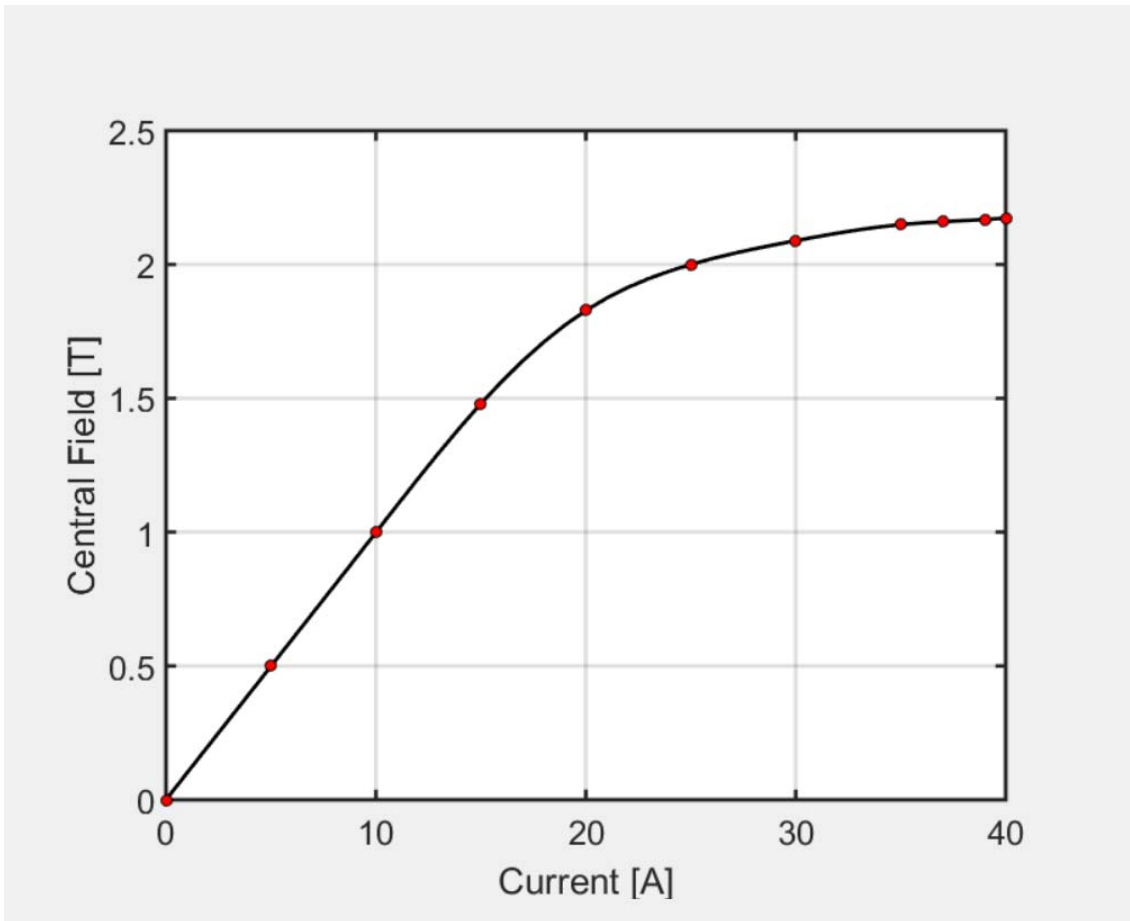
GMW offers poles optimised for EPR applications. Two examples are shown below for pole face spacing of 14mm. Each pole gives good uniformity across the excitation range for frequencies up to 40GHz but each is optimised to give excellent field uniformity at either K-band or the Q-band. Similar custom poles are available on request for any frequency in the 0-40GHz frequency band.

Waveband	L	S	C	X	P	K	Q	U	V
λ [mm]	300	100	75	30	20	12.5	8.5	6	4.6
f [GHz]	0.8-1.2	3.4-3.8	4	9-10	15	24	34	50	65
B [T]	0.035	0.13	0.14	0.34	0.54	0.85	1.22	1.8	2.3

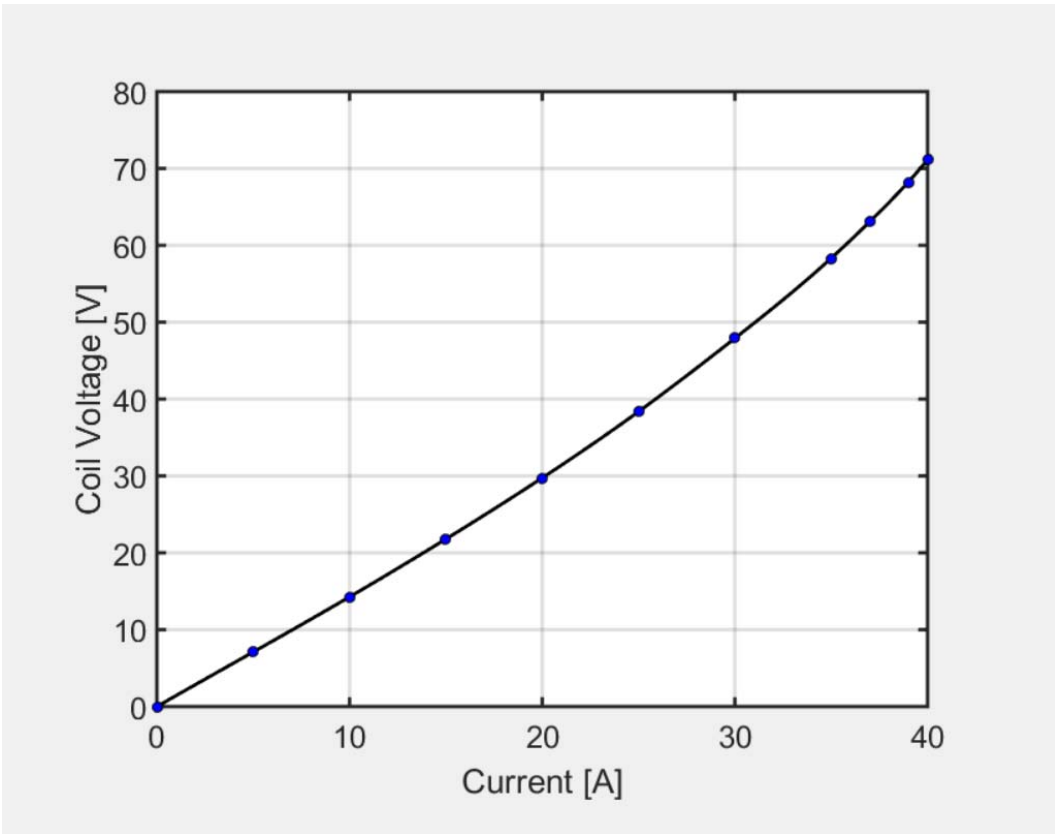


9. EXCITATION CURVES AND FIELD UNIFORMITY

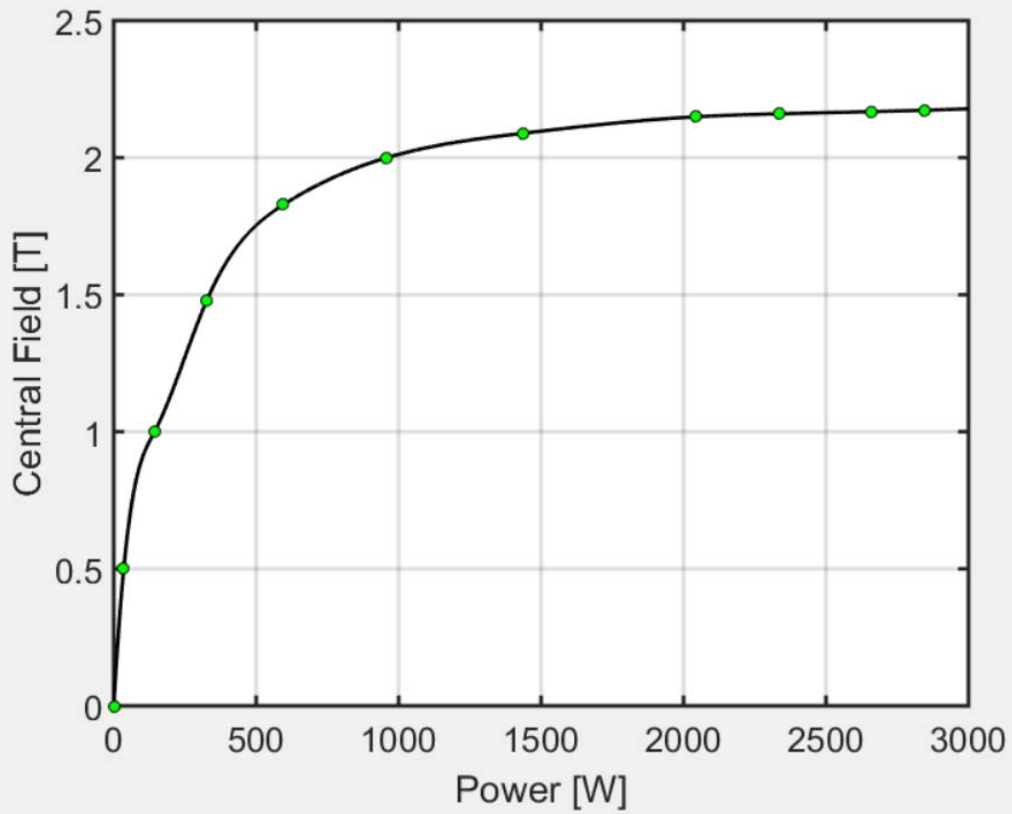




Excitation curve at 10mm pole gap for standard pole (pole face diameter 16mm) with all windings connected in series and coils at minimum spacing. Peak achievable current is 35A in a triangle waveform and is limited by maximum cooling plate temperature of 65°C.

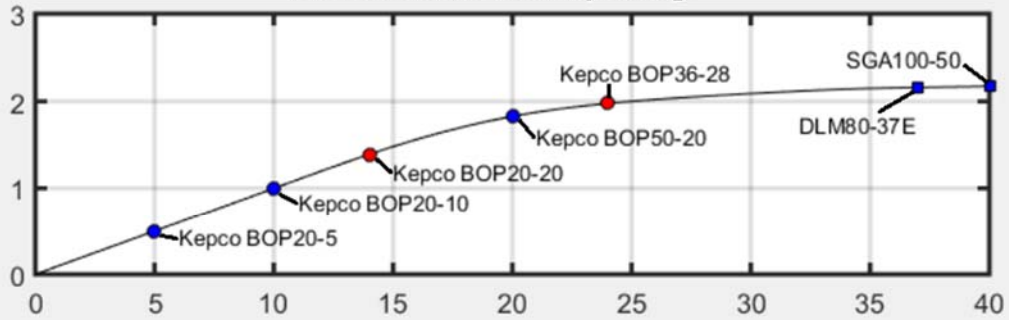


Current versus voltage curve for all windings connected in series. The departure from linearity is due to coil heating.

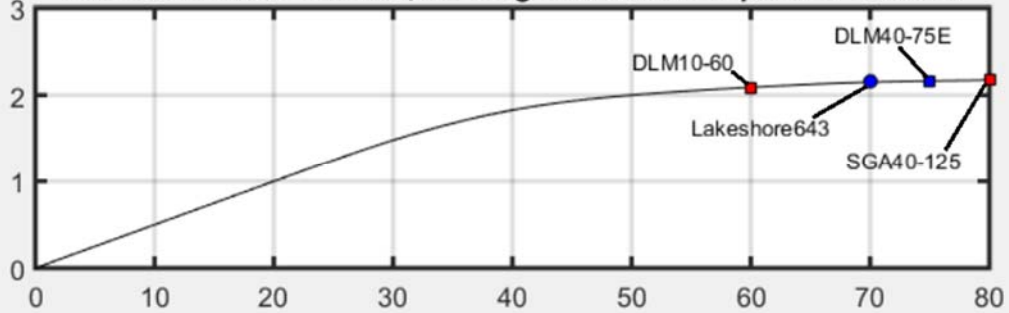


Peak achievable field against available power for standard pole (16mm pole face diameter) at 10mm pole gap and minimum coil spacing. This plot assists the selection of power source for desired performance.

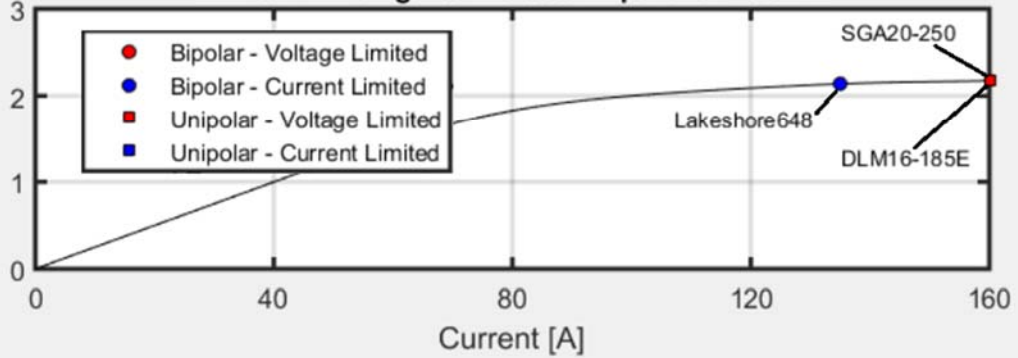
All four windings connected in series - 1.418Ω
Coils at minimum spacing



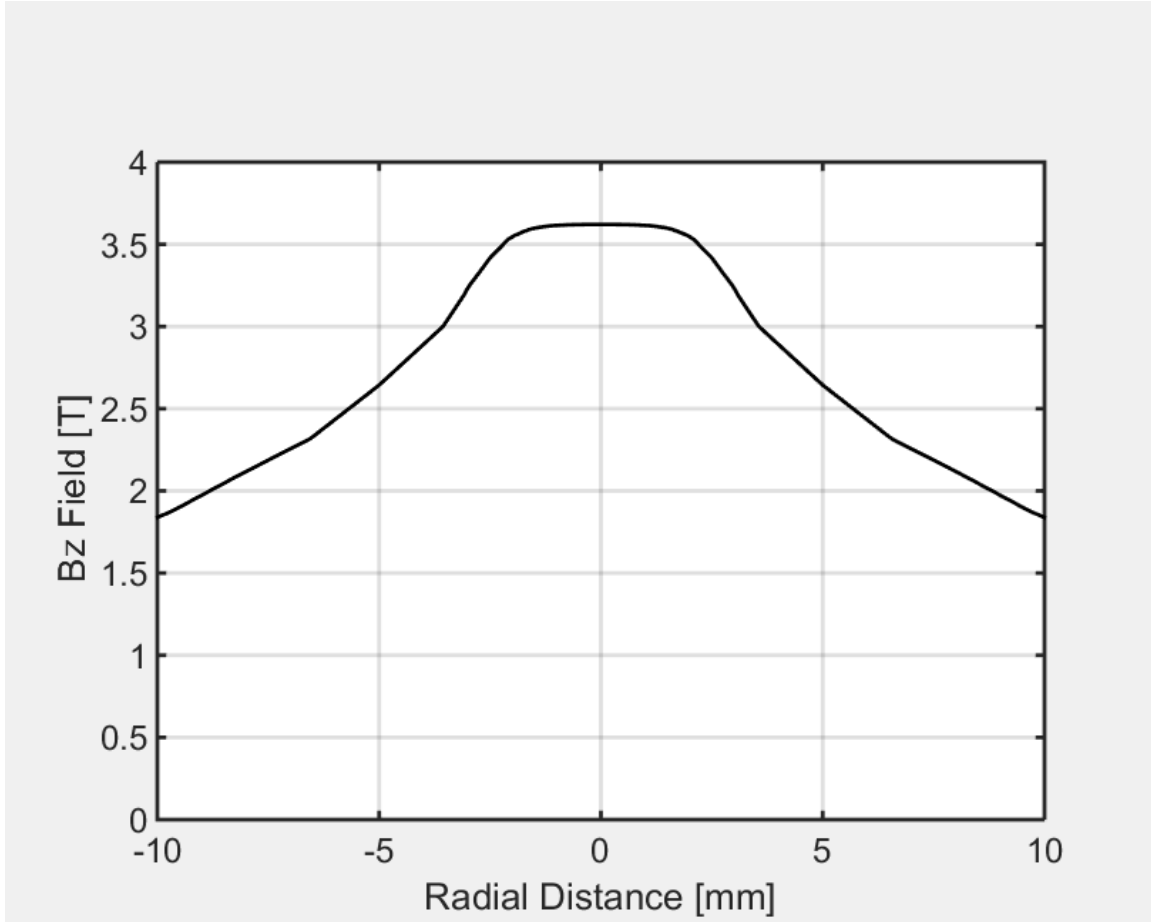
Coils connected in series, windings connected in parallel - 0.355Ω



All four windings connected in parallel - 88mΩ

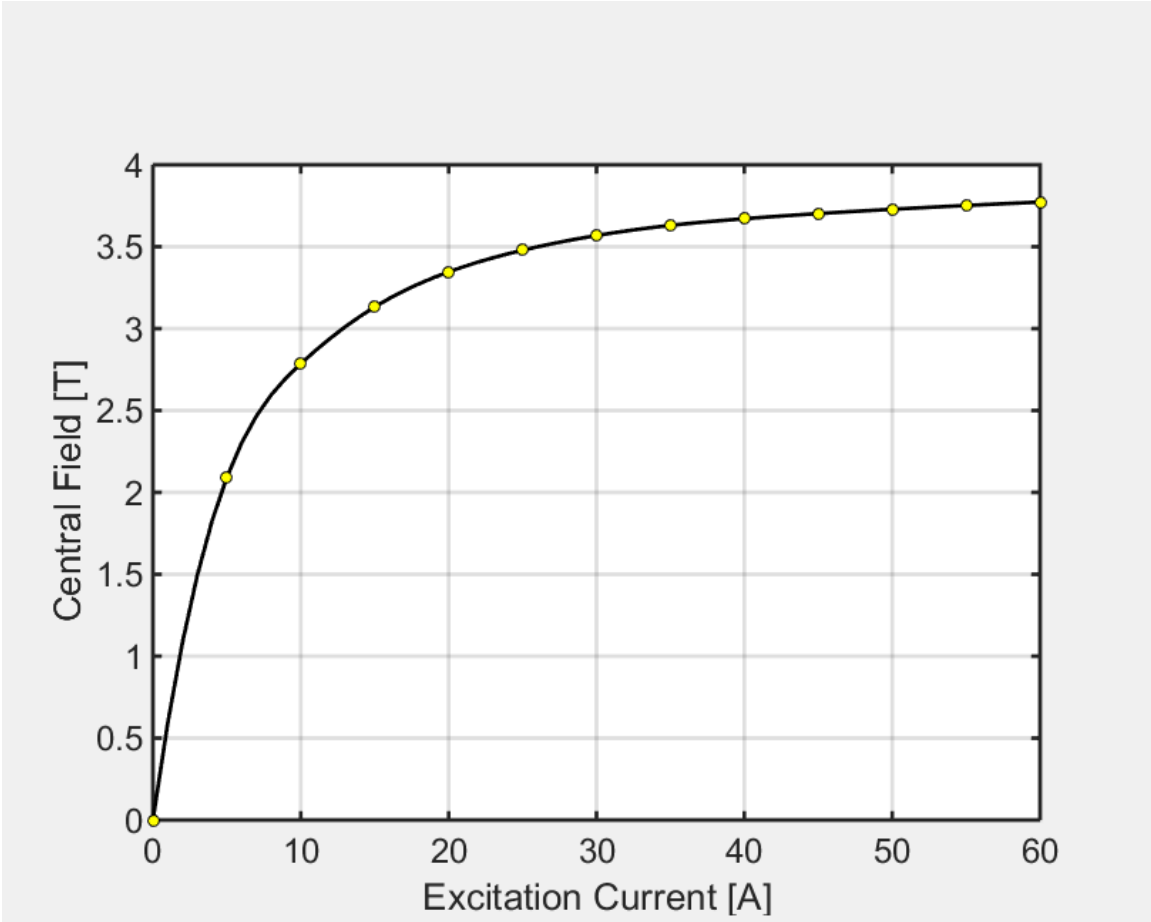


Field Uniformity in the Median Plane



Field profile in the median plane for the 5mm pole face diameter pole. Excitation current is 35A and coils are at minimum spacing. The field uniformity is better than $\pm 0.5\%$ over $\varnothing 3\text{mm}$.

- Peak continuous field 3.71 Tesla
- Peak pulsed field 3.85 Tesla
- Field uniformity $< \pm 0.5\%$ over $\varnothing 3\text{mm}$
- Higher uniformity field available on request.

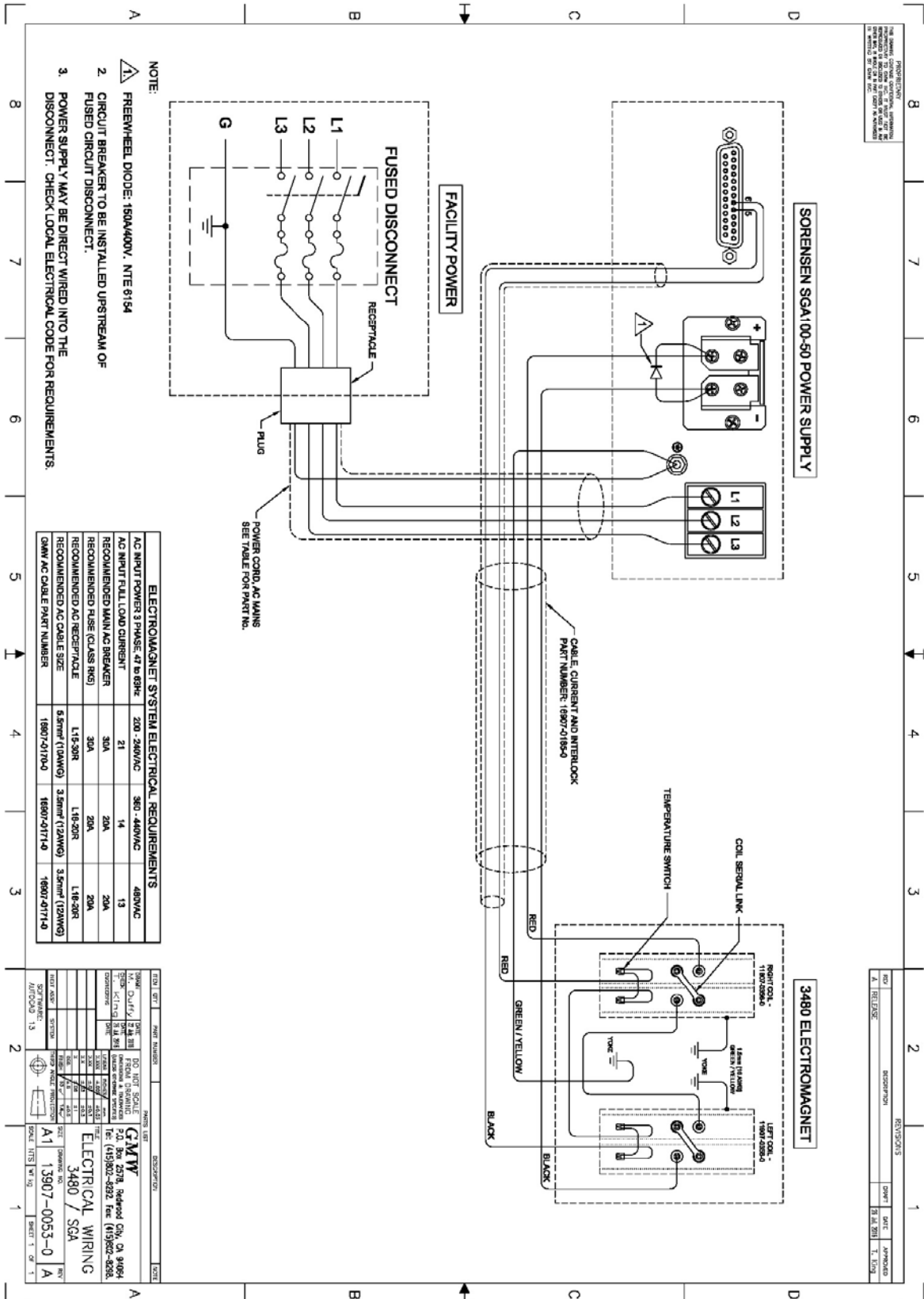


Performance of optimized pole for 2mm pole gap. Continuous operation is possible up to 35A with a triangle waveform possible up to 60A peak.

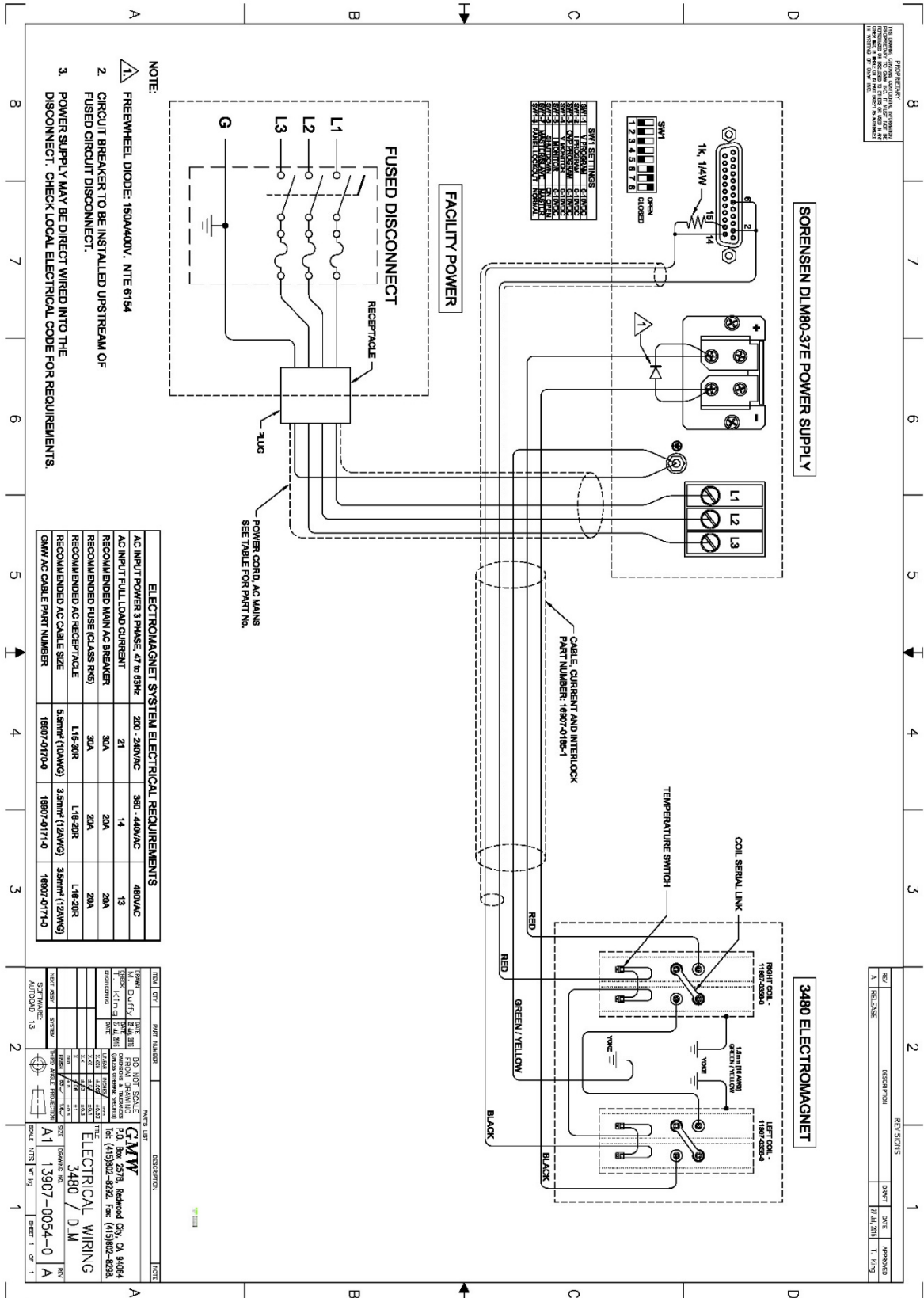
10. TEST DATA

11. WIRING DRAWINGS

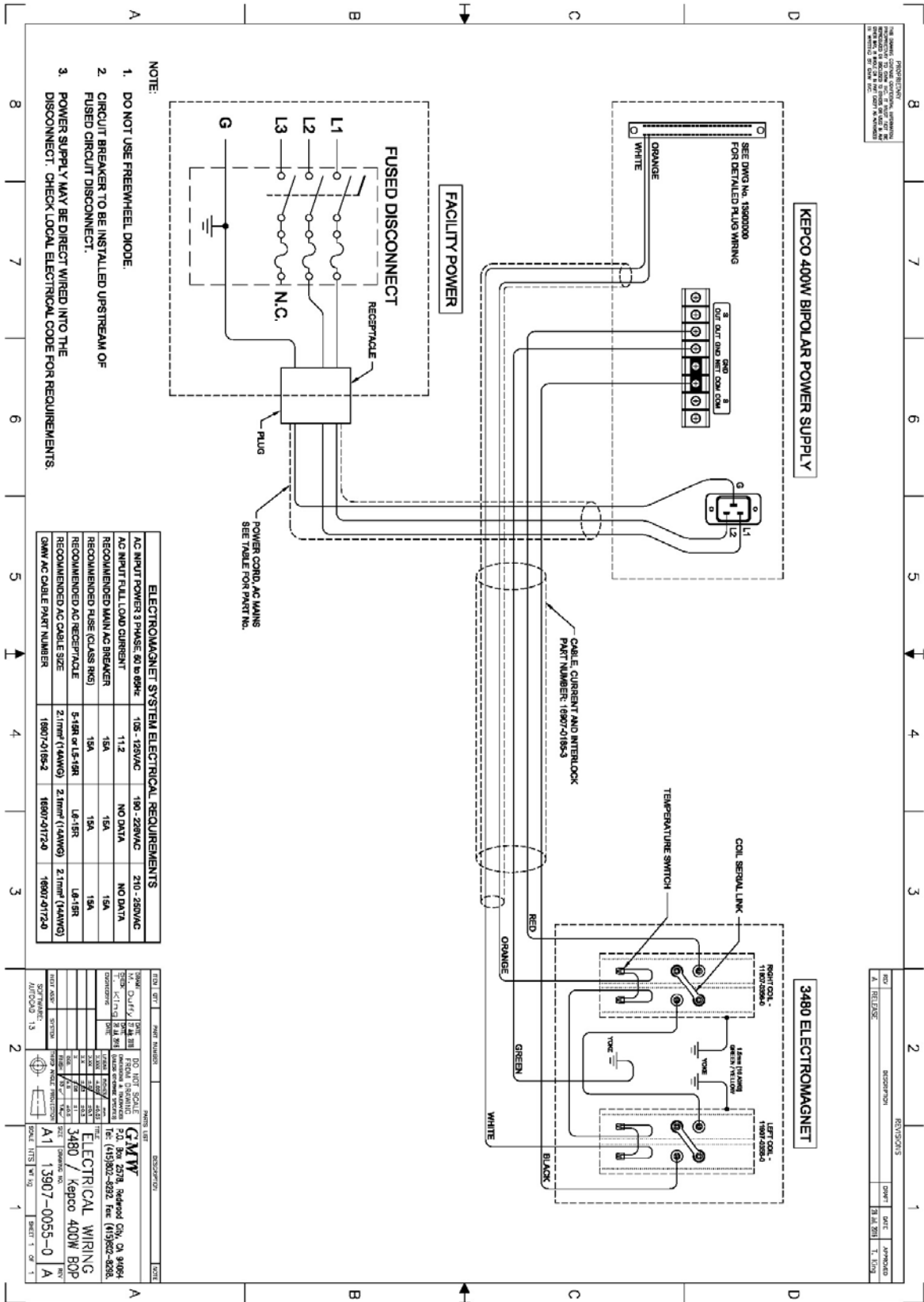
11.1 Drawing 13907-0053-0_A 3480 Electrical Wiring SGA



11.2. Drawing 13907-0054-0_A 3480 Electrical Wiring DLM80-37E



11.3. Drawing 13907-0055-0_A 3480 Electrical Wiring Kepco BOP 400W



11.4 Drawing 13907-0056-0_A 3480 Electrical Wiring Kepco 1kW BOP

